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CONTENTS

Volume 1, No 1, 2021

EDITOR MATERIAL

REVIEW

EMPIRICAL ARTICLE

BOOK REVIEW

MEETING ABSTRACT

LEARNING FROM THE PAST

EDITOR'S MATERIAL

Grand Challenges in Modern Sciences

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Abstract. We present a new interdisciplinary the Natural Systems of Mind (NSoM) journal. The editorial team believes that this journal will be able to provide an adequate response to the Great Challenges of modern sciences. Analysis of the journals indexed in the Scopus bibliometric database revealed that the key drawback of modern science is its excessive differentiation and the weakness of interdisciplinary generalization. A facet approach does not allow us to catch the holistic nature of human being and to realize a theoretical breakthrough in the study of the Sapient Human Behavior (SHB). We identified the forty branches of science, the integration of which could create a platform for breakthrough in the SHB research. The analysis of this journals showed that, according to 2021, the most common areas of research are Communication, Microbiota, Oncology, and Artificial Intelligence. At the same time, analysis of the publication landscape revealed several journals covering various aspects of the NSoM. Most of these journals are industry-specific and do not consider the subject in its diversity. The article ends with a Manifesto which proclaims the principles of publication.

Keywords: Natural Systems of the Mind, Grand Challenges in Sciences, Sapient Human Behavior (SHB), Main Science Trends, Publication Landscape

A time to scatter stones and a time gather them.
Ecclesiastes 3:5

Introduction

The history of science development testifies that brain storms are replaced by a breeze of applied research, the thunderous rumblings of new theories are replaced by a uniform information noise of citations. New boundaries of the possible in newly discovered areas of sciences are fencing off by an impregnable wall, behind which scientists are rapidly delving into the study of particular aspects and no longer see the horizons of future science.

The key drawback of modern science is its excessive differentiation and the weakness of interdisciplinary generalization. A facet approach does not allow us to catch the holistic nature of human being and to realize a theoretical breakthrough in the SHB research. Nowadays, the impossibility of solving either a major scientific problem, or an AI-systems design in the framework of only one scientific discipline becomes especially evident.

The mission of the NSoM is to promote effective international multidisciplinary interaction of specialists in the SHB research the Systems approach. We aim at understanding SHB through the study of systems interaction of the human brain, the mind, body, society, and AI-technology.

A huge number of controversial studies on the interaction of the brain and the mind, the mind and society, the brain and AI-technologies, and other forms the idea of exhaustion of the possibilities of rational knowledge of the world, of the limitations of the scientific method. But the louder the statements about the end of

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science sound, the closer is the scientific revolution. Blessed is "a time of scientific revolutions" leading to the breaking down of interdisciplinary barriers and changing the landscape of science. The degree of freedom of science is ever-increasing. What seemed impossible yesterday becomes possible today. Nowadays, any ideas, guided by not only verified calculation but also intuition and inner belief in their correctness, can be put forward and considered.

The main importance of future discoveries is these they will allow scientists a breakthrough beyond the line dividing the brain, the mind, society, and AI-technology. The breakthrough of SHB research can be a step against the prevailing canons of modern sciences. The questions are whether your ideas are crazy enough to be true, or have you enough courage to put forward and implement your new ideas?

Cognition of an individual is the cognition of the whole world. In an individual, as in a mirror, the entire universe is reflected. For millennia, the outstanding minds of humanity have been trying to solve a fundamental problem about the nature of Sapient Human Behavior. Due to the extreme complexity of this fundamental problem, research is often poorly reproducible. It needs a thorough description of experiments by indicating the essential conditions affecting the results obtained. The multiple reiterations of studies are required in different samples and under different conditions. That is why we welcome both previously unpublished materials at the intersection of various scientific disciplines of the systems foundations of the SHB research, as well as the replication of scientific data to confirm the reliability of the facts and identified patterns.

The history of sciences testifies that nothing can be neglected in science; it is precisely what cannot be that may point to the ways of a scientific discovery. That is why we urge the readers to pay attention to the randomness and the slightest deviations from the regularities.

The history of science development teaches us to draw a strong inspiration from the scientific work of the past generations' scholars. Their breakthrough ideas were often not properly received by the scientific community at that time, but whose ideas are especially may turn out to be especial relevant today. In this regard, the editors of the journal are planning to republish articles or excerpts from earlier publish works.

As is well known, it is impossible to embrace the immensity. One of the most complex problems, which faces the team of editors, is to identify branches of science the integration of which could create a possible platform for a breakthrough SHB research. The analysis of the main trends in the Natural Systems of the Mind research is given in the second section of the manuscript.

The main trends in SHB research

We analyzed both the content of manuscripts and the dynamics of publication activity over the past ten years (i.e., from 2010 to 2021). The evidence suggests that traditionally a large number of publications are presented in Medicine as well as Mathematics & Statistics. There is less research carried out in such fields as Biological Systems of the Mind, Pharmacology & Biochemistry, Social Sciences, and History & Philosophy of Science. The share of Psychology publications against the background of the above scientific areas seems to be extremely low.

Of particular note is the tremendous pace of Big Data Analysis development. The number of publications in this scientific branch increased in 287 times over the past ten years. The accelerated rates of development have been observed in such fields of science as Sentiment Analysis (13.6), Artificial Intelligence (10.7), Data-Driven Analysis (9.2), and Microbiota (8.5) according to publication activity. A huge number of manuscripts were revealed on Communication issues, namely, 76472 articles were published in 2019 alone. Therefore, this section is not represented in the charts.

Among the selected sections of the Biological Systems of the Mind (Fig. 1), the sections Brain-Computer Interfaces (2.35) and Neuroimaging (2.0) have the highest rates of publication. In 2014, there was a significant decline in the field of Endocrinology research. Now, the interest in endocrinological research has increased again and has recovered to the 2011 level.

The number of publications has more than doubled across all the selected areas of Linguistics over the past decade (Fig. 2). However, there are only a few publications on the Linguistics and Mind. The Sentiment Analysis is developing the most rapidly. This tool allows data analysts to assess a public opinion through the analysis of the sentiment of the text (positive, neutral or negative). It should be emphasized that one of the oldest sciences, Mathematics & Statistics, also continues its fruitful development by being embodied in new branches (Fig. 3).

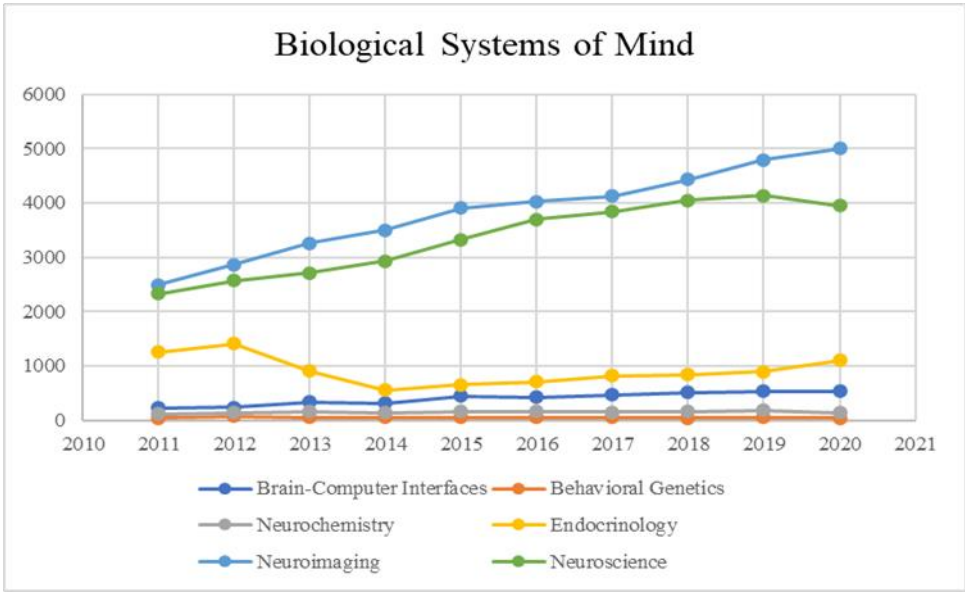

Fig. 1. Publication activity in the field of Biological Systems of Mind.

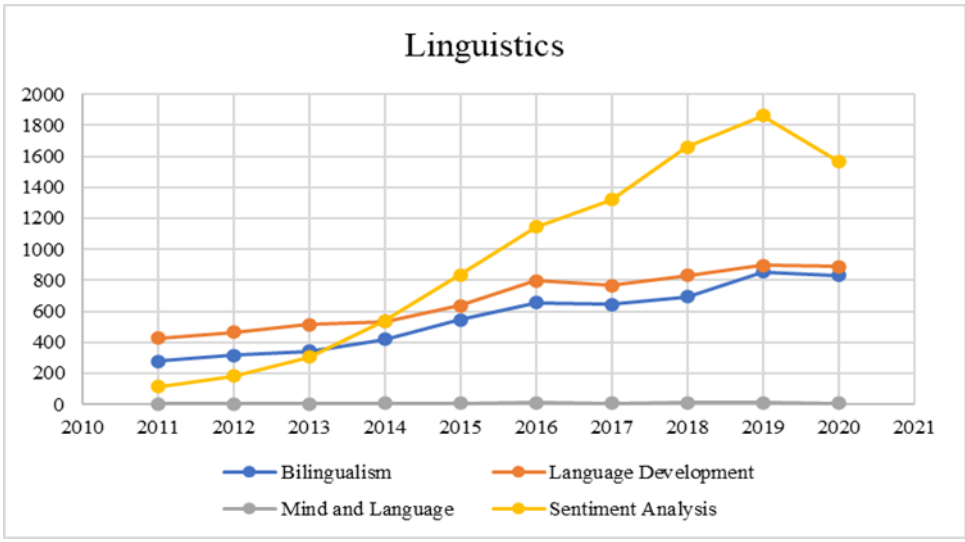

Fig. 2. Publication activity in the field of Linguistics.

The dynamics of publication activity in Medicine (Fig. 4) show a steadily increasing growth in the field of Oncology. It should be emphasized that among the selected branches of Medicine, the Microbiota section may be especially promising for studying the SHB systemic foundations.

According to the data presented in Fig. 5, there are five times more publications in Cognitive Psychology than in Comparative Psychology and four times more than in the Psychology of Religion & Spirituality. However, the growth rate of publication activity in Educational Psychology, Comparative Psychology, and Psychology of Religion & Spirituality is twice as high as in Cognitive Psychology. Despite the growth in publication activity, the total number of publications in Psychology is still low.

According to the data obtained (Fig. 6), the branches of Pharmacology & Biochemistry are distinguished by a uniform rate of development. However, the number of publications in Biochemistry and Molecular Biology is many times greater than in other sections.

The graph presented in Fig. 7 shows a uniform and sustainable development of certain sections in the History & Philosophy of Science until 2014, after which there is an increase in publication

activity in the field of Anthropology. It is noteworthy that in 2014 there was also an increase in interest in Social Sciences, among which the interest in Propaganda dominates (Fig. 8).

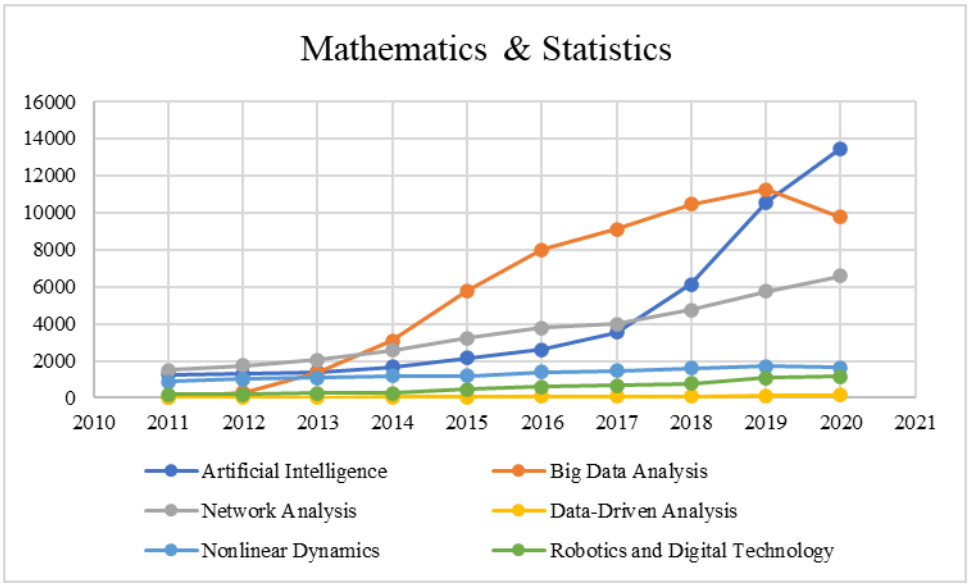

Fig. 3. Publication activity in Mathematics & Statistics.

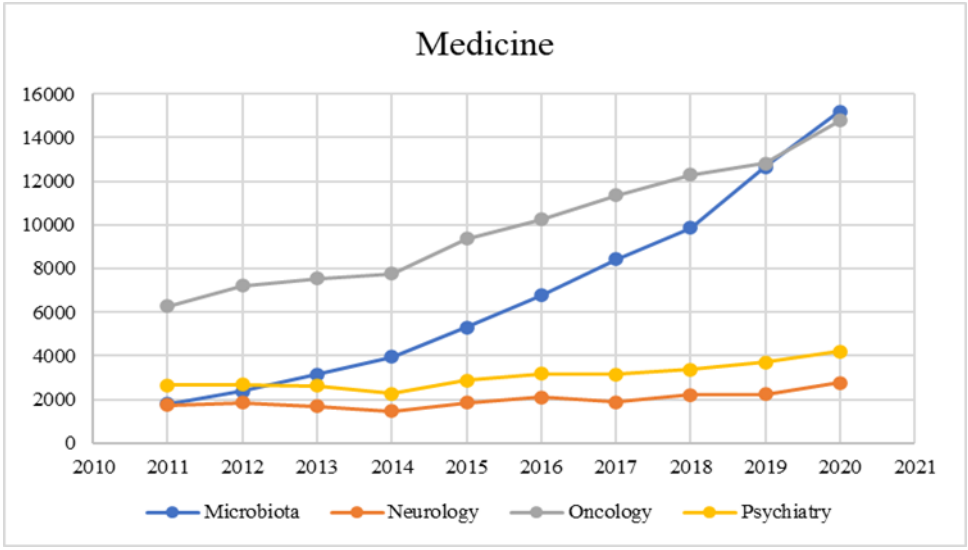

Fig. 4. Publication activity in Medicine.

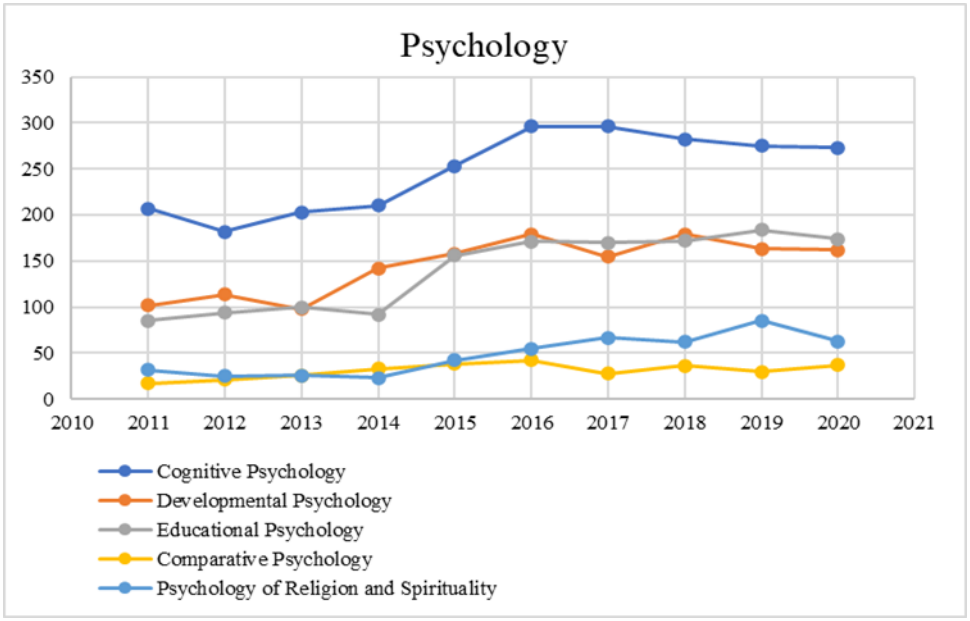

Fig. 5. Publication activity in selected branches of psychology.

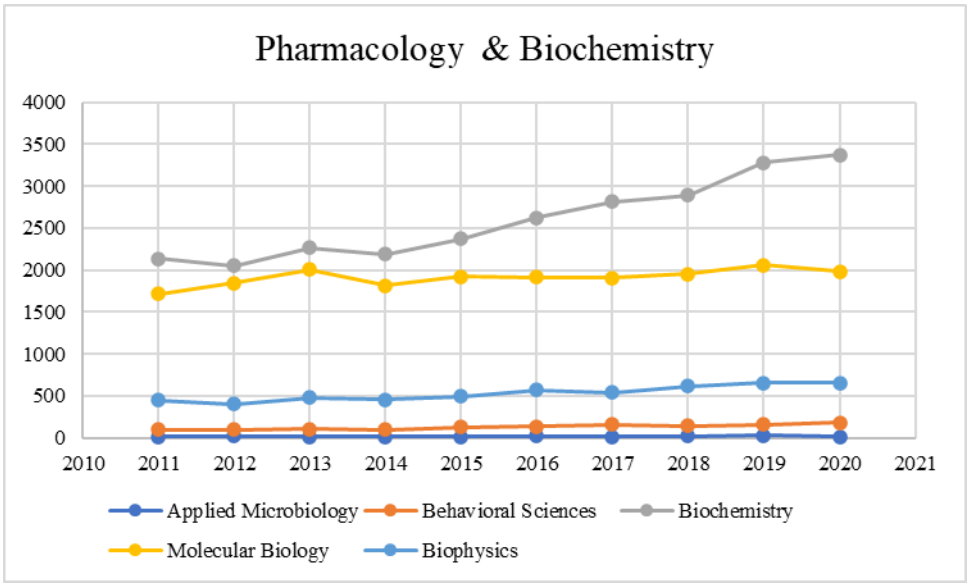

Fig. 6. Publication activity in Pharmacology & Biochemistry.

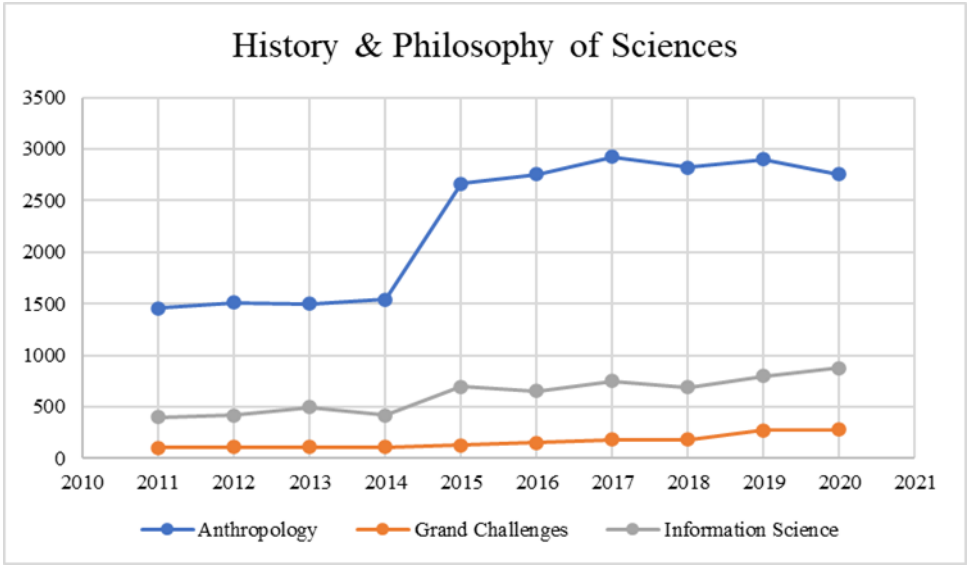

Fig. 7. Publication activity in History and Philosophy of Sciences

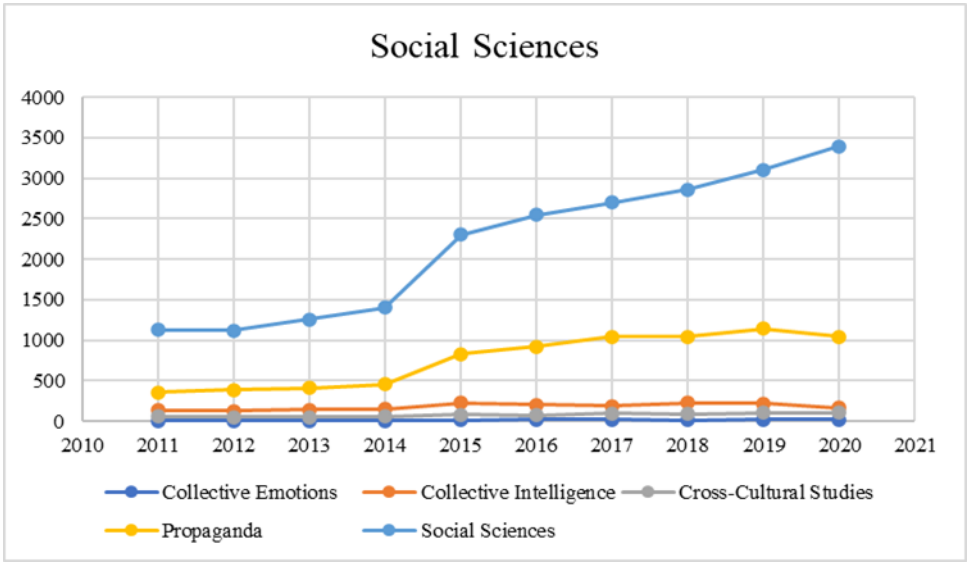

Fig. 8. Publication activity in the fields of Social Sciences.

The place of the NSoM in international and Russian publication landscape

The comparison of the Russian and world trends in the publishing process, taken from the title, does not aim at opposing the Russian science to the world one. Nevertheless, such a comparison is justified for two reasons in our article. First, the NSoM largely inherits a publishing culture of the Russian Federation. This is neither good nor bad. The Russian publishing culture has a number of advantages, which we will discuss later. Secondly, this journal is international and published only in English language. Therefore, it seems appropriate to consider the place of our publication not only among international, but also among Russian scientific media.

International scientific landscape

We reviewed all the journals in the Scopus bibliometric database that have the word Mind in their names. The titles of the journals, their Cite Score, theme, and publisher are presented in Table 1.

Table 1. The list of journals in the title of which the word "Mind".

No	Title	Cite Score	Theme	Publisher
1.	Mind and Language	2.01	Philosophy	Wiley-Blackwell
2.	Advances in Mind-Body Medicine	1.18	General Medicine	InnoVision Communications
3.	Mind and Matter	0.63	Philosophy	Imprint Academic
4.	Brain and Mind	N/A	N/A	N/A
5.	Emotions and States of Mind in East Asia	N/A	N/A	Brill
6.	Phenomenology and Mind	N/A	N/A	Firenze University Press
7.	Time and Mind	0.25	Archeology (arts and humanities)	Taylor & Francis
8.	Mind	1.58	Philosophy	Oxford University Press
9.	Mind, Brain, and Education	2.01	Education	Wiley-Blackwell
10.	Mind, Culture, and Activity	0.93	Social Sciences	Taylor & Francis
11.	Mindfulness	3.10	Health	Springer Nature
12.	Mind and Society	0.49	Philosophy	Springer Nature

N/A – the data not available

It should be noted that the number of this journals is limited. They thematically belong to very different disciplines and not cover the person's holistic nature. Thus, there is a need in an interdisciplinary journal and a free niche is available in the international scientific landscape. Let's consider each edition in more detail.

Brain and Mind is currently out of print. It was published from 2000 to 2003 (three issues per year). The journal was positioned as "A Transdisciplinary Journal of Neuroscience and Neurophilosophy", i.e. the main emphasis in publications was placed on neurosciences. This topic will be presented in the NSoM.

Emotions and States of Mind in East Asia refers to literary publications and is not a journal, but rather a serial Eastern manuscript. It has been published since 2010. The last volume came out in 2020. Despite the seemingly complete discrepancy in topics, the NSoM will include some aspects of considered publications. In particular, it is planned to publish the Psychology of Religion & Spirituality manuscripts.

Phenomenology and Mind is the closest to the NSoM. First, it is important to stress, that it is published by Firenze University Press (FUP), all of whose journals are in the public domain. Secondly, despite the fact that the journal focuses on publications in the field of philosophy, it also deals with interdisciplinary problems in social, cognitive, and other fields.

Mindfulness is an actively developing journal published by Springer Nature.. The journal has been published since 2010 and has 12 issues per year for the last two years. The Mindfulness refers more to practices and their empirical verification. And it is of no great interest to our journal.

Time and Mind has 4 issues per year. The journal features scholarly work addressing cognitive aspects of cross-related disciplines such as archaeology, anthropology, folklore, sociology, and psychology that can shape our understanding of archaeological sites, landscapes and worldviews. In general, publications in this journal are highly specialized (and thus do not correspond to the logic of the NSoM). However,

there are the articles directly related to psychology.

Mind is the oldest journal with the longest history. It has been published since 1876. The current publisher is Oxford University Press. It is interesting to note that now this journal is the absolutely philosophical journal. Although first it was conceived as a place to determine the subject and role of psychology in the system of natural sciences. Over the years, the journal published such authors as L. Carroll, B. Russell, W. James, A. Turing, N. Chomsky, C. Darwin, C. Hempel, D. Searle, and others. Currently, the journal is being published four times per year. The articles are devoted still to a wide range of philosophical problems. An invariably large section is devoted to a review of published books, which will also be presented in the NSoM. We are not aim at competing with the Mind's publications, but nevertheless we will include the section "History and Philosophy of Sciences" in our journal.

Mind, Brain, and Education has been published since 2007 and, as the name suggests, publishes articles on the interrelationship of learning, brain, and the mind. This journal is the official publication organ of the International Mind, Brain, and the Education Society (IMBES). The mission of this journal, as noted on the website, is to facilitate cross-cultural collaboration in biology, education, cognitive, and developmental sciences. Indeed, a significant portion of the articles published in the journal was a result of international cooperation. The journal is published 4 times per year. The journal pays great attention to the special issues based on the materials of conferences, as well as thematic issues. For example, the first issue of 2019 was devoted to the problem of Cyberlearning, which seems to be especially relevant in the context of the COVID-19 pandemic. In general, the journal is focused on educational practice and can be considered as the standard for publishing pedagogical articles. The practice of specialized issues seems to us very promising. We are planning special issues in which from the standpoint of different sciences one or another urgent problem will be considered.

Springer Nature has been publishing *Mind and Society* since 2000. The frequency of publication is two issues per year. But in 2017-2018 the issues were merged. The journal is close to economics. The subtitle reads: Cognitive Studies in Economics and Social Sciences. However, the journal according to the Scopus classifier, belongs to Philosophy. Economic issues, in general, remain outside of the NSoM scope. As the Russian satirist K. Prutkov said, "It is impossible to embrace the immensity". We do not preclude the possibility of covering economic effects on various aspects of human life in the NSoM special issues.

Mind, Culture, and Activity is a highly interdisciplinary journal, but within social sciences. It is published by one of the largest international publishers Taylor & Francis. The publishers in write their introduction: "We encourage interdisciplinary contributions – including, but not limited to, anthropology, psychology, sociology, history, philosophy, education, linguistics, critical race theory, media studies, queer studies, disability studies, and performance studies. We particularly encourage reports of research which have engaged partnerships reflecting a diversity of cultures, nationalities, and perspectives, especially which engage those that have been traditionally marginalised in the field». The journal topics are exclusively focused on cultural diversity. The NSoM has a much broader range of topics.

Mind and Matter is very close to the NSoM in terms of topics. It has been published since 2003 and is the official organ of the Society for Mind-Matter Research. The goal of the journal is to publish papers in the exciting fields of mind-matter relationship. The main directions of research are neuroscience, cognitive science, behavioral science, physical approaches, mathematical modeling, data analysis, philosophy of science, philosophy of mind, applied metaphysics, cultural and social studies, and history of ideas. However, the NSoM adds to the presented areas both traditionally humanitarian as anthropology, and also natural sciences, like biochemistry. Moreover, we do not limit ourselves to the topic of material substrate for mental phenomena.

Advances in Mind-Body Medicine focuses primarily on non-drug treatments. The authors of the journal do not oppose themselves to traditional medicine, but their focus on possible additions: spiritual help, yoga, and others. A medicine section is also planned in the NSoM, but we focus on the interdisciplinary approaches to treatment.

The latest issues *Mind and Language* journal have been published by another major international Publishing House Wiley-Blackwel, 5 times a year since 1986. The journal covers research in the field of consciousness and language, primarily, linguistics, philosophy, psychology, artificial intelligence, and cognitive anthropology. A special section dedicated to

linguistics is also planned in the NSoM.

Thus, the release of the Nature Systems of Mind journal thematically includes most of the existing journals, but amplifiers interdisciplinary interaction and offers authors and readers a possibility of discussion a much wider range of topics than those presented in the journals currently published. This makes it possible to fill the existing gaps in the interdisciplinary SHB research of Homo sapiens. The analysis of English-language journals proves that the appearance of such a journal is long overdue in the scientific community.

Russian publishing landscape

Despite the fact that the NSoM is an international journal which is published in English, it is made in Russia and by a team of Russian editors. In this regard, it inevitably absorbs the peculiarities of Russian publication culture. In the Russian Federation, narrow-topic journals are very rare, most of such journals arose in the last 5-10 years. Usually, the reputable journals publish papers on a wide range of issues within a certain field of science. As examples, we will cite some journals indexed in international bibliographic databases: "Questions of Psychology", "Psychological Journal", "Experimental Psychology". The only English-language journal "Psychology in Russia: State of the Art" also publishes works in all branches of psychology. In this sense, the emergence of a new interdisciplinary journal, occupying an important niche in human sciences, seems highly promising. The forty thematic headings, planned in our journal, are united in eight directions: Psychology, Biological Systems of Mind, History and Philosophy of Sciences, Linguistics, Mathematics & Statistics, Medicine, Pharmacology and Biochemistry, and Social Sciences. According to our bibliometric analysis, the integration of these branches of science can create a platform for breakthrough SHB research into the nature of human behavior.

Finally, most Russian journals have open access. The NSoM is not an exception. However, Russian open access has its own peculiarity. It is usually implied that open-access journals (as opposed to journals distributed by subscription), the authors must pay for their publications. In our journal, all articles will be posted on the Internet for free download and the authors will not be charged at all. We do not exclude the possibility of changing this scheme in the future, but at the initial stage of the journal's formation it will be like this.

The owner of the NSoM is the Institute of Psychology of the Russian Academy of Sciences. In every issue we will reserved at list one translated works of Russian authors, which have already become classical in Russia, but are not known to the English-speaking readers.

We believe that the implementation of this plan would allow us to overcome the gap between the Russian and world psychology not only in actual experimental research, but also in development of theoretical foundations and methodological basis of modern sciences about Sapient Human Behavior.

The first issue of the NSoM will contain an article by Boris Fedorovich Lomov. He was the first director of the Institute of Psychology of the Russian Academy of Sciences (USSR Academy of Sciences). This article was published in 1989 in the “Psychological Journal”. The selection of this publication is not accidental. B.F. Lomov was the founder of the systems approach in psychology which implied the integration of different sciences about man. The NSoM serves the same purpose. The basic principles of the publication activities of the NSoM are presented in the next section of the manuscript.

Manifesto of the Natural Systems of the Mind

I. We maintain high standards through a rigorous peer-review alongside with strict ethical policies. The manuscripts of the authors who violate the code of professional ethics (plagiarism, fraudulent use of data, false statements of authorship) will be rejected.

II. We proclaim the principle of open access to publications which makes interdisciplinary research available online to everyone all over the world. However, we believe that the authors themselves have the right to decide to share or not to share their database.

III. We aim at understanding sapient human behavior (SHB) through the research of systems interaction of the human brain, the mind, body, society, and AI-technology.

IV. We call for the study of Sapient Human Behavior simultaneous at the macro-, meso- and micro- levels.

V. We are committed to developing the generation of scientists of the future who would have considerable courage and would be able to overcome interdisciplinary barriers.

VI. We welcome the replication of the studies on different samples and under different conditions.

VII. We invite you to put forward and consider any ideas about the nature of Sapient Human Behavior. As they may seem insane at first glance. The question is whether they are crazy enough to be true?

VIII. We call upon the researches to pay attention to the randomness and the slightest deviations from the regularities. In science, nothing can be neglected, it is precisely what cannot be, may points to the way of scientific discovery.

IX. The information and material contained in publications are for educational, research, and information purposes only.

X. The Natural Systems of Mind makes every effort to ensure the accuracy of the information contained in publications. Our journal makes no representations or guarantees to the accuracy, completeness or suitability for any purpose of the Content of the publications. Any views expressed in the publications are the views of the authors and not the views of the Natural Systems of Mind.

Welcomes

The Natural Systems of Mind is an international multidisciplinary open-access journal, and the Editors welcome submissions from scholars around the world. Publications will be free of charge until 2025. The journal presents original and valuable papers from various fields of science in Sapient Human Behavior.

The journal welcomes both previously unpublished materials at the intersection of various scientific disciplines on the study of the systemic foundations of SHB as well as the replication of scientific data to confirm the reliability of the earlier obtained facts and findings.

All submitted manuscripts are subject to initial appraisal by the Editor, if it found suitable for further independent anonymous expertise, to peers' high-quality reviews.

The Natural Systems of Mind journal which it expected to be publish four times a year (No1 - March, No2 -June, No3 -September, No4 – December) has following sections in each issue: Editor's Material, Reviews, Empirical Articles, Brief Reports, Case Studies, Book Reviews, Comments, and Meeting Abstracts.

All manuscripts accepted for publication receive DOI.

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Author contributions. All persons entitled to authorship are listed. The contribution of all authors is roughly equal. The authors approved the final version and bear responsibility for all aspects of the publication.

Competing interests. None.

REVIEW

Psychology of the Possible and the Paradigm of Probabilistic Prognosis

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Abstract. The main directions and current state of the Probabilistic prognosis paradigm development are elucidated. Namely, studies of advance reflection phenomena, hypotheses generation and unconscious anticipation are described. Predictive coding theory in neurobiology is presented briefly which is actively working out at present in order to explain brain mechanisms of probabilistic prognosis. In line with the analysis of the main provisions of the Probabilistic prognosis paradigm, the monograph by V. V. Znakov "The Psychology of the Possible" (2021) is reviewed. In the V. V. Znakov's book, the Possible category is considered in different fields of psychology and is understood as a content which is potentially accessible to a human being in a perspective. The structure of V. V. Znakov's conception of the Possible is built as a fractal system of triads. In this context, new steps have been done in the study of understanding, spirituality and truth problems.

Keywords: The Possible category, a fractal system of triads, problems of understanding, spirituality and truth, probabilistic prognosis, generation of hypotheses, advance reflection, unconscious anticipation, predictive coding theory

The monograph by Viktor Vladimirovich Znakov "The Psychology of the Possible" [57] has been published, which has shown a new extremely productive stage in the author's study of a person's subjective world in the context of his (her) being. It's clear that the Possible phenomena analyzed, are quite in line with anticipation and probabilistic prognosis paradigm in psychology, which has rather long history of development already, and is working out actively at present because of very high level of contemporary human life uncertainty. Let's consider the main ideas of the book firstly, and then the most developed studies in the frame of anticipation and probabilistic prognosis paradigm, mentioned by Znakov shortly and described by the present author in more details.

The monograph is seen as a new development of the tradition of being and consciousness, and person in the world investigation, grounded by S.L. Rubinstein [36, 37] in Russian psychology. For many years Znakov worked at the Institute of Psychology, Russian Academy of Sciences in close cooperation with one of the nearest followers of S.L. Rubinshtein — A.V. Brushlinsky, who created a general methodological approach in psychology on the basis of the Subject category [14] — one of the central ones in his Teacher's legacy. Therefore, the prolongation of the named profound tradition is natural and logical scientific way for Viktor Vladimirovich.

The book on Psychology of the Possible is the fundamental scientific work that reveals the philosophical, psychological, epistemological, culture — oriented and methodological content of the Possible category. Its development is traced in different fields of psychology, and characteristics are given to the concepts of affordance (opportunities provided by the environment for a subject), a predictor (a prognostic parameter and a prognosis tool). And, certainly, the author's conception of the possible is of principle theoretical importance, and its structure is built as a fractal

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system of triads. These are three realities that form the human world actuality: empirical, socio cultural and existential. It would be useful to see a clearer definition of the category "reality of the world" — intuitively it can be understood precisely as the mentioned above category of a person' subjective world in the context of his being. A subject distinguishes and understands these three realities with the help of the three key categories — "necessary", "plausible" and "impossible". Besides, Znakov reveals several triads in his analysis of the Possible: the three characteristics of the unthinkable as a subspecies of the impossible; the three types of determination of his understanding of external and internal world corresponding to the three realities; the three types of understanding proper in cognitive, hermeneutic and existential traditions: understanding as knowledge, as interpretation and as comprehension, which corresponds to assessments of the truth, correctness and truthfulness of statements understood by people in communicative situations, as well as the three types of internal conditions of understanding: verbal and figurative signs, cognitive symbols and existential symbols; the three types of social knowledge: cognitive, conventional and spiritual; the three trends in the development of the psychology of the possible: going beyond the limits of the specific activity of the subject; disclosure of the plurality of variants of the dynamics of development, ways of self-change of subjectivity in a random unpredictable world, analytical distinction between "necessary", "plausible" and "impossible"; the three promising areas of psychological research on understanding post truth and lies. Such a clear structure reflects the logical completeness of the Possible concept.

Already in the listing of the epistemological triads considered by the author, it is clear that the analysis of the problem of understanding passes as a cross-cutting topic in the content of the book. In the development of this topic, he thereby makes another serious step (using new materials) towards the development of the previous equally fundamental stage in its study [56]. In the context of Psychology of the Possible Znakov also develops two other major directions of his research: the problems of spirituality and truth. Earlier the author outlined the main milestones in the understanding of spirituality by comparing the positions of psychology and religion [54], and now he extensively examines the phenomenology of the spiritual, discusses its definitions, genesis in mental activity, theoretical models and approaches to its study. The novelty of the author's view of human spirituality lies in considering it as a three-component mental formation, the emergence of which has meta-personal, activity and spiritual-practical grounds. As for psychological problems of truth, Znakov has already analyzed them in details at the level of a monographic publication [55]. In the new book, he specifically focuses on how in modern society, truth and falsehood are correlated in Russian and Western culture, and how the significance of the truth is reduced.

In the light of the first of the identified triads the author discriminates the key categories of necessary, verisimilar and impossible, and within the framework of the latter one, the sub-concept of unthinkable is highlighted. It is extremely interesting. He attributes the specifics of the necessary to empirical reality, the verisimilar to the socio-cultural reality (and this is his next advance in the development of the problem of truth), and the impossible and the unthinkable — to the existential one. Five! types of the impossible are distinguished as found in the literature: as a contradiction between a logically permissible (not contradicting the laws of logic) and physical inadmissibility of an action (a contradiction to the laws of nature); as unreasonable, the cause of which cannot be determined; as not verisimilar (absent in the past human experience) — but the author emphasizes that this concept and the concepts is not identical to of the impossible as unknown, unknowable, meaningless.

Constructive characteristics of poorly developed concepts of the unthinkable and post-truth are given. The three characteristics of the unthinkable are: suppression of irrational by rational; going beyond boundaries of the usual moral reasoning, due to a moral choice impossibility; such a discrepancy between knowledge and the existential experience of a subject who understands the world, in which he finds himself in an ambivalent position: at the same time, it is necessary and impossible to see the unthinkable. Two directions of post truth studies are highlighted: political (fake news) and philosophical-anthropological: untrue information, which is present in the mind nevertheless and influence the behavior of thousands of people (including lie).

In general, Znakov understands the possible following S.L. Rubinstein as content, potentially accessible to a human being in a perspective. The

two options of the "possible" category are separated — as an intellectual and personal choice from alternatives (truth or lie, altruism or selfishness, justification or conviction) and as the disclosure of new potentialities of an already, it would seem, analyzed topic of research, on which the modern psychology of understanding focuses.

As a direct student of B.G. Ananyev, Viktor Vladimirovich gives his characteristic of a functional organ [3]. It has to be mentioned at the same time, that earlier A.A. Ukhtomsky [45, 46] identified a temporary combination of various forces of the organism, capable to guarantee a certain achievement. Then N.A. Bernstein [11] described a functional organ as a temporary structure for combining various resources that provided purposeful human activity. In the theory of P.K. Anockhin, the functional system of a behavioral act psycho physiological mechanisms (temporarily formed to perform a specific task) has the same meaning [5, 6]. Later A.N. Leont'ev [27] has grounded (based on psychological material) that a functional organ is generated by a subject's task. It has been confirmed empirically: a temporary operational structure is built that combines cognitive resources with mechanisms of effort and activation, in order to solve a sensory task [20]. The concept of a functional organ was systematically developed by V.P. Zinchenko [51, 52] in the fields of engineering psychology and methodology.

The obvious urgency of the "Possible" concept developing is determined by the rapid changes in the modern world, which generate a high uncertainty in human life. Therefore, it's is completely justified Znakov's correlation of this concept with the problems of forecasting, anticipation, probabilistic prognosis in Russian psychology. Let's note that we would like to start the consideration of the phenomenon of anticipation with the book by B.F. Lomov and E.N. Surkov [29]. Znakov highlights justification of anticipation general meaning as an imminent property of all mental processes in their development, the necessary readiness of the subsequent stages of development by the previous ones [39]; V.D. Mendelevich's anticipatory concept of neurotic disorders, in the pathogenesis of which anticipatory failure plays a leading role [19]. Viktor Vladimirovich also characterizes this topic in the field of psychology of thinking, being a specialist in it. It is an emotional activation as an anticipation of a principle for solving a problem [44]; demarcation of anticipation and prognosis as different ways of achieving the possible, established by the ratio of cognitive and emotional components of prognosis when solving mental problems [13]; the interpretation of thinking as a movement towards the possible, which has not yet been conceived, the idea of dynamic control of uncertainty with the emphasis on anticipation and prognosis [23, 24]. In this context, Znakov refers to the definition of probabilistic prognosis as an assessment of: which actions are most likely to achieve a success in a changeable situation [17] and to the analysis of relationships between the real and the possible [34].

Certainly, Znakov's study of the Possible is quite close to anticipation and probabilistic prognosis paradigm in psychology. The present author also monitors the directions of works in this field, while systematically conducting experimental and theoretical studies in threshold-type tasks primarily, where decision-making always has a probabilistic nature, since subjective uncertainty is high (the levels of which are precisely set by the stimulation values) due to the sharp deficiency of input sensory or perceptual information [42]. Let us briefly summarize the most developed areas of works in cognitive psychology, supplementing Znakov's materials with our analysis [40, 42]. In the classical theory of perception, such phenomena are described to be a process of perceptual hypotheses testing in order to decide: which object has been perceived, made by probabilistic prognosis of their reliability when moving from features to categories [12]. In cognitive neuroscience, the generation of hypotheses is recognized as one of the main functions of the cerebral cortex, and perception is considered through anticipation [32, 33]. Probabilistic prognosis in behavior has been actively studied ([17]. P.K. Anockhin used this term to characterize the acceptor of an action results as a functional system component [38], but gave it a more global meaning, generalizing it to the principle of advance reflection of external events by the brain [4]. Active advance reflection is considered in the Anockhin's school not only as a universal attribute of all living beings' existence, which appears with the emergence of life and is represented at all levels of its organization [1], but it is understood as one of the leading functions of mind in Russian psychology as a whole. When developing methods for controlling the accuracy of advanced reflection in choosing behavior (according to Anockhin), a theoretical conclusion has been formulated that the brain is not a logical, but a predictive device. To obtain hypotheses with a controlled level of

confidence, a theory of probabilistic semantic inference was proposed, which combined logical inference with calculations of probabilities and showed that in the theory of knowledge there is not only passive, catching up, but also active, anticipatory control of a probability of a decision made correctness [47, 48].

The idea of hypotheses rivalry is also realized in the model of consciousness as a competition of possible multiple sketches of behavior — portions of the stream of consciousness at different stages of their analysis (corresponding to simultaneous and asynchronous patterns of brain activity) -— and the choice of one of them (Multiple Draft Models: [16]). It is similar to the conception of consciousness, which constantly test possible unconscious hypotheses about what is happening. The response awareness is the result of an unconscious process of choosing and checking one of them [2]. The model is also similar to a multi valued world image as a dynamic system of multilevel hypotheses and their continuous generation. The image of the world performs the function of a continuous prognosis as a tool of uncertainty radical reduction [43] — this work is also cited by Znakov in the section on anticipation). The conception of pre-adaptation to uncertainty has been developed as a fundamental strategy for living systems development in the course of unpredictable evolutionary routes [8]. Possible (what can happen as a result of a subject's activity) and probability are productively distinguished [28]. Znakov characterizes possible in a similar way — as a person's potential.

In modern neurobiology, anticipation processes are described by Predictive Coding Theory, the key idea of which is that the brain is a multilayered predictive mechanism [15, 18, 31]. Neural processing involves the interacting upstream of sensory data and the downstream of predictions about it. Each brain level receives information from the both streams and uses the Bayesian scheme for their coordination. This scheme is applied widely in cognitive science and points that the brain evaluates the posterior probabilities of hypotheses compared when choosing the most probable one between them (see [21], for example). Even a choice of an optimal behavior under uncertainty, made by insects and rodents, is often explained by decision making models using Bayesian probabilistic decision rule. And in general, the major models of decision making under uncertainty, describe it in terms of subjective probabilities of possible outcomes and of the outcomes expected utility, i.e. of their subjective values.

In humans' visual discrimination [41, 49] and in slow-warm lizards one [50], in auditory discrimination in humans [49] and in assessment of stretching in them [30], choices of erroneous decision are slower and are more often accompanied by hesitations than choices of correct decisions. Apparently, an individual doubts before making a mistake and therefore acts slowly, while he typically gives correct responses without many doubts and therefore quickly, although he does not know when he will be mistaken or will respond correctly. It may be interpreted as an unconscious anticipation of forthcoming responses in uncertainty tasks. At the level of physiological mechanisms, the unconscious slowdown and uncertainty of erroneous decisions are explained by the conception of activity (before making mistakes) of cortical and sub cortical error - determinining neurons. After making erroneous decisions, the activity of error - detecting neurons is recorded [9; 25, 26]. From the standpoint of the model of decision-making and confidence in sensory and perceptual tasks, which we develop, unconscious uncertainty of an erroneous decision is the result of the accumulation of an insufficient amount of unconscious information evidence in favor of this decision choosing. But in case of sufficient evidence, the decision is made more confidently and turns out to be correct [40]. "Confidence during the decision process" and "confidence after the decision made" were recorded experimentally [35]. This echoes the theoretically distinguished primary unconscious confidence before choosing between alternatives, which serves for a person as a subjective indicator of which one to choose, and secondary conscious confidence as a subjective assessment of correctness of an already made decision [41]. In our model mentioned, these two phenomena correspond mathematically to the evidence and the confidence itself — as the magnitude of the evidence deviation from the decision-making criterion.

It is not accidentally that in the modern era of ever-increasing uncertainty in life, several classes of conceptual-mathematical models have been developed which describe decision-making as a choice between alternatives and assessment of confidence in it. Indeed, in the absence of accurate and complete knowledge, the decision is made with the help of prognosis of the goal achievement. In such conditions, confidence in the hypothesis chosen is often the only psychological tool of

decisions correctness prognosis and controlling. We have reviewed such models and develop our model in the paradigm of probabilistic prognosis as the basic mechanism of perception and choice of actions in situations of uncertainty, using the typical example of them: sensory and perceptual tasks of similar objects discrimination [40]. Confidence is viewed as a subjective indicator of future decision predicted effectiveness and as an internal feedback for assessing a decision already made. The model is based on the psychophysical Signal Detection Theory and the Bayesian paradigm, in which a formal evidence variable is introduced in favor of a certain hypothesis about an object perceived. Evidence means sensory and perceptual information received by a subject, which he uses to choose a response. Evidence is an unconscious intermediate variable between input information and a decision made. Really a person feels a degree of confidence in the future response, and on the base of confidence he chooses that response alternative, a predicted utility or success, or correctness probability of which is assessed as maximal by the brain. Confidence is conscious when he is required to evaluate it. By modifying Bayes' rule, forming of the evidence and decision-making criteria is described (which happens strictly before a decision made), as well as the control of responses utility and correctness probability with their help.

In conclusion, let us note the promising directions outlined by Znakov for further research. They are studies of post truth and lies understanding: the ratio of cognitive and personal predictors of untruthful statements, rational conscious and emotional unconscious components of judgments, internal psychological conditions and external socio-psychological circumstances of alternative realities generation. Other areas of empirical research of the Possible are associated, in particular, with psychology of post-traumatic stress disorder (PTSD). Znakov mentions the technique of "anticipatory coping" with difficult life problems to be a person's desire to avoid doubtful situations [7]. We add that signs of PTSD occur only in 14–20% of people who have experienced the influence of intensive stressors. Thus, it is possible to overcome negative effects of such stressors by person's psychological resources mobilizing [22]. In addition, non-trivial empirical phenomena of prognosis and anticipation are described as tools for the possible analyzing not only in the future, but also in the retrospective past [53]. Undoubtedly, a deep analysis of Psychology of the Possible, carried out by Viktor Vladimirovich, will open up new methodological ways to investigate this problem, which are so needed today. The materials we have collected, obtained ourselves and briefly presented here, illuminate additionally processes of anticipation and probabilistic prognosis.

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The Issue of Psychogenesis and its Aspects

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Abstract. The article describes the main components of the model of psychogenesis, considered in several aspects: logical, evolutional (historical) and ontogenetic. It is shown that attempts to search for the basics of the mind in the structure of nervous system are meaningless; firstly, it is necessary to find out the role of nervous system in the process of organism adaptation to the environment. To solve this issue, it is required to describe the basic physical characteristics of the environment. The article claims that the process of psychogenesis is a complex multilevel phenomenon that must be considered at least in four directions: mathematical, physical, anatomic-physiological and psychological ones

Keywords: psychogenesis, logical aspect, evolutional aspect, ontogenetic aspect, four-level model of psychogenesis.

Psycho-physiology, clinical psychology, correctional psychology and some other disciplines use knowledge situated "on the border of two substrates" between the mental and the non-mental. This is the reason of questions about the essence of the mental, about its genesis (psychogenesis), about the laws of psychogenesis, about borders between the mental and the non-mental. There are some problems in studying this topic.

We suggest that psychogenesis is managed by some general laws, not only physiological and psychological ones. We will explore the laws connected (in our point of view) to psychogenesis and well-known in general sciences (mainly in mathematics and physics) and will try to connect them with psychogenesis.

Key issues of psychology and psycho-physiology

Issues solved by psycho-physiology which is situated literally "on the border of two substrates" are seen in so called key issues of psychology. There are following issues:

1. *The psychophysical issue* – place that the mind occupies in the nature, relationship between the mental and the physical.

2. *The psycho-physiological issue* – relationship between mental and physiological processes: the question whether nervous substrate of the mental exists should be answered.

The issue of borders between mental and physiological phenomena is also important. Usually it is thought that this border is the border between irritation and sensation. But this is not so. Now such borders can be discussed: 1) physiological irritations – mental sensation; 2) physiological reactions – mental state; 3) movements – action; 4) nervous system features – temperament; 5) makings – abilities.

3. *The psycho-gnostic issue* – degree of mental cognition of objects and phenomena (whether the mind reflects the environment properly).

4. *The psychosocial issue*: which is the relationship between individual and social mental phenomena? Here the connection with psycho-physiology means that the process of evolution of individual and social mental phenomena is managed by the same laws.

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Three aspects of psychogenesis

Psychogenesis is the main issue of psychology which has several aspects:

A. *The logical aspect*. Which laws of nature lead the evolution of mind? N.A. Kozyrev, a famous physicist, said that organisms cannot create things that do not exist in nature. They can only gather and use things laid in general features of the world. These features should also exist in inanimate nature. Unusualness of the mental is explained not by unusualness of the laws of psychogenesis, but by the fact that usual laws in unusual combination take part in psychogenesis. The issue of mental disorder genesis is the reverse side of the logical aspect of psychogenesis [13].

Which natural mechanisms "participate" in realisation of mental phenomenon? The first step is such feature as integrity. It can characterise both elementary sensation and public consciousness. Consequently, if there is the whole, its elements also should be found. Elements within the whole are not equal: there are dominants among them. If there are elements within the whole there is also a structure. Elements and a structure give a function that is determined both by the elements and by the structure. A mental phenomenon is a dynamic whole existing in development and in a particular environment.

Our idea is based on the expansion of the universe after the Big Bang. It is well known that during the expansion the universe not only takes more and more space but also becomes more differentiated and acquires new features. Organisms need to create more and more accurate mechanisms of environment reflection: the more differentiation is, the better the anticipation is developed.

There are two main features of the environment: ambiguity and non-equilibrium. Ambiguity means: a) relativity; b) uncertainty; c) incompleteness. Non-equilibrium means: a) self-organisation, b) periodicity, c) dominance (attractivity), d) discreteness – continuity.

Adaptation is the instrument of man-environment interaction. It includes two processes: reflection and regulation. Reflection is highlighting of objective features in the environment (the exo-mind) and their connection with genetic memory (the endo-mind). These two currents of information are connected to each other by the meso-mind; it helps to form behaviour contributing adaptation of a subject to the environment. There is also the meta-mind responsible for psycho-social phenomena [1].

Reflection devices were formed during the evolution step by step. Evolution had more than one stage. There was nuclear, chemical, biological, social and cultural evolution. Evolution is eternal continuity of self-organisation processes.

The differentiation and integration processes are instruments of evolution. The last ones represent ambiguity and non-equilibrium on the biological level. These processes control morphogenesis, psychogenesis, socio-genesis, labour-genesis, ethno-genesis, culture-genesis. Differentiation and integration processes, changing each other periodically, contribute creation of non-equilibrium situations in the biosphere. Morphogenesis process creates such a set of elements within the organism that finally leads to creation of new functions: one of them is called "the mind".

The physical world view is the system of invariants different by level of generality (from the topological level to the metric one). Every invariant complies to a physiological functional system (FS), formed according to self-organisation laws. The invariant is one of FS activity products. Here the invariant is the attractor of self-organised FS.

Psychogenesis is managed by some fundamental laws of nature which also work in other disciplines, but their combinations in psychology are unusual. There are no specific laws of mind creation: it is possible to explore the mind using natural-scientific methods. It does not mean that psychology can adopt laws of other disciplines (for example, physiology). Psychogenesis is bifurcation point, after that the typical laws of psychology become to work. But general laws work on the stage of psychogenesis, after that irreversible changes and development of the mind occur.

The opinion that psychology is an individual case of physiology is based on an "optical illusion" and, in fact, is a typical logical error like "post hoc, ergo propter hoc" ("after that" means "because of that"). This illusion appears every time when explorers register physiological and mental phenomena together. Some physiological changes indeed occur when psychological ones do, but not as the reason of them. Both psychological and physiological laws, and also more general ones that should be mostly

connected with laws of holistic phenomena, work in psychology.

Integrity laws and mind phenomena

We are going to study cases when psychologists use data received in other disciplines for explanation of mind phenomena.

Al least, four levels can be highlighted in this case.

1. *The mathematical level*. Formally the objective of psychogenesis is that a device able to stabilise the "slipping" environment is needed. Nervous system is adjusted to distinguishing invariant features in chaotic currents of information.

Psychology and geometric invariants

There are well-known physical invariants: the Avogadro constant, the Planck constant, etc. Many physiological parameters (heart rate, blood pressure, body temperature etc.) also can be considered as invariants. The term of invariant was introduced in psychology by J. Piaget. There are Koffka's perceptive constants (invariants). According to D.V. Atkinson's law, the sum of the strategies of success ambition (Ps) and failure avoidance (Pf) equals a constant. The sum of their probabilities equals 1. L.M. Vekker's works explaining mental processes with algebraic invariants are also widely known. All these theories consider invariant as an attractor of self-organised system [1; 2].

Mental reflection (perception is a special case) can be formally considered as conversion from one coordinate system to another, and it does not depend on the mechanisms leading this conversion.

Which transformations can be done with the image of reflected object considered here as a geometric shape situated on any background plane?

The metric invariant. We can rotate the background plane of representation around the origin or move the object. Direction between two points, line segment division ratio, vector length, a scalar product, an angle between two lines, position of three points on one line, parallel and perpendicularity do not change here. Invariance of shape features connected to plane orientation is lost during such transformation.

The similarity invariant. We can multiply all coordinates of the object and a ρ coefficient. These geometric transformations have a centre in the origin and homothety coefficient ρ. Homothety ("situated equally") is straight or reverse relatively to a particular point (the centre of homothety) position of similar shapes. Segment length and triangle area will not conserve, but the relationship of segment lengths or areas will do. Linear position of points, parallel of lines and an angle between two lines conserve.

The affine invariant. A plane of representation can be stretched or squeezed along one of coordinate axis or at some angle in relation to the origin. In this case following concepts will be affine: line, line segment, midpoint, parallel lines, triangle, quadrilateral. Equation of non-parallel segments, perpendicularity of lines, equilateral triangle, right-angled triangle, rhombus, rectangle, circle, rotation of a vector around a point or an axis. All triangles and also all parallelograms are affine-equivalent.

The projective invariants. Let us turn the plane of representation on an angle. During a projective transformation planes and points lying on a line transform to points situated on the same line. In the projective plane not only two different points determine a line uniquely, but also two different cross always in the same point. Three points situated on one line are dependent, points that are not situated one a line are independent. There is no parallel principle here. Parallel lines can cross. All triangles are identical, and so are all quadrilaterals. Unlike the affine invariant, there are no terms "ellipse", "parabola", "hyperbola" here.

The topological invariant. Let us add new transformation of the projective plane: it can be, for example, wrapped to a hemisphere with unequal random edges. Only the fundamental features of a shape remain after such projection: connectivity, compactness, dimensionality, weight, fundamental group, homology groups. All circular spaces are equivalent, there are no terms "line", "curve" [6; 11].

The diagram of connection of perceptive image formation stages and the system of geometric invariants is following: 1. The opened outline stage corresponds to the topological invariant. 2. The "amorphous spot" stage corresponds to the projective invariant. 3. The stage of curvature sudden variations distinction corresponds to the affine invariant. 4. The stage of common-suitable perception corresponds to the similarity invariant. 5. The stage of suitable shape representation corresponds to the metric invariant [7; 8].

Besides invariant theory that let consider a

mental phenomenon as a holistic composition, there are mathematical theories studying structural characteristics of such objects. Graph theory, which allows describe complex objects formally is an example.

The issue of integrity and the graph theory

Many features of holistic objects do not depend on features of their elements, and mostly existence of these elements is enough, and their interaction is typical. Why graph theory is so attractive for psychologists? There are several kinds of issues that can be solved using methods of this theory.

The first group of tasks was just described above – this is studying of general laws of mind establishment that needs elements and links between them. General psychology, psychophysiology, animal psychology, differential psychology are interested in this kind of studying. The second group is represented by tasks of algorithmic phenomenon description. The language of the mentioned theory permits us to build a model of activity, to imagine processes of decision making, learning and interiorisation, formation stages of thinking actions, phonetic sounds etc. visually. The third group includes combinatory tasks of social psychology, sociology and labour psychology [10; 19; 23; 24; 25].

There are tasks connected to scheduling, organisation of transport flows, designation, reliability assessment, managing information flows etc. [4; 16; 26].

The main terms of the graph theory. Like other disciplines, the graph theory use symbols that give "economy" of thinking and makes the instrument of studying more flexible. Most of these symbols came from the set theory.

The rule setting the corresponding between set elements is called representation and meant by the letter F with indication of original and represented elements. The original element is indicated straight after the letter F, the represented one is indicated after the equal sign in curved brackets: Fa1={b1}, Fa2={b2} etc.

A kind of representation in which each element of the original set corresponds to only one element of another one is called single-valued, if there are more elements, this is a multi-valued representation. This connection of elements let us consider some of them as representations of the other ones. This is first-degree representation. We can also consider representation of higher degree and reverse representations of any degree. For graph determination we should have an *X* set and an *F* representation set.

Kinds of graphs. O-regular graph is a graph that consists only of isolated vertices. In a complete graph each pair of vertices is connected by an edge or a directed edge. In a connected graph there is a chain that connected each pair of vertices. Isomorphic graphs correspond to a particular list of vertices but their edges and vertices are situated in different ways. A graph which has at least two adjacent vertices connected by more than one edge is called a multigraph. In a planar graph its edges cross only in vertices [12; 14; 20].

Thus, there are formal procedures that permit to explore the relationships between the elements within the whole that do not depend on particular essence of these elements.

Development process of the mental whole has several levels. The second level is the physical one.

2. *The physical level*. Solving the issue of psychogenesis we have discovered that exploring anatomic-physiological organisation of nervous system and organism shows nothing until we answer the question: "What means nervous system for adaptation of an organism to the environment?". And one more question: "Which are physical features of this environment?".

In terms of physics psychogenesis is a phase change from diffuse state to structured one. Psychogenesis is a change of phase state of a combination of environmental features, like change of state of matter, for example, for water these states are: ice, liquid, vapour, plasma. We should add that in case of I. Prigozhin's non-equilibrium thermodynamics the number of possible nonlinear non-equilibrium phase changes much more than classical phase changes, because open systems demonstrate a huge number of possible spatial-temporal relationships of extremely complex nets, including chaotic meta-stable states. This permits to develop the mathematical aspect of psychogenesis considerably, using methods of nonlinear dynamics and the complex net theory for adequate modelling of real, realising approaches to psychogenesis [18].

Conservation laws and invariance of physical quantities

In physics, invariants are connected to conservation laws.

Conservation laws are some fundamental physical laws disclaiming conservation (i.e. invariance) of particular physical quantities. The most famous among them are laws of conservation of mass, energy, linear momentum, angular momentum and charge. It is also interesting that, although conservation laws were introduced in specific fields of physics (for example, laws of conservation of energy and linear momentum appeared in Newtonian mechanics), they are general.

According to *E. Noether's theorem*, conservation laws are closely related to symmetry of space and time. These laws are significant for science: they demonstrate not only the invariance principle, but also *the symmetry principle* [15; 22].

For example, the law of conservation of linear momentum is the consequence of space uniformity: all points of space are equivalent, and translation does not change the system [15; 22].

E. Noether's theorem connects the law of conservation of angular momentum with such a type of symmetry as space isotropy – constancy of space when a reference frame is turned on a particular angle [15].

According to E. Noether, the law of conservation of energy is connected with time uniformity. It means that all time segments are equivalent to each other, and the moment when an event happens is not important from the physical point of view.

E. Noether connected the law of conservation of charge with gauge invariance of phase changes. In other words, all existing phase processes are possible thanks to the law of conservation of charge [15; 22].

The term of "geometric invariants" are well connected with E. Noether's theorem that permits to explain the "symmetry" of mental phenomena. Like in physics there is a connection between conservation laws and features of space and time, geometric invariants in psychology can be connected with phase changes in a perceptive image.

The evolution of theories in organic chemistry

Compound structure theories and reactive capacity theories (i.e. theories that explain connection of atoms in a molecule, their interaction within a molecule and process of chemical reactions) form a theoretical base of organic chemistry. The development of organic compound structure concepts includes several stages which can be characterised in following way:

The theory of radicals ("the dualistic theory"). The essence of this theory: all compounds are made of oppositely charged particles (elements) by electrostatic attraction forces. In organic compounds not only atoms but also their groupings (radicals) can be called charged particles. The theory of radicals was the base for classification of organic compounds, in some cases an explanation of their features was succeeded.

The theory of types. It was created by J. Dumas on the basis of the radical theory that he rejected, but the term "atom grouping" (or "radical") was conserved. J. Dumas supposed to classify organic compounds by types. For example, acetic and chloroacetic acids belong to the same type.

The unitary theory. This theory supposed by C. Gerard and O. Loran based on the replacement principle. All organic compounds can be formed from particular types by replacement of hydrogen atoms by organic (hydrocarbon) groupings – radicals. This theory let scientists predict and synthesise new classes of compounds (organic acid anhydrides, polyoles).

The structure theory. The term "valence" that means "capacity of an element to attract a particular number of atoms of other elements" has appeared. A. Kekulé supposed carbon quadrivalence principle and proved that carbon atoms can connect to each other and form long chains. A.M. Butlerov supposed the term "structure" that reflected a sequence of atom connection in a molecule. He also supposed to use dashes between the atoms to explain a sequence of atom connection in a molecule.

Classic electronic theories of chemical bonds. In organic chemistry there are problems similar to those in psychology: in the first case we should find laws of unification of elements (atoms) in bigger groups (molecules), in the second case we should establish laws of formation of bigger

mental phenomena (images, emotions etc.) from elements, or laws of unification of people in groups and labour activity [10; 23; 24; 25]. This circumstance let us suppose that in both cases there are more general laws partly represented in chemistry and psychology. 23 V.M. Bekhterev's laws should be mentioned here [1]. To sum up, the mind phenomenon is a "legal" natural phenomenon managed by fundamental natural laws, and we can describe it in terms of given laws. The laws of chemistry and psychology can differ only particularly.

The main principles of quantum organic chemistry. The classic theory was complemented by quantum chemistry, based on physical discoveries on dual (corpuscular and wave) nature of electrons. Mechanics of microcosm (wave mechanics) was created. E. Schrödinger installed an equation linking wave nature of a moving material particle (in particular, of an electron) that has spatial coordinates and energy:

$$\frac{d^2\Psi}{dx^2}+\frac{d^2\Psi}{dy^2}+\frac{d^2\Psi}{dz^2}+\frac{8\pi^2 m}{h^2}(E-U)\Psi=0$$

Here $\Psi(x, y, z)$ is the wave electron function that depends on its spatial coordinates. Physically it means that its square (Ψ^2) characterise probability of electron location in a particular space point. E is for full energy of an electron, U is for potential energy, h is for the Planck constant, m is for mass of an electron.

Thus, chemists trying to solve the issue of unification of atoms in a molecule tend to consider that inner features of elements are driving force of this unification. These features are: electron charge, valence, atomic structure of a molecule.

Features of the whole (a molecule) depend on structure of connections between elements: basic features, quantity and chemical structure of elements; the set of initial elements and their combination; energy of given connection. The last one characterise stability of the whole. A stable state is a state that has less elements (energy minimisation principle) [17].

3. *The anatomic-physiological level.* The task to solve is stabilisation of the streams of given information. It is carried progressively and has several levels. According to G. Shepherd, there are 5 levels of nervous systems organisation: a) micronets (the lower level of nervous net organisation; it consists of particular synapses and their pre- and postsynaptic structures); b) local nets, formed by collateralisation of pathways and interneurons; c) local modules (cortical columns, glomeruli, nucleuses, ganglia); d) the areas and lobes of the brain; e) hemispheres [28].

4. *The psychological level.* Invariant searching is necessary for world view formation. The process of invariant searching stops when incoming information begins to repeat. Here an invariant is an attractor of the process of environment view by searching its stable (invariant) features. The "world view" formed in this way is highlighted thanks to using the system of individual values [1].

The issue of integrity in biological and anthropological sciences

The laws explaining existence of the whole are explored by different biological sciences, although they can be formulated in different ways. For example, there is a question in physiology and anatomy, which criteria of brain department classification should be chosen for future construction of more general brain structures (and, finally, behaviour) from these "elements". And despite basic concepts about brain structure and its division into parts are recognized, there are many discussions about the role of these parts in general brain activity [3].

In biology and physiology the question about relationship of the elements and the whole, structure of the whole in connection with the function of physiological systems is actively discussed. Indeed, discussions about role of system approach in exploration of biological objects came to psychology from physiology. However, the laws described in physiology do not permit us to explain mental phenomena on this basis. They do not consider all circumstances, in other words, the laws of the physiological whole cannot be applied to the mind, because the mind (including social phenomena), is more diverse than the physiological whole.

Concepts explaining behaviour organisation

Our aim is to begin the synthesis of all existing theories to a holistic structure that let us explain fairly cast group of mental phenomena. Let us summarise mentioned theoretic concepts

Table 1. Behaviour elements and integrity

Author	Discovered features of the hypothetical mental whole (as a phenomenon)
I.M. Sechenov	1. There are inborn and purchased types of behaviour. 2. Self-regulation is the main principle of existence of the whole that also during the evolution
I.P. Pavlov	1. Reflex self-regulation as a way of adaptation. 2. There are inborn types of behaviour (unconditioned reflexes as elements of the whole); purchased ones (conditioned reflexes) are based on them. 3. An unconditioned reflex is the base of the whole. 4. Occurrence of the whole needs synchronization of elements (unconditioned reflexes) and indifferent signals
V.M. Bekhterev	1. Mental and physical phenomena are leaded by the same laws of being (23 laws). 2. Besides the biological evolution, there is the mental one and also the mental selection. 3. There are two types of reflexes: simple (inborn) nervous one and mental (combined, purchased) one
J.B. Watson	There are inborn reactions and, based on them, integral ones, which are formed according to the laws of permutations and combinations. It is possible to change one element for another within the whole without destroying of its main function
A.A. Ukhtomsky	1. Organisms live in a probabilistic environment. For successful adaptation it forms its own image of the environment (chronotope). 2. For reflection of environmental features nervous system forms its nervous code (a constellation of nervous centres that has features of the whole). The main factor (dominant) and elements (subdominants) exist within this whole. There is compliance between the structure of environmental traits (features) and the constellation of nervous centres formed for this reason. 3. The constellation and its dominant are the essence of a physiological mechanism, needed for integration of contradictory and exhaustive information about the environment. Integration is an adaptor that allows organisms to act in a probabilistic environment.
K. Lashley	The mental whole consists of particular elements. At least, quantity of the elements and the structure of links between them are the most important for the cases of learning, not their content and features (the elements are equivalent). All the elements can be replaced by each other
E. Tolman	1. Purchased elements of behaviour (based on Watson's molecular units, known now as functional systems) are affected by genetic factors that determine motives of behaviour. A motive is concentrated past experience. 2. There are "sense" components (dominants) in the environment, that makes it non-equilibrium. 3. Behaviour is discrete
L.V. Krushinsky	1. There are inborn and purchased types of behaviour. The last ones are based on extrapolating reflexes. 2. The quantum of discrete behaviour is an unitary reaction
Ethologists (K. Lorenz, N. Tinbergen, J. Uexküll, W.	1. Behaviour is discrete. The quantum of behaviour is a set of fixed actions (SFA). 2. Many fairly complicated types of behaviour are combinations of inborn elementary ones. 3. Final objective of different types of behaviour is adaptation. Items of adaptation

Craig)	are SFA, display, inborn allowing mechanism (IAM), imprinting, offset activity, redirected activity, intentional movements, regression, hyperactivity, ritualization etc.
P.K. Anokhin	1. Behaviour is discrete. 2. The act of behaviour is holistic phenomenon. Elements of this whole are described (there are 5 of them). 3. Self-regulation of the whole is possible. 4. Phase character of existence of the whole. 5. Integrative character of the whole
N.A. Bernstein	1. Behaviour is discrete. 2. Number of elements of the mental whole is equal to six. 3. There are different levels of the whole, connected to the level of motion regulation. 4. Self-regulation of the whole. 5. Integrative character of the whole
D.O. Hebb	1. Any mental phenomenon is based on a holistic neuronal unit called "a cell assembly". There is a hierarchy of assemblies and corresponding hierarchy of mental phenomena. 2. Features of "cell assemblies": integration, convergence, equipotentiality, statistic links between the elements, invariance
G. Miller, E. Galanter, K. Pribram	1. Behaviour is discrete. 2. The nervous substrate and corresponding types of behaviour have many levels
Activation concept of D. Lindley, E. Duffy, R. Malmo etc.	1. There are different levels and types of behaviour that depend on activation level (the existence of the whole depends on its energetic charge). 2. There are three types of activation: vegetative, behavioural, cortical
M.N. Livanov	1. Integrity of nervous substrate corresponds to the mental whole. 2. The mental whole is dynamic. Character of link between the elements of the whole determines its function (mental). 3. The mental whole changes periodically. 4. The features of the mental whole are coded both in special and temporal features of the substrate (the holographic principle)
A.M. Ivanitsky	1. The subject-environment interaction is discrete. 2. The mental whole is layered: one layer is connected to non-specific assessment of events, and another one to specific assessment.
A.R. Luria	The mental whole has layered structure. There are three layers corresponding to three sections of the substrate: the energetic unit, the unit of information conversion, the programming unit
I.T. Kurtsin	The mental whole has layered structure. There are three layers corresponding to three sections of the nervous system: "the somatic brain", "the visceral brain", "the mental brain"
E.N. Sokolov	The mental reflective mechanism is necessary for reduction of ambiguity of the environment. This mechanism distinguishes events with high and low level of probability that makes the environment non-equilibrium. There are dominants in the environment

R.I. Kruglikov	1. The mental whole (the image of the environment) is a combination of elements based on present and memorised information. 2. Excessiveness of the image is necessary for consideration of different variants of the events development. The last fact is the consequence of high ambiguity of the environment.
A.S. Batuev	1. The environment is highly ambiguous. 2. There are inborn behavioural programmes, but they cannot be used properly because of the ambiguity of the environment. 3. The act of behaviour is holistic phenomenon that has elements (inborn programmes), structure and function. Union of the elements is led by the dominant motivation. The sign of the felt emotion is a signal of biological quality of the event
V.B. Shvyrkov	1. Behaviour is based on inborn programmes (IP). Number of them reflects a story of adaptive organism-environment relationships during the evolution. 2. New types of behaviour appear thanks to free ("not full" with IP) neurons that reflect the system, also conditioned by the structure of the environment. 3. The act of behaviour is holistic phenomenon that has elements (IP), structure and function

The analysis of the heritage of several generations of biologists and psychologists exploring the issue of mind genesis has highlighted several stages in development of modern approach to the issue of mental whole (MW) formation. On *the first stage* it is noted that the MW is based on "inborn atomic structures" (i.e. reactions, unconditioned reflexes etc.), the laws of interaction of the MW with the environment. *The second stage* is characterised by detailed studying of the laws of unification of elements to the whole: it was discovered that their integration needs elements "managing" this process (dominants). On *the third stage* the axiological non-equivalence of the environmental features for the whole is noted: some features are more valuable than the others, it makes the environment non-equilibrium for the subject. Behaviour is a way of connection with the environment necessary for adaptation to it. Behaviour discreteness is established. MW is considered as a dynamic system. *The fourth stage* is characterised by the statement that "the quantum of behaviour" is layered. *The fifth stage* is characterised by the statement that events happening in the environment are probabilistic, and consequently the main function of the mind is decrease of its ambiguity

B. *The historic (evolutional)* aspect of psychogenesis: "How the mind has been formed during the process of evolution"? The logical aspect explains how the formation of the mind must proceed, which logic the process has, which relationships the substrate and the mind have, which kinds of the mind are possible. The evolutional aspect demonstrates the real process of psychogenesis.

The most important issue is the connection of psychogenesis with the laws of evolution and explanation of different mental phenomena (cognitive and emotional phenomena, behaviour), stages of their development and their phylogenetic age. Another issue is the relationship between the substrate and the mind on different stages of evolution. The data we have let us consider that the relationship of an organism with the environment on different stages of evolution are led by different departments of nervous system. However, different forms of behaviour in general remain similar, and complication of substrate causes only differentiation of behaviour. All the anterior nervous devices conserve in the brain but change the function and become devices controlling the base of behaviour (the reticular formation, the thalamus) and participating in organism state control.

C. *The ontogenetic aspect:* "How does the mind develop during the process of ontogenesis, which stages does psychogenesis have"?

In psychology ontogenesis is the formation of basic mental structures of a human being during his or her childhood. If considered wider, ontogenesis is the mental development process during all life.

Basing on von Baer's laws of embryology and the biogenetic law, we can suppose that the

ontogenetic stages of mental development are the same that the evolutional ones. This rule exists, in particular, in the process of thinking development. According to the Leontyev – Fabry theory, evolution of the mind had several stages: 1. The sensor mind stage. 2. The perceptive mind stage. 3. The intelligence stage. 4. The consciousness stage.

Limitations of modelling possibility of the mind as a natural phenomenon

Psychogenesis can be considered at least in four aspects. Such representation of the process let us build models of psychogenesis in the future, what can be fairly important in the epoch of common computerisation and robotisation. We think that modelling of the "mind" resembles modelling of the nuclear. In both cases explorers deal with an invisible (for some reasons) object. Physicists gathered the knowledge received in experiments. Finally, when there was enough knowledge, E. Rutherford created the model of the nuclear that satisfied to new knowledge. Something similar can occur in psychology.

Theories of oscillatory neuronal nets are much closer to our approach [5]; they are different from mainstream deep learning and consider the role of synchronisation of neuronal oscillations appropriately (from the point of view of the psychogenesis model).

The understanding of psychogenesis (a random process) requires introduction of the term "computing irreducibility". It means that we cannot predict behaviour of the modelled mind as a complex system, except repeating of real stages of ontogenetic (and evolutional) development. When we consider coincidence of psychogenesis correctly, there is no shorter way of evolution than the natural course of time. In this case it comes to relation of the logical and the evolutional aspects of psychogenesis.

Thus, the traditional point of view considering that exact knowledge of the laws let us predict psychogenesis exactly is not correct in the case of nonlinear and random dynamics (as in our case).

We can declare that all trial of exact mind model creation that needs total intelligence algorithmisation are led by the K. Gödel's incompleteness theorem [27] and also are connected with Kolmogorov-Cheytin's statements [9] about limits of complexity, which obviously limit opportunities of these concepts. In other words, there are objective limits in mind algorithmisation. Whether mind algorithm was created by engineers, it will differ from natural version of the mind. And it means that robots cannot dominate a human being, certainly if he or she does not cease active interaction with the environment. The situation in physics is quite similar: it is impossible to create "the theory of Everything".

The issue of brain dynamics modelling is closely connected to the Many-Body Problem. Recent works of theoretical physicists developing the theory of critical phenomena (phase changes) show a close relationship of discussed issue with existing models of spatial and temporal regulating and occurrence of so called long-range correlations (neuronal assemblies synchronisation). Such explorers as Dante Chialvo note that the mind works in standard mode in a so called "critical point"; this fact let us include elaborations of nonlinear dynamics and bifurcation theory [21;29].

Anyway, invariant searching issue (invariants are order parameters of environment considered as the main aim of psychogenesis), can be solved using powerful apparatus of theoretical physics.

We can base our model of psychogenesis on the following statements.

Conclusion

1. The mental reflection of the environment corresponds to its features, as a key to a lock.

2. Exploring the features of the mental reflexive instrument, we can explore the features of the environment.

3. Exploring the features of the environment, we can discover the requirements of the environment to the mental reflexive instrument.

4. Solving the issue of psychogenesis, we have discovered that studying anatomic-physiological organisation of nervous system and organism does not give us any information until we will know the role of nervous system in the process of adaptation to the environment.

5. A mental phenomenon is holistic. It consists of elements, structure and has a particular function. A mental phenomenon is a dynamic self-organised whole which changes over time. The mental reflexive instrument is aimed at identifying invariant features of the environment.

6. The mind has layered structure. The holistic mind consists of spheres put one into another. We call them endo-mimind, meso-mind, exo-mind and meta-mind. These spheres are isomorphic.

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EMPIRICAL ARTICLE

Validation of the Portuguese Version of the Structure of Temperament Questionnaire (STQ-77PT) Based on A Brazilian Sample

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Abstract. This paper reports the validation of the Portuguese version of the Structure of Temperament Questionnaire (STQ-77Pt) using a Brazilian sample of 248 participants (M/F = 126/122). The study examined STQ-77Pt's factorial structure and its psychometric properties in terms of reliability, and construct and concurrent validity. Maximum-likelihood confirmatory factor analysis showed that STQ-77Pt has a factor structure similar to that found in the English, Russian, Chinese and Polish versions. The study also compared the STQ-77Pt scales with two other tests available in Portuguese language (the Ten-Item Personality Inventory, TIPI, based on the Big Five approach; and the Sensation Seeking Scale Form V, SSS-V). Results were consonant with the theory. There were high positive correlations between the scales of Neuroticism as measured by the STQ-77Pt and the TIPI, as well as between Sensation Seeking as measured by the STQ-77Pt and the SSS-V; the STQ-77Pt scales of Social Endurance and Social Tempo showed high correlations with the corresponding TIPI scale of Extraversion; and the STQ-77Pt Empathy scale was found to have a positive relationship with the TIPI scale of Agreeableness. These results suggest high reliability and concurrent validity of the STQ-77 measure for Portuguese-speaking researchers and practitioners.

Keywords: temperament, concurrent validity, Structure of Temperament Questionnaire, Five Factor Inventory, Sensation Seeking scales, Functional Ensemble of Temperament.

The concept of temperament refers to neurochemically-based individual differences in behavioral regulation, which are present both in pre-cultural individuals (animals, infants) and adult humans (Trofimova, Robbins, Sulis, & Uher, 2018). In contrast to temperament, personality describes individual differences primarily from the socio-cultural perspective. Moreover, temperament relates to universal dynamical features of behavior that are most consistent and most predictable across a variety of situations whereas personality include systems of values and attitudes that can suddenly change in specific situations (Strelau, 1987). A search for biomarkers of consistent behavioural patterns (temperament traits in healthy individuals and psychiatric disorders continues) (Trofimova et al, 2018; Trofimova & Netter, 2021). In this search, it is important to have psychometric instruments that were developed on adults and not children samples (Trofimova, 2019). It is also important that these instruments are in line with models of behavioural regulation proposed in neuroscience, and not just based on parents' observations of their children.

Since temperament pertains to the most

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consistent and biologically (neurochemically)-based aspects of behavior, it could be a basis of what are considered the "soft skills", i.e. consistent behavioural patterns based on dispositions for learning (Robles, 2012).

A comprehensive neurophysiologically-based model of temperament was offered in the form of the Structure of Temperament Questionnaire (STQ) over 30 years ago by Vladimir Rusalov (Rusalov, 1989, 1997, 2004, Rusalov & Trofimova, 2007). This model was then upgraded and rearranged by Irina Trofimova based on her analysis of the functionality of neurotransmitter systems and opioid receptor systems, known as neurochemical model Functional Ensemble of Temperament (FET; Trofimova, 2016, 2018, 2019, 2021a,b; Trofimova & Robbins, 2016) and based on functional constructivism approach (Trofimova, 2017, 2021a,b). The STQ-77 is structured in line with the FET, which has 12 components, grouped in line with the three-block model offered by Luria (1962) in reference to the three neuroanatomic functional systems regulating human behavior (Rusalov & Trofimova, 2007; Trofimova, 2010a, 2010c, 2016, 2018, Trofimova & Sulis, 2010, 2011).

A critical difference between the STQ and other models of temperament is that the STQ inherits the activity-specific approach to the structure of temperament proposed by Rusalov (1989; 1997; 2018). Thus, instead of the following a "general arousal" approach, that considers only one general energetic trait (such as Extraversion or Activity), in the STQ-77/FET model, the temperament traits pertain to different aspects of activity, such as the motor-physical, social-verbal and mental aspects, which are based on different neurophysiological systems and should be assessed separately (see also Trofimova & Robbins, 2016). Furthermore, it uses the benefits of the FET model, which validates the STQ-77 with the links to specific neurochemical biomarkers.

The final STQ-77/FET model considers twelve different temperament traits: nine systems (and traits) regulating the formal functional aspects of behavior (energetic, dynamic and orientational, each assessed in three domains (intellectual, physical and social-verbal), together with three systems related to emotionality (neuroticism, impulsivity and dispositional satisfaction) (see Figure 1).

Then, with the goal to assess the concurrent validity of the STQ-77Pt, we compared it with two other internationally well-known scales that measure stable biobehavioral individual differences and that are available in the Portuguese language: the Ten-Item Personality Inventory (TIPI; Gosling et al., 2003) and the Sensation Seeking Scale Form V (SSS-V; Zuckerman, 1994). Based on the theory and previous research using the English, Russian, Chinese, and Polish versions of the STQ-77, we developed three hypotheses regarding the relationship between four STQ-77Pt dimensions and their analogues in other scales:

H3: The STQ-77Pt scale of Sensation Seeking will have a significant positive correlation with the analogue scale of the SSS-V.

H4: The STQ-77Pt scales of Social Endurance and Social Tempo will have significant positive correlations with the TIPI scale of Extraversion.

H5: The STQ-77Pt scale of Neuroticism will have a significant positive correlation with the TIPI scale of Neuroticism.

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H5: The STQ-77Pt scale of Neuroticism will have a significant positive correlation with the TIPI scale of Neuroticism.

Besides examining closely analogue scales, we also tested hypotheses regarding less conspicuous relationships among the STQ-77 and other scales. First, a positive relationship is theorized between STQ-77's Empathy scale and TIPI's Agreeableness scale. Empathy refers to the sensitivity of an individual to another person's state and expectations. Individuals high in empathy are described as very attentive to the sense of justice, equality and appreciation, tending to participate

in altruistic and volunteer activities, even having problems keeping subordination boundaries in issues of community values and in the helping of others. Likewise, individuals high in Agreeableness are described to also be altruistic, putting the interest of others before their own needs and interests, they also tend to have a high opinion of human nature and dislike being the center of attention, and to (Costa & McCrae, 1989). Given these similarities, we hypothesize that:

H6: The STQ-77Pt scale of Empathy will have a significant positive correlation with the TIPI scale of Agreeableness.

Figure 1. The design, descriptions and abbreviations of the scales of the Structure of Temperament Questionnaire (Compact, STQ-77) that follows the framework of the neurochemical model Functional Ensemble of Temperament (FET).

Functional aspects of behavior	**Behavioral orientation to types of reinforcers:**	**Preferred speed of integration of actions**	**Energetic maintenance of activities**
Mental aspects	Probabilistic processing PRO	Plasticity PL	Intellectual (Mental) Endurance ERI
Implicit, more probabilistic	*... to learning causality and probabilities of events*	*in generation of new behavioral programs in changing situations*	*Sustained attention*
Social-verbal aspects	Empathy-autism EMP	Social Tempo TMS	Social-verbal Endurance ERS
Explicit, more deterministic:	*…to others people's motivation*	*speed of pre-learned social-verbal elements of actions*	*Sociability (ability to sustain prolonged communications)*
Physical-motor aspects	Sensation Seeking SS	Motor-Physical Tempo TMM	Motor-Physical Endurance ERM
	…to physical sensations and HPA arousal	*speed of using pre-learned physical elements of actions*	*ability to sustain prolonged physical activity*
Emotional amplifiers of orientational, dynamical and energetic aspects	Neuroticism, NEU	Impulsivity, IMP	Satisfaction-confidence, SF
	Low tolerance of uncertainty and novelty, negativity bias in expectations	*A degree of how premature the integration of actions is, emotional reactivity*	*A tendency for approval bias, being (sometimes overly) optimistic and confident*

Method

Sample

The STQ-77 was administered to 248 subjects (M/F = 126/122, *Mean* age in years = 29.48, *SD* = 9.06), including 132 undergraduate students enrolled at the entrepreneurship program in Universidade Federal Fluminense, Brazil, who received course credit in a general management course. We also recruited 116 senior-level professionals who volunteered for this study. All participants signed a consent form to participate in this study.

Measures

Compact Structure of Temperament Questionnaire (STQ-77) (Rusalov & Trofimova, 2007). The STQ-77 has 77 statements, assigned to 12 temperamental scales (6 items each) and the validity scale (5 items) listed below. Subjects respond according to a Likert scale format: "strongly disagree (1)," "disagree (2)," "agree (3)," "strongly agree (4)". The STQ-77 organizes the 12 temperament scales into four sub-groups:

1. The Physical Aspects group: Physical Endurance, (ERM), Physical Tempo (TMM) and Sensation Seeking (SS).

2. The Social Aspects group: Social Endurance (ERS), Social Tempo (TMS) and Empathy (EMP) (orientation of actions in response to another person's emotional state).

3. Mental (Probabilistic) Aspects group: Mental (Intellectual) Endurance (ERI), Plasticity (PL) (the ability to adapt quickly to changes in situations, to change the program of action, and to shift between different tasks) and

Probabilistic Processing scale (PRO) (the ability of an individual for adequate understanding and expectations of probabilities and causal relationships between events, the efficient extraction and processing of new knowledge).

4. The Emotionality group involves three scales referring to a tendency to be optimistic, confident (sometimes overly optimistic) regarding one's own performance, and unaffected by other people's warnings and criticism (dispositional Satisfaction, SF); the emotional reactivity, a poor ability to control immediate impulses for actions (Impulsivity, IMP), and a tendency for expectations of negative outcomes and low tolerance of uncertainty (Neuroticism, NEU). Finally, the Validity scale assesses the social desirability bias in the answers, with results within the range of 15-20 on this scale being considered invalid as this indicates a positive impression bias in the responses.

Ten-Item Personality Inventory (TIPI). The TIPI was developed by Gosling et al. (2003) as a short questionnaire to assess the Big-Five personality dimensions of Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism (Costa & McCrae, 1989). Within each dimension, one item represents a positive pole, the other a negative pole. For this study, we utilized the Portuguese version by Nunes et al. (2018). The reported reliability coefficients ranged between .48 and .68, which is a common range for short scales, as the original authors explain.

Sensation Seeking Scale Form V (SSS-V). The SSS-V was elaborated by Zuckerman (1994) and is a questionnaire consisting of 40 forced-choice questions designed to assess individual differences in optimal level of stimulation along four sub-scores: Thrill and Adventure Seeking; Disinhibition; Experience Seeking, and Boredom Susceptibility. For this study, we utilized the Portuguese version by Oliveira (2008). The reported reliability coefficients ranged between .69 and .86.

This study was approved by the Ethics Committee of Universidade Federal Fluminense and written informed consent was obtained from the participants before they entered the study.

Procedures

All subjects received debriefing and signed an informed consent form before testing. University students received a practicum credit for their participation. Statistical processing included the calculations of the descriptive scale statistics (means, SD, confidence intervals), reliability coefficients (Cronbach's alphas) and correlations among all the measures applied. We also performed exploratory and confirmatory factor analysis with the aim to assess how well the measured variables represent the theoretical latent dimensions.

Translation. The translation of the STQ-77 into Brazilian Portuguese involved five steps. First, two bilingual researchers, from Universidade Federal Fluminense and Pontifícia Universidade Católica do Rio de Janeiro, independently translated the English version of the STQ-77 into Brazilian Portuguese. Second, each version was independently back-translated by a native speaker. Third, the two independent versions were compared, and the semantic equivalence was discussed with another bilingual researcher, with expertise on psychometrics. Fourth, a third version was developed by consolidating the two previous versions. It was subsequently submitted to an expert panel discussion composed of one clinical psychiatrist, one clinical psychologist and one psychometrist, all of whom with the expertise and qualifications to perform an appropriate evaluation of not only the language but also the content of the items. Finally, this consolidated version was back-translated and assessed by the authors of the original STQ-77.

Factor analysis. For the confirmatory factor analysis, three models were evaluated in this study. Model 1 is a first-order model consisting of the twelve temperament scales. Models 2 and 3 are second-order models consisting of four and seven factors, respectively. The two latter models were based on the results of the exploratory factor analysis conducted in this study and on previous factor solutions of the STQ-77 (see also Trofimova, 2010a).

Results

Descriptive statistics

Table 1 shows the descriptive statistics. Means and standard deviations (SD) are reported for for the male and female sub-samples and for the full sample. Confidence intervals of the standard deviations (CI SD) are also reported for the full sample. It is noteworthy to highlight that our sample—composed of university students and senior-level professionals—displayed high means in the scales of PRO (high average ability to extract and process new knowledge) and ERS (high average capacity of social endurance).

The rightmost column in Table 1 shows the reliability coefficients measured by the Cronbach alphas (Alpha). All alpha values were in the acceptable range (0.70-0.79). These results lend support to H1, indicating that the STQ-77Pt scales have sufficient internal consistency.

Table 1. Means, Standard Deviations (SD) and Alphas for the STQ-77Pt scales

	Male Sample		Female Sample		Total Sample			
	Mean	SD	Mean	SD	Mean	SD	CI SD	Alpha
ERM	15.42	3.68	14.83	3.69	15.13	3.69	3.39-4.05	.76
TMM	15.62	3.73	15.00	3.92	15.31	3.83	3.52-4.20	.79
SS	16.95	3.51	15.44	3.88	16.21	3.76	3.46-4.13	.77
ERS	17.12	3.73	17.48	3.71	17.30	3.72	3.42-4.08	.76
TMS	16.30	3.39	16.56	3.48	16.43	3.43	3.15-3.76	.74
EMP	15.95	2.59	15.98	2.44	15.97	2.51	2.31-2.75	.71
ERI	16.59	3.12	16.48	3.42	16.54	3.27	3.00-3.58	.71
PL	15.03	3.30	15.06	3.50	15.04	3.39	3.12-3.72	.72
PRO	18.86	3.19	17.27	3.33	18.08	3.35	3.08-3.67	.70
SLF	14.66	3.83	13.16	3.32	13.92	3.66	3.36-4.01	.70
IMP	16.23	3.44	16.92	3.51	16.57	3.49	3.20-3.82	.74
NEU	15.19	3.40	15.89	3.53	15.53	3.48	3.20-3.81	.71

Note. SD: standard deviations; CI SD: confidence intervals for the standard deviations; Alpha: Cronbach coefficient. Male sample, N=126. Female sample, N=122. Total sample, N= 248.

Table 2. Item-total correlations of the STQ-77Pt items

	ERM	TMM	SS	ERS	TMS	EMP	ERI	PL	PRO	SLF	IMP	NEU
item 1	.73	.70	-.59	.65	.67	.69	.56	.62	-.64	.66	.66	.65
item 2	.73	.72	.75	.57	.66	-.56	-.71	.64	-.53	-.55	.70	.61
item 3	.46	.73	.70	.67	.69	-.69	.63	.69	.64	.51	.63	.63
item 4	.76	.76	.61	-.74	-.70	.53	.62	-.63	.69	.65	.65	.64
item 5	-.57	.74	.65	-.64	-.62	.68	-.58	.66	.68	.70	.71	.63
item 6	.78	.53	.65	-.75	-.62	.68	.72	.62	.62	.72	.61	.65

Note: Zeros before the comma are omitted. All values are significant at $p < 0.001$.

Item-total correlations of the STQ-77Pt scales and Confirmatory Factor Analysis

Table 2 shows the item-total correlations of each STQ-77Pt scale. The results show that all items but one (item 3 of the ERM scale) had an absolute correlation coefficient of at least '.50' with their respective scale. Moreover, about half of the items had a strong absolute correlation coefficient of at least '.70'. All reversed items entered with a negative sign, as expected. Finally, all values were significant at $p < 0.05$. These results lend additional support to H1.

We evaluated three different structural models in this study, using maximum-likelihood Confirmatory Factor Analysis (CFA). Model 1 represents the twelve-factor solution (Figure 2). Model 2 represents the four-factor solution (Figure 3, left side). Model 3 represents the seven-factor solution (Figure 3, right side). The results indicate that the factor structure of the STQ-77Pt follows the activity-specific structure of previous versions of the STQ-77. Specifically, it distinguishes between the scales of physical, social, mental and emotional aspects of behavior, thus providing support for H2.

Figure 2. CFA of the twelve-factor model

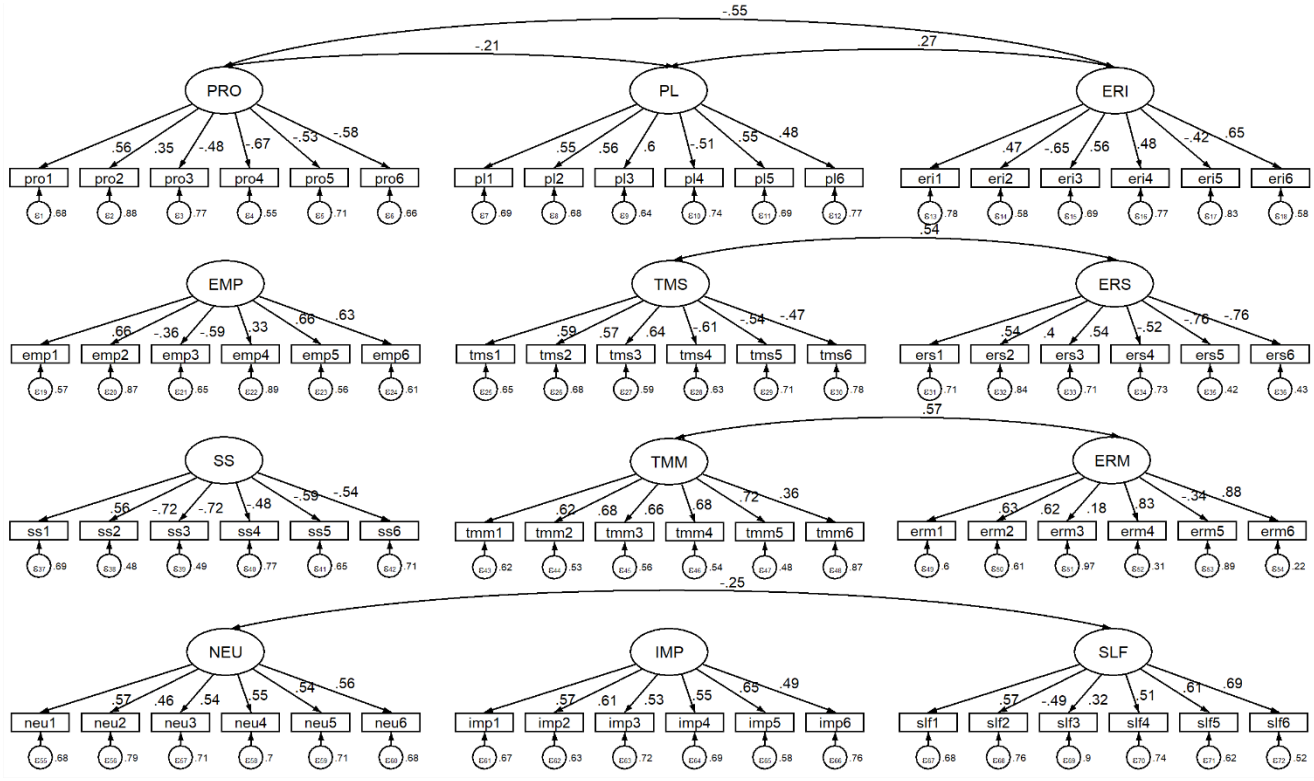
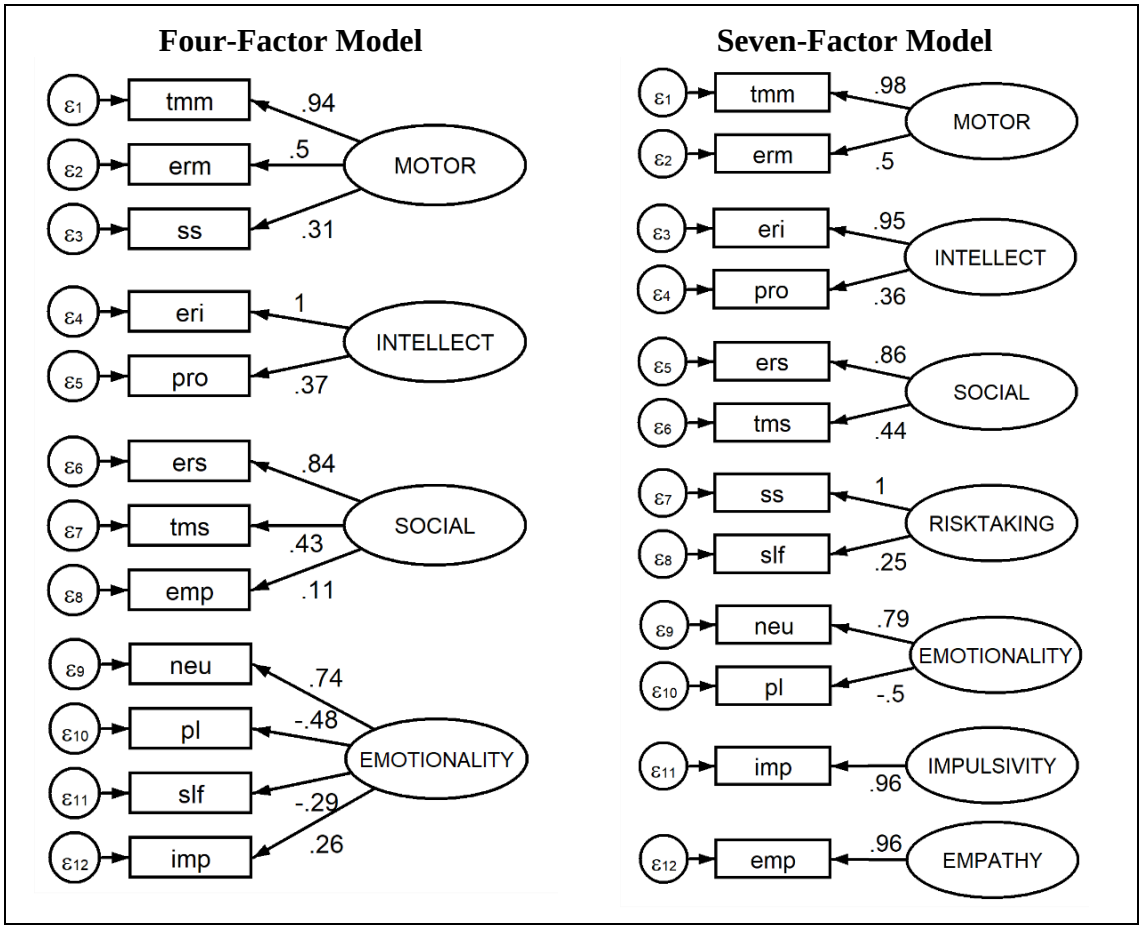


Figure 3. CFA of the second-order models.



Concurrent validity

Table 3 shows the results of correlational analysis (ρ) of the associations between the scales of the STQ-77Pt, TIPI and SSS-V. The results were in accordance with all proposed hypotheses regarding concurrent validity (H3-H6). In line with H3, the STQ-77Pt scale of Sensation Seeking had a very significant positive correlation with the total Sensation Seeking score in the SSS-V (ρ = .53; $p < 0.001$). Likewise, in line with H4, the scales of Social Endurance and Social Tempo had significant positive correlations with the TIPI scale of Extraversion (ρ = .22; $p < 0.01$ and ρ = .17; $p < 0.05$, respectively). Also, in line with H5, the STQ-77Pt scale of Neuroticism also had a very significant positive correlation with the TIPI scale of Neuroticism (ρ = .31; $p < 0.001$). Additionally, we tested correlations between the STQ-77's Empathy scale and the TIPI scale of Agreeableness, as well as the SSS-V scale of Disinhibition. In line with H6, there was a significant positive correlation between Empathy and Agreeableness (ρ = .53; $p < 0.01$). Finally, there was a significant negative correlation between Empathy and Disinhibition (ρ = -.20; $p < 0.01$).

Table 3. Correlations among the STQ-77Pt and comparison scales.

	TIPI (*N* = 181)												
	ERM	TMM	SS	ERS	TMS	EMP	ERI	PL	PRO	SLF	IMP	NEU	V
N							-.19**				.18*	.31***	
E				.22**	.17*				-.25***				-.19**
O			.21**										
A			-.19**	.16*		.22**							
C							.25***				-.18*		.30***
	SSS-V (*N* = 132)												
	ERM	TMM	SS	ERS	TMS	EMP	ERI	PL	PRO	SLF	IMP	NEU	V
TAS		.24*	.51***	.20*				.18*				-.32*	
ES		.27*	.48***	.24*						.24*	.22**	-.20*	
DIS			.29***	26*		-.19**				.20**	.16*		-.15*
BS													-.17*
SSS			.48***	.24*						.22**	.18*	-.21*	

Discussion

Internal Consistency

Our study shows that the reliability and internal consistency of the STQ-77Pt are sufficient, thus supporting for H1. The alphas for each of the 12 STQ-77Pt scales were within the acceptable range. The scales with the worst but still acceptable performances were PRO and SLF. This can be an artifact of the sample, given that it consists mostly of university students or professionals with a high level of education, thereby the high average PRO. The distribution of SLF, with a greater variation than the other variables, may also have been affected by the large presence of entrepreneurs in the professional sample since previous research identified a relationship between overconfidence and entrepreneurship (Baron, 1998). Despite these remarks, the alpha values obtained were satisfactory even for these variables. In sum, the overall results suggest that the items are internally consistent and a valid representative of their scales.

Factor Structure

To gauge whether the STQ-77Pt follows the activity-specific structure of previous versions of the STQ-77, we conducted Confirmatory Factor Analysis (CFA). Specifically, we evaluated three different structural models: four-, seven- and twelve-factor solutions. These models were particularly useful to compare the factor structure of the new STQ-77Pt with those in the validated English, Chinese, Polish and Russian versions of the STQ (Rusalov & Trofimova, 2007; Trofimova, 2010a,b). These previous results showed that the factor structures of all four language versions were consistent with the theoretical STQ model and found four factors unifying 12 scales: the factors of Physical (Motor), Social, Mental (Intellectual) Activity, and the factor of Emotionality.

In this study, our results were consistent with the theorized factor structure of the STQ, thus lending support to H2. For the twelve-factor solution (Figure 2), all but one observed variable (i.e., the scale items) displayed an absolute loading of more than '.30' in their respective scales, which is in the acceptable range (Figure 2). The exception was item "erm3" with a small loading of '.18' in its factor, ERM, which refers to the ability to sustain prolonged physical activities. It is a surprising result, given the item description "I can finish a prolonged manual job without taking a break" and the good results regarding its variance (σ^2 = .93 on a 4-point Likert scale) and distribution (skewness = -.01; kurtosis = 2.03). Still, this exception does not change the conclusion that, overall, the twelve-factor solution of STQ-77Pt is consistent with both the theorized structure and with previous versions of the STQ.

The four-factor solution (figure 3, left side) was identified as the best fit for the data. The first factor (MOTOR) represents the deterministic and more explicit physical-motor aspects of behavior: Motor Tempo (TMM); Motor Endurance (ERM); and

Sensitivity to Sensations (SS). The second factor (INTELLECT) represents the functional aspects of behaviors geared toward more implicit, probabilistic, and complex contexts: Probabilistic Processing (PRO) and Mental Endurance (ERI). The third factor (SOCIAL) represents the social-verbal aspect of behavior: Social-verbal Endurance (ERS); Social Tempo (TMS); and Empathy (EMP). Finally, the fourth factor (EMOTIONALITY) represents the emotional reactivity aspects of behavior. It is the combination of four sub-scales: low tolerance of uncertainty and novelty (Neuroticism; NEU), inability to adapt quickly to changes in situations (the reverse of Plasticity; PL); tendency to be unsatisfied, untrusting and non-optimistic about reality (the reverse of Satisfaction; SLF); and the initiation of actions based on immediate emotional reactivity rather than by advanced planning or reasoning (Impulsivity; IMP). Therefore, this four-factor model is well aligned with the theory and previous studies regarding the STQ-77 and the functional ensemble of temperament (Trofimova et al. 2018; Trofimova & Robbins, 2016; Trofimova & Sulis, 2011; ; Rusalov & Trofimova, 2007). These results, showing a good separation between the scales of physical, social, mental and emotional aspects of behavior, thus, lend support for H2.

We also included a seven-factor solution (figure 3, right side) to offer an intermediate version that is more granulated than the suggested four-factor solution. The same initial factors of the four-factor solution remain (MOTOR, INTELLECT, SOCIAL and EMOTIONALITY), but some items are redistributed to compose three new factors. The factor RISKTAKING is composed by the combination of Sensation Seeking (SS), which includes the underestimation of outcomes of risky behavior, and Satisfaction (SLF), which includes the tendency to sometimes be overly optimistic about reality. The factor of EMOTIONALITY, which had "lost" the element of SLF to the RISKTAKING factor, loses another element—impulsivity, which now composes a new factor of its own (IMPULSIVITY). Finally, Empathy (EMP) is dissociated from the SOCIAL factor to constitute another factor of its own (EMPATHY). This redistribution of elements among the three extra factors is also consonant with the functional ensemble of the temperament theory and with previous studies of the STQ-77.

In sum, in line with H2, we find that the factor structure of the Brazilian Portuguese version of the STQ-77 is consistent with that found in other studies using STQ-77 versions in English, Chinese, Polish and Russian versions (Trofimova, 2010a,b). Furthermore, we found that our best factor solution (the four-factor solution) largely replicates that found in Trofimova (2010a), with the factors of pertaining to physical (MOTOR), social-verbal (SOCIAL), and mental (INTELLECT) activities composing the first three factors, and the last factor being that related to emotionality.

Concurrent validity

We used two internationally known tests that were available in the Portuguese language to gauge the concurrent validity of the STQ-77Pt. We organize our discussion into four sub-topics, each reflecting one of the big functional group (Physical-Motor; Social-Verbal; Probabilistic-Intellectual; Emotional Amplifiers), as follows.

Physical-Motor Scales (ERM; TMM; SS). The investigation of concurrent validity of this group of scales was mostly limited to the Sensation Seeking scale of the STQ-77; however, the results also showed significant correlations between TMM and some dimensions of the SSS-V. Regarding the SS results, they largely support H3: we found that the STQ-77Pt's SS scale was correlated with all the sub-items of Zuckerman's SSS-V, as well as the overall SSS score. This result is not surprising, given that both scales measure stable biobehavioral individual differences regarding sensation seeking. Moreover, we found that the STQ-77Pt's SS scale had a positive correlation with the TIPI scale of Openness. We understand that this relationship may be due to the aspects of Openness that regard to the enjoyment of new and different activities, and the association of Openness with a high need for variety in the respondent's life, and with liberal beliefs regarding the social, political, and moral spheres (Costa & McCrae, 2008). Thus, it is not surprising that people high in Openness will also display sensation seeking behaviors, as those have also been associated with high levels of Experience Seeking, susceptibility to boredom and disinhibition. Moreover, we found an interesting relationship between TMM and SSS-V scales. This correlation was mainly driven by the Thrill and Adventure Seeking (TAS) and the Experience Seeking (ES) scales, indicating a connection between a high level of TMM, which measures the speed of using pre-learned physical elements of actions, and the desire to engage in physical activities, such as mountain climbing, skydiving, or scuba diving, as well as the desire to experiment with new things, especially those that provide unusual sensations and experiences.

Social-Verbal Scales (ERS; TMS; EMP). ERS was positively correlated with TIPI's Extraversion,

corroborating the first part of H4. ERS also had a positive correlation with Agreeableness, and a negative correlation with Neuroticism. The former relationship may be due to the sociability factor embedded in both Agreeableness and Social Endurance scales. The latter may be due to the fact that Neuroticism has been associated with "embarrassment or shyness when dealing with people, especially strangers" (Costa & McCrae, 2008, p. 244), which in turn would not be expected to go hand-in-hand with high Social Endurance. Interestingly, ERS had a positive correlation with SSS-V, indicating a connection between Social Endurance and the seeking of new experiences, possibly through social disinhibition and, perhaps particularly, through a "nonconforming general lifestyle with like-minded friends" (Zuckerman, 2007, p. 13). Regarding the results of the TMS scale, they were in line with its hypothesized positive relationship with Extraversion, thus corroborating the second part of H4. TMS was also negatively related to Neuroticism, again replicating the result found for ERS. Regarding EMP, the results were in line with H6, showing a positive correlation with Agreeableness. Interestingly, EMP was also slightly correlated with Neuroticism and Openness. These results could motivate further studies. Finally, the EMP scale showed a negative correlation with Disinhibition (SSS-V), indicating that those with a behavioral orientation toward emotional states and needs of others may be less prone to be hedonistic, "wild" or utilize alcohol as a means for disinhibition. Possible associations of this type were suggested by the author of sensation seeking theory, Marvin Zuckerman describing a hedonistic lifestyle, 'wild' parties, sexual variety, and drinking to disinhibit" (Zuckerman, 2007, p. 13). Individuals high in Disinhibition tend to participate more in drug use, alcohol use, vandalism, and/or unsafe sex. This is a sharp contrast with the previous description of the behavior of those high in Empathy, who tend to be pro-social, caring, and even have difficulties in establishing their boundaries (Rusalov & Trofimova, 2007).

Probabilistic-Intellectual Scales (ERI; PL; PRO). Although we did not hypothesize a priori about the relationships for the group of scales, there were some significant results. ERI had a positive correlation with Conscientiousness while being negatively correlated Neuroticism. The association between ERI and Conscientiousness may be due to the fact that ERI involves the suppression of stimuli other that those related with the task at hand, which can be useful for the facets of Conscientiousness related to getting chores done without delay, completing tasks successfully, and being deliberative. The same ERI characteristic of suppressing stimuli may be negatively related to the facet of Neuroticism regarding immoderation (i.e., the non-capacity to resist temptations) and, perhaps, Hostility, with ERI helping to withhold the likelihood of manifesting anger or irritation. PL was correlated with Conscientiousness and with the Thrill and Adventure Seeking dimension of the SSS-V, which are interesting results to explore in further studies. Also of interest are the results regarding PRO. Like PL, PRO was also positively correlated with Conscientiousness. PRO also had a very significant negative correlation with Extraversion, as well as a slight negative correlation with Agreeableness, results which could also be explored in further studies.

Emotional Amplifiers (SLF; IMP; NEU). NEU, as measured by the STQ-77Pt, had a positive correlation with TIPI's Neuroticism, corroborating H5. NEU was negatively correlated with the SSS-V scales of Thrill and Adventure Seeking and Experience seeking, indicating that those sensation seeking behaviors are less likely to be found in persons with low tolerance for uncertainty and novel situations. IMP was positively correlated with TIPI's Neuroticism. This result is not surprising, given that impulsiveness and immoderation are facets of the lexical approach to Neuroticism (Costa & McCrae, 2008, 1989). Additionally, IMP had a negative relationship with Conscientiousness. This association is also not surprising given that Conscientiousness entails the facets of self-discipline and deliberation, both of which go counter to the premature the integration of actions represented by IMP. SLF did not have any significant relationship with the TIPI scales. Interestingly, all emotional amplifiers (SLF; IMP; NEU) were significantly correlated with the total SSS-V score. NEU was negatively correlated with the SSS, while SLF and IMP were positively correlated with the SSS. Although we did not have specific hypotheses for these relationships, they in fact replicate previous findings (Trofimova, 2010a,b,c; Trofimova & Sulis, 2011).

Overall, the results regarding the concurrent validity of the STQ-77Pt are in line with the predictions from theory and with findings from previous studies.

Conclusion

In conclusion, this study aimed to investigate psychometric properties of the STQ-77Pt using a Brazilian sample. The STQ-77Pt provides a brief screening for temperament traits, i.e., the most consistent and biologically (neurochemically)-based aspects of behavior. The results show that the STQ-

77Pt has internal and structural validities similar to the initial version. Specifically, the reliability analysis showed sufficiently high alpha values, and the structure of the STQ-77Pt analyzed using the CFA showed that the STQ-77Pt items were grouped according to the assigned scales. That is, the grouping of scales followed the activity-specific approach, resulting in the aprioristic theorized factors of Motor aspects, Social aspects, Mental aspects and Emotionality, also largely replicating previous CFA studies using other STQ-77 versions (Rusalov & Trofimova, 2007; Trofimova, 2010a).

The correlations between scales were in line with the theory (Rusalov & Trofimova, 2007), and corroborated our hypotheses. The STQ-77Pt scale of Sensation Seeking had a significant positive correlation with the total Sensation Seeking score in the SSS-V. The scales of Social Endurance and Social Tempo had significant positive correlations with the TIPI scale of Extraversion. Neuroticism also had a significant positive correlation with its analogue scale in the TIPI. Finally, STQ-77's Empathy scale had a significant positive correlation with the TIPI scale of Agreeableness, and a very significant negative correlation with the SSS-V scale of Disinhibition. This study, therefore, demonstrated sufficient psychometric properties of the STQ-77Pt as an adaptation of this test to Brazilian sample.

The use of the STQ-77Pt will be beneficial in a series of settings, helping academics, practitioners in clinics and in the industry to assess the most stable neurochemically-based individual differences and gauge their association with a myriad of other individual and behavioral characteristics. For instance, practitioners in the industry may utilize the STQ-77Pt to study the basis of what are considered important "soft skills", such as communication, responsibility, positive attitude, professionalism, flexibility, teamwork, work ethic, etc., which are in high demand in the workplace (Robles, 2012). In academia, it opens new avenues of research for Portuguese-speaking scholars, as well as practitioners, allowing them to perform novel research, draw new insights or make important decisions informed by the most consistent biologically-based traits in adults.

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A Test "Elementary Logical Operations": Psychometric Characteristics on The Russian Sample

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Abstract. This paper reports on the validation of an Elementary Logical Operations test (ELO) using a Russian sample of 556 participants, aged from 13 to 69 (M/F = 247/304) including adolescents, youths, adults, and alcohol addicted people. The study examined a factor structure and psychometric properties of the ELO test in terms of reliability, construct and concurrent validity. Factor analysis revealed two-component model, the nature of which requires further psychological analysis. Mean scores of the ability to perform elementary logical operations increased from adolescence to adulthood. Differences in indicators of the ELO was not identified in the samples of men and women. Significant differences were found between the sample of the norm (adolescents, youths, adults) and alcohol addicted people. Significant correlations were confirmed between the ability to perform Elementary Logic Operations and all the conceptual abilities under study (Generative abilities, Categorical abilities, and Abilities to classify). Correlations were not found between character traits and the ELO scale which testified to the discriminative validity of the test. General Liner Modeling (Multivariate Tests and Tests of Between-Subjects Effects) showed a significant effect of the ELO on the indicators of Intelligence and Verbal Creativity. Thus, the study demonstrated that the Elementary Logical Operations Test (ELO) provided a brief screening of individual's intellectual and creativity traits.

Keywords: Elementary Logical Operations, Validity, Reliability, Conceptual thinking, Intelligence, Creativity

Development of methods for the evaluation of ability to perform elementary logical operations (ELO) is linked closely with the fundamental problem of reasonable human behavior, key role of which plays conceptual thinking. Thinking, as R. L. Solso, O. H. MacLin, and M. K. MacLin noted, can be thought of as the crown jewel of cognition, it is spectacularly brilliant, one of the great wonders of Homo sapiens [21]. Thinking, concept formation, logic, and decision making are the last links in the information processing chain, ensuring intelligence and adaptation [20]. Human intelligence emerges as a result of conceptual thinking and conceptual learning [11] that reorganizes all mental processes [27]. Conceptual thinking provides a combination of "control and freedom" that determines the productive capabilities of human intelligence [12]. Conceptual thinking ensures the formation of an integral structure of human intelligence [24].

M.A. Kholodnaya noted that conceptual thinking (conceptual abilities in Kholodnaya's terms) is a new generative type of intellectual abilities that determines the productivity of the processes of conceptualization and provides the possibility of generating new mental contents that are not presented in actual external circumstances and are absent in the acquired individual knowledge; ability to create new semantic contexts based on words from far-off semantic fields. The researcher identified three types of conceptual abilities, such as (a) semantic ability, i.e., the ability to form semantic networks and the operation of the content of verbal signs; (b) categorical ability, i.e., the ability to use

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categories of varying degrees of generalization and the discovery of relevant features of the thought object; and (c) generative ability, i.e., the ability to generate new mental contents [6,7].

We consider conceptual thinking as the person's ability to operate with concepts, to establish connections and relationships between the essential features of objects, to understand the logical sequence of events. Based on this understanding of conceptual thinking, the set of conceptual abilities, proposed by M.A. Kholodnaya, should be expanded by including, at least, the ability to perform elementary logical operations, which provides reasonable behavior through identifying true or false propositions, truth or falsity of the picture of the world. The more complete the essential properties of reality are reflected in the picture of the world, the better is a person oriented in oneself, as well as in the world and society.

Some psychologists believe that logic has no connection with actual human behavior. However, M. Wertheimer stressed that this is a mistake. He wrote: "*For application to behavior merely presupposes a connecting axiom, approximately as follows: behavior will be unreasonable, will fail of achievement, will run into trouble, if it is determined by factors parallel to mistakes in the sense of traditional logic*" [29]. No matter how we treat the logic envisaged in the Organon of Aristotle yet, it has great merits:

"In the decisiveness of its will to truth;

in the concentration on the basic difference between a mere assertion, a belief and exact judgement;

in its emphasis on the difference between hazy concepts, hazy generalizations, and exact formulations;

in the development of a host of formal criterion which are suited to testing for, and discovering mistakes, haziness in thinking such as unjustified generalization, jumping at conclusions;

in its emphasis on proof;

in the seriousness of the rules of discussion;

in the insistence on stringency and rigor in each individual step in thinking" [1].

Logic, according to Aristotle, is an instrument of cognition of the truth, an organon of thought. Truth is understood by the philosopher as the correspondence of thoughts to being. "*True*," – believed Aristotle, – "*is to say that the existing is and the non-existent no*". Just as the hands are the instrument of the body, so the mind is the instrument of the soul. The laws of logic govern our thinking only insofar as it is directed at already existing, and not only at possible or emerging objects.

S. L. Rubinstein emphasized that conceptual thinking is formed in the process of historical development based on social practice. Real thinking is a movement of thought that reveals connections and relationships. Thinking takes place in generalizations, it always goes from particular to general and vice versa. The specific content of thinking is a concept. A concept is a generalized knowledge about an object based on the discovery of its essential correlations and relations. Thinking is the result of the interaction of the external and inner world of a person. Since the mind, the inner world is determined indirectly through the relationship to the objective, external world, so the logic of things (objects of thought) enters into the mind of the individual. Thus, the logical is not opposed to the psychological, but is a determining principle in the consciousness of a person. The psychology of thinking cannot be reduced to logic, but it cannot be divorced from the definition of an objective essence in logic [14].

R. L. Solso, O. H. MacLin, and M. K. MacLin viewed thinking as a general process of considering of an issue in one's mind, which results in the formation of a new mental representation. Mental representation is a hypothetical pattern of mental or brain activity that reflects some feature of the world, of the person, or of the interaction between the person and the world. The scholars defined concepts as ideas or groups of ideas (tangible or intangible) that share specific common features or characteristics. Logic is the science of thinking based on laws that determine the validity of a conclusion. An appealing feature of using syllogistic logic in cognitive research is that it makes it possible to evaluate, or validate, the correctness of the thought process on the basis of its form rather than its content. It is possible in syllogistic logic to reduce statements of fact to symbols and manipulate them, as in mathematical equations, without regard to the physical reality they may represent [21].

L. Wittgenstein defined thought as a logical picture of interrelated facts, a proposition endowed with meaning. He wrote: "The totality of true thoughts is a picture of the world. … The

proposition constructs a world with the help of a logical scaffolding, and therefore one can actually see in the proposition all the logical features possessed by reality…" [28]. Thus, logic is viewed not as a science, but as a way of constructing the world in which one signified always and everywhere corresponds to only one signifier that allows us to think and say clearly. In logic nothing is accidental: if a something can occur the possibility of this must already be prejudged earlier [28]. The picture of the world can agree with reality or not, it can be true or false.

According to Plato, propositions are the smallest logical unit of conceptual thinking. L. Wittgenstein considered proposition as a picture of reality, which can be true or false, depending on the correspondence or discrepancy with the picture of reality. He pointed out that propositions show the logical form of reality. Propositions describe reality by its internal properties, that is, the structure of relations, combinations between the attributes of objects. The essence of propositions is to communicate a new sense to us. The proposition expresses what is contained in a definite and clearly specifiable way: the proposition is articulatable. L. Wittgenstein clarified that in order to understand a proposition, it is necessary to know the situation that it represents, therefore we understand the proposition without its sense having been explained to us. In a proposition, a situation is created by individual experience and there should be as many distinguishable parts in it as in the situation it represents.

L. Wittgenstein emphasized that the elementary propositions are fundamental for the comprehension of the other kinds of propositions. The philosophe noted: "*If all true elementary propositions are given, the result is a complete description of the world. The world is completely described by giving all elementary propositions, and adding which of them are true and which false"* [28]. The main feature of an elementary proposition is that no elementary proposition can contradict other propositions. The elementary proposition is the simplest kind of proposition which consist of names in immediate combination. Name is a set of symbols used to perform certain functions. The elementary proposition asserts the existence of an atomic fact. The atomic fact is determined by the connections among objects (entities, things).

In the present work, we have focused on the psychometric aspects of our newly developed test. First, we examined whether the ELO test demonstrates sufficient internal consistency and tested the following hypotheses:

H1: The internal consistency of the ELO test is sufficient.

Next, we examined ELO's factor structure and its psychometric properties in terms of reliability and contribution of the items to the scale.

H2: The Item-total correlations of the ELO items is sufficient.

H3: The test structure is represented by one factor.

Then, with the goal to estimate the concurrent and construct validities of the ELO, we compared it with three scales that measure various aspects of conceptual thinking and that are being developed in the Russian Psychology: the Categorial Ability (Generalization of three words test [7, 9]), Generative Ability (Concept Synthesis Test [7,9]), and the Ability to Classify objects (Free sorting words technique [10]). Based on the experimental research (Kholodnaya &Volkova [8]; Shcherbakova, Makarova, & Nikiforova [18]; Rusalov & Naumova [15]; Sipovskaya [19]; Volkova [26], et al.), we developed a hypothesis regarding the relationship between ELO and other conceptual abilities scales.

H4: The ELO scale has a significant positive correlation with the scales of conceptual abilities (Generative abilities (GA), Categorical abilities (CaA), and Abilities to classify (ACl)).

Since complex intellectual structures such as intelligence and creativity involve different levels of cognitive processes, it can be expected that the basic intellectual function as measured by ELO will be conceptual ability.

It is shown that generalized characteristics of temperament in the intellectual sphere (intellectual scales of temperament) have high correlations with indicators of psychometric intelligence (Wechsler's scales) [15]

H5: The ELO scale has significant positive relations with the scales of Analytical Intelligence, Verbal and Non-verbal Creativity, and with the intellectual scales of temperament.

In order to test the discriminant validity, we assessed the correlations among the ELO scale and character traits. As a tool for psychological assessment, the intelligence approach contrasts to the personality ones. Personality scholars describe individual differences in terms of behavior or character traits, while intelligence

experts refer mainly to the cognitive qualities of mind and problem solving. Assessment of personality traits is most often carried out through the questionnaires, whereas intelligence is measured using a set of universal test problems that are less language dependent and less prone to distortion of findings due to social desirability. Based on the above considerations, we assume that there is no relationship between the indicators of character traits and the ability to perform elementary logical operations

H6: The ELO scale has no significant correlations with the character scales.

Method

Sample

The Elementary Logical Operations was administered to 556 subjects, aged from 13 to 69 (M/F = 247/304; mean age in years = 19.79, SD = 8.66) including adolescents (13.78, SD=0.60), youth (20.03, SD=1.42), adults (39.96, SD=10.10), and alcohol addicted people (41.50, SD=7.13). The study involved respondents from Moscow, Kaluga, and Ufa. They signed a consent form before participating in this study and then filled in the test papers.

Measure

The Elementary Logical Operations (ELO). The ELO had 24 statements, assigned to evaluate ability to perform elementary logical operations. Respondents were offered to compare the ratio among the values of A, B and C and to draw the conclusions from the analysis of these ratios.

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Table 1. Stimulus

	Elementary Logical Operations (ELO)	**Truth**	**False**
1.	**A** is equal to **B**, and **B** is equal to **C**, then **C** is equal to **A**		
2.	**A** is equal to **B**, and **B** is greater than **C**, then **C** is greater than **A**		
3.	**A** is equal to **B**, and **B** is equal to **C**, then **C** is not equal to **A**		
4.	**A** is equal to **B**, and B is less than **C**, then **C** is not equal to **A**		
5.	**A** is equal to **B**, and **B** is greater than **C**, then **C** is not equal to **A**		
6.	**A** is equal to **B**, and **B** is less than **C**, then **C** is equal to **A**		
7.	**A** is not equal to **B**, and **B** is equal to **C**, then **C** is not equal to **A**		
8.	**A** is not equal to **B**, and **B** is equal to **C**, then **C** is equal to **A**		
9.	**A** is greater than **B**, and **B** is equal to **C**, then **C** is not equal to **A**		
10.	**A** is greater than **B**, and **B** is equal to **C**, then **C** is equal to **A**		
11.	**A** is greater than **B**, and **B** is greater than **C**, then **C** is not equal to **A**		
12.	**A** is greater than **B** and **B** is greater than **C**, then **C** is equal to **A**		
13.	**A** is more than **B**, and **B** is more than **C**, then **C** is more than **A**		
14.	**A** is more than **B**, and **B** is more than **C**, then **C** is less than **A**		
15.	**A** is less than **B**, and **B** is equal to **C**, then **C** is not equal to **A**		
16.	**A** is less than **B**, and **B** is less than **C**, then **C** is not equal to **A**		
17.	**A** is less than **B**, and **B** is equal to **C**, then **C** is equal to **A**		
18.	**A** is less than **B**, and **B** is less than **C**, then **C** is equal to **A**		
19.	**A** is less than **B**, and **B** is less than **C**, then **C** is less than **A**		
20.	**A** is less than **B**, and **B** is less than **C**, then **C** is more than **A**		
21.	**A** is part **B**, and **B** is part **C**, then **C** is greater than **A**		
22.	And part **B**, and **B** is equal to **C**, then **C** is greater than **A**		
23.	And part **B**, and **B** is equal to **C**, then **C** is less than **A**		
24.	**A** is part **B**, and **B** is part **C**, then **C** is equal to **A**		

For example, if **A** is equal to **B** and **B** is equal to **C** then "**C** is equal to **A**". This conclusion is true. And the conclusion "**C** is not equal to **A**" under the given conditions is false. There are four possible answers: (1) C is equal to A; (2) C is not equal to A; (3) C is greater than A; (4) C is less than A. Only those problems were offered that had only one correct answer. The test tasks for the ELO test were presented in Table 1.

The test time was limited to four minutes. The raw score was calculated by the number of correct answers in accordance with the keys (STable 2). Raw scores were converted to S-scores through percentile standardization (STable 3). The ability to perform Elementary Logical Operations is considered as high if S-score ≥ 7 and as low if S-score ≤ 3.

Generalization of three words test [7,9]. The test was developed to assess Categorical Abilities (CaA), namely, the ability to generalize; ability to identify common essential features of three concepts and to select a reference generic category. The respondent was given three words and was asked to find out common feature among these concepts and then to name this feature. For example: **lighthouse – newspaper – bonfire.** The measure of generality of each answer was assessed:

0 score – only two words out of three were generalized, or thematic generalization was based on situational connections (street, town, man, etc.);

1 score – generalization through a specific feature (beautiful, large, built by man, many details, can give light, long, etc.);

2 score – generalization based on an essential characteristic using a strict generic category (signals, sources of information).

Thirty seconds are allotted for each triad of words.

The Concept Synthesis Test [7,9]. It was designed to measure *Generative abilities* (GA). The researcher pronounces three words and offers the respondents to compose one or more sentences that would include all the three words. For instance: **computer – tornado – pin.** The time limit was 3 minutes. The answers were rated 0, 1, 2 and 3 scores:

0 score – the test taker uses only two target words in a sentence, for example, "*A **pin** and a **tornado** could hurt a human*".

1 score – the test taker includes three target words in a sentence, but either two of them are used in the same functional role being opposed to the third one or all three words are used in the same functional role: "*A **tornado** lifted a **pin** and a **computer** into the air*".

2 score – the test taker includes three target words in a sentence for description of a concrete situation: "*Children were watching a movie about a **tornado** on a **computer** and were playing with **pins**".*

3 score – the test taker includes three target words in a sentence, linked together either on the basis of a generalized category or analogy, or by causal relation, or by common complex context: "*A **pin** and a **computer** are artificial objects made by human, and a **tornado** is a natural phenomenon which is beyond human control*" or "*A **pin** got inside a **computer** caused a short circuit, which made a man switch his attention from the computer and he heard the news about an oncoming **tornado***" [18].

The Free sorting words technique [10]. This diagnostic tool was used to measure the Ability to Classify objects (ACl). The respondent was asked to divide 35 words, denoting various aspects of the concept Time, into groups in the most convenient and logical way from the respondent 's point of view. The test taker was to indicate a classification attribute for each group. Task run time was limited to five minutes. One score was awarded for each adequately specifiable classification attribute. The classification index was calculated as a number of specifiable classification attributes divided by the total number of the identified groups. The closer the classification index was to one, the more accurately the objects were classified.

The Standard Progressive Matrixes (SPM) [13]. SPM is a well-validated measure of fluid reasoning ability (gF) [3]. The Raven's Standard Progressive Matrixes contain 60 nonverbal items. Each item consists of 3 × 3 matrix with a missing piece to be completed by selecting an answer from six or eight alternatives. Time for completing the tasks was 20 minutes.

The Torrance Test Creativity Thinking (TCT) [2] in Tunick's adaptations for Russians [23]. TCT consists of a verbal (verbal creativity) and a figural (nonverbal creativity) test battery. In this study, the Unusual Use subtest was used to evaluate Verbal Creativity and the Incomplete Figures subtest was implemented to assess Nonverbal Creativity. Originality rate was determined based on E. V. Volkova's data for 18–24-year-old respondents [25].

The Structure Temperament Questionnaire [16]. STQ-S was used for evaluation of Intellectual Activity (IA). Shortened version of the Structure Temperament Questionnaire (STQ) contained 26 items. STQ-S had a high correlation with full version of questionnaire STQ. The given scale is thought to be temperamental scale of intelligence measured by Wechsler test [17].

Character traits are scored with shortened version of the questionnaire developed for measuring human character. This questionnaire contained 20 items. The shortened version of questionnaire had a high correlation with full-version of questionnaire ($r>0.6$; $p < 0.05$) and a high internal consistency. Character scales covered such traits as hyperthymicity, stuckness, emotivity, pedanticity, anxiety, cyclothymicity, demonstrativeness, excitability, dystimicity, and exaltations [17].

Procedures

Statistical treatment empirical data included descriptive statistics of raw data (Means, SD, Skewness, and Kurtosis) and reliability statistics (Cronbach's alphas) for the ELO scale. The test scores corresponded to the normal distribution (Skewness and Kurtosis =±1). The reliability of the tested parts was assessed on the basis of correlations between the sum of scores of even and odd items. The structure of connections among test items was identified on the basis of Factor Analysis (Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization). Absolute loadings of 0.50 or stronger were taken as significant. Differences in indicators of the Ability to perform Elementary Logical Operations were identified (Student's t-test, ANOVA) in comparable samples of men and women, adolescents and youths, adults of norm and alcohol addicted.

A percentile standardization procedure was carried out to convert the raw scores into a single scale of S-scores. Evidence for concurrent validity of the ELO test was demonstrated through significant correlations with all conceptual abilities under study: Generative abilities (GA), Categorical abilities (CaA), and Abilities to classify (ACl). Discriminatory validity of the ELO test, according to theoretical concepts, implies the absence of significant correlations with character indicators.

The use General linear modeling (General Linear Model: Multivariate Tests) makes it possible to statistically analyze the peculiarities of the relationships among ELO indicators and indicators of conceptual abilities (GA, CaA, ACl), temperamental Intellectual Activity (AI), Intelligence, Verbal and Non-verbal Creativity.

Results

Descriptive statistics

Table 1 shows the descriptive statistics. Test scores corresponded to the normal distribution (Means and standard deviations (SD) were reported for the male and female sub-samples and for the full sample). The reliability measured by the Cronbach Alpha coefficients were in the acceptable range (0.87-0.95). These results testified that the Elementary Logical Operations scale had sufficient internal consistency (*H1*).

Table 2. Means, Standard Deviations (SD) and Alphas for the samples

		Male Sample		Female Sample		Total Sample		
		Mean	SD	Mean	SD	Mean	SD	Alpha
Total Sample	13-69	18.61	5.03	18.35	5.18	18.46	5.10	.92
Adolescence (N=201)	13-15	17.81	5.56	17.90	5.80	17.85	5.67	.91
Youth (N=295)	18-24	19.36	4.52	18.74	4.76	18.97	4.68	.87
Adults (N=30)	25-69	20.70	2.71	23.00	1.00	20.00	2.72	.91
Alcohol addicted (N=30)	27-55	14.50	5.20	13.20	2.58	14.19	2.72	.95

Item-total correlations of the ELO and Factor Analysis

Item-total correlations of the ELO items varied from 0.502 to 0.745 p=0.001 (STable 6), except item 2 (r=0.347, p=0.001). Correlation between test parts, the sum of scores obtained on even test items and the sum of scores received on odd test items, was 0.848 p=0.001 (STable 5), which testified to the stability of the results of individual sets of test items or single items of the test.

Descriptive statistics (KMO = 0.901; Bartlett sphericity values =5382.020; Df = 276; p = 0.001) showed that we have sufficient grounds to apply Factor Analysis [22]. Theoretically we assumed that there is one factor. However, we received two-and four-component models (Principal Component Analysis. Varimax with Kaiser Normalization). According to the Cattell's scree test, two-component model was determined (Figure 1), because the optimal number of components (factors) was above the inflection point of the curve where the graph turns into a straight line [4,5]. This model cumulatively explained 47.399 % of the variance of the primary scales. Percentage of the explained variance for each factor was 25.51(1, 3-12 items) and 21.89% (16-24 items), respectively (STable 8).

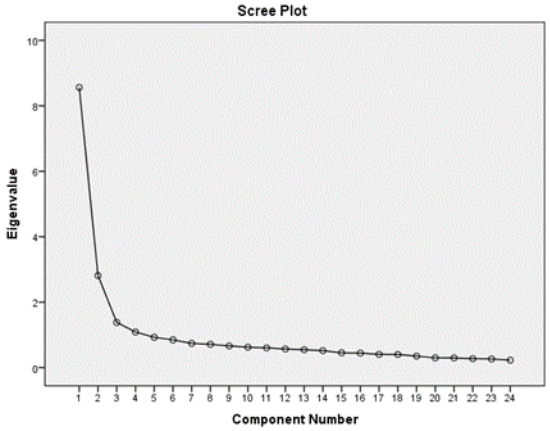

Figure 1. Scree Plot

Based on Eigenvalues greater than 1, we identified four significant factors which described 57.68% of variance of the correlation matrix. Percentage of the explained variance for each factor was 16.68; 16.62; 15.29; and 9.079, respectively. The first factor combined 5-12 items, the second –12-18 items, the third – 19-24 items, and the fourth – 1-4 items (Stable 9). Comparison of the two- and four-component models showed that they do not contradict each other. Moreover, the Four-Component Model makes the Two-Component Model specific. However, the question of the nature of these findings requires further psychological analysis of the thinking operations when solving these kinds of elementary logical problems.

Multiple Comparisons

Mean scores of the ability to perform elementary logical operations increased from adolescence to adulthood (Figure 2). Differences in indicators of the Ability to perform Elementary Logical Operations were not identified (Student's t-test; ANOVA, Multiple Comparisons, Bonferroni correction) in samples of men (18.61±5.03) and women (18.35±5.18), youth (18.97±4.68) and adults (20.00±2.72), but significant differences were found between the sample of the norm (adolescents, youths, adults) and alcohol addicted people (14.19±2.72) as well as between the sample of adolescents (17.85±5.67) and adults (20.00±2.72). More detailed information was presented in Supplementary materials (STable 10).

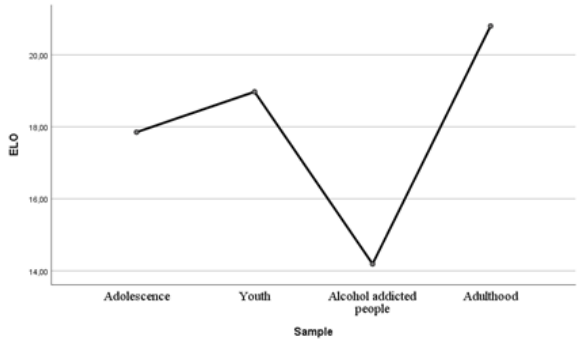

Figure 2. Mean Plots for comparable samples

Concurrent validity

Before assessing the concurrent and discriminatory validities, all raw scores were converted into a single scale of S-scores through a percentile standardization procedure (STable 3). Significant correlations among the ability to perform Elementary Logic Operation with such conceptual abilities as GA, CaA, and ACl were revealed (Table 3). The data obtained confirmed the concurrent validity of ELO. Thus, hypothesis *H2* was supported.

Discriminatory validity

According to the data presented in Table 4, significant correlations were not found between the indicator of the ability to perform Elementary Logical Operations and those of Character traits. This fact supported the hypothesis *H6* of the discriminative validity of the ELO test**.**

Table 3. Correlations of the ELO with conceptual abilities scales

	Generative abilities (GA)	Categorical abilities (CaA)	Abilities to classify (ACl)
Ability to Perform Elementary Logical Operations ELO	0.176**	0.124*	0.148**

Total sample. N= 556. *p< 0.05. **p< 0.01. ***p< 0.001.

Table 4. Correlations between the ELO and Character scales

ELO	Hyperthymicity	Stuckness	Emotivity	Pedanticity	Anxiety	Cyclothymicity	Demonstrativeness	Excitability	Dystimicity	Exaltation
Pearson Correlation	.110	-.047	-.096	-0.074	-.055	-.040	-.033	-.053	.001	-.014
Sig. (2-tailed)	.057	.425	.106	.212	.352	.495	.582	.369	.988	.816

General Linear Model: Multivariate Tests and Tests of Between-Subjects Effects

The data obtained matched GLM requirements. Box's Test of Equality of Covariance Matrices of the dependent variables (Intelligence, Verbal Creativity, and Nonverbal Creativity) were equal across groups (Box's M=162.522; F= 0.897; Sig.=0.792). Levene's Test of Equality of Error Variances testified that the errors variance of the dependent variables was identical across groups (Table 5). The dependent variables (Intelligence, VC, and NC) were S-Scales. The independent variables (ELO, GA, ACl, and CaA) were categories with low, mean, and high levels of conceptual abilities (ELO, GA, ACl, and CaA).

Table 5. Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
Nonverbal Creativity	1.218	55	238	.160
Verbal Creativity	1.278	55	238	.109
Intelligence (SPM)	1.628	55	238	.07

General Linear Model (Multivariate Tests, Pillai's Trace) revealed a statistically significant main effect of the ELO factor on the gradation of Intelligence, Verbal and Non-verbal Creativity indicators (F=2.527; Hypothesis df=6; p=0.020). The interaction of factors CaA * ACl (F=2.012; Hypothesis df=12; p=0.021) and GA * CaA * ELO (F=1.616; Hypothesis df=18; p=0.050) also significantly affected the gradation of Intelligence and Creativity

indicators. The covariate of Intellectual Activity (IA) as a temperamental indicator had a significant effect on the dependent variables of Intelligence, Verbal and Non-verbal Creativity. This covariate also changed the statistical significance of the factors (ELO, GA, ACl, and CaA) and their interactions (F=2.828; Hypothesis df=3; p=0.039). More detailed information is presented in additional materials (STable 12).

General Linear Model (Tests of Between-Subjects Effects) showed:

- The independent factor ELO effected significantly the distribution of the Intelligence indicator (3.663, 4.675, 5.680; F = 6.879, p = 0.001).
- Interaction between independent factors of Categorical abilities (CaA) and of Abilities to classify (ACl) influenced significantly the distribution of Nonverbal Creativity (F = 2.684, p = 0.032).
- Interaction between independent factors of Elementary Logical Operations (ELO) and of Abilities to classify (ACl) effected significantly the distribution of Verbal Creativity Scores (F = 2.417, p = 0.049).
- Interaction among independent factors of Elementary Logical Operations (ELO), of Generative abilities (GA), and of Categorical abilities (CaA) had a significant impact on the distribution of the Verbal Creativity Score (F = 3.089, p = 0.006).

Thus, hypothesis *H5* was partially confirmed. The results obtained showed a significant effect of ELO on the indicators of Intelligence and Verbal Creativity. However, this pattern was not found in relation to Non-verbal Creativity (STable 14, 16).

Conclusion

This study demonstrated that Elementary Logical Operations Test (ELO) provided a brief screening of intellectual traits (*H5*). Significant positive relationships were found among the ability to perform Elementary Logical Operations with Generative, Categorical Abilities and the Ability to Classify objects. The main effect of the ELO scores on Intelligence and Verbal Creativity indicators were confirmed.

The results showed that the Elementary Logical Operations scale had sufficient internal consistency (*H1*), concurrent (*H2*) and discriminatory (*H6*) validities. We believed that the ELO test structure was single-factor. However, we revealed existence of two-and four-component models. The issue of these the ELO test factor structure requires further investigations. The results showed that the Ability to perform Elementary Logical Operations increased with age. It should be emphasized that the differences between men and women were not found. However, a strong significant decrease in the Ability to perform Elementary Logical Operations was revealed in a sample of alcohol addicted people, which makes it possible to use this test as a non-invasive tool for assessing the measure of alcohol intoxication.

We believe that the study of thinking in general and intelligence in particular can make a significant contribution to solving such theoretical problems as understanding of the mechanisms of reasonable human behavior.

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Before Brains:
Spatial Specialization and Communication in Bacterial Biofilms Herald Brain Morphology

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Abstract. Data from paleontology, geo- and biochemistry, genetics and other fields of knowledge allow one to consider the communities of the most ancient representatives of living beings, microorganisms, as prototype elements of nervous systems of "complex" animals. Based on geologically early spatial and functional specialization, like the morphological one, a new look on the basic architectonics of brains is proposed. The emergence of communications between individual units and their groups signaled by electrographic data on interaction between the units and the formation of communities cast light on the evolutionarily earliest mechanisms of social relations.

Keywords: *microorganisms, morphological heterogeneity, physiological diversity, population heterogeneity, specialization, communication, ion channels, electrical activity, synchronization*

The structure of the nervous system may be
an important component for the reconstruction of
a long-past evolutionary event, however an auxiliary one.
S.V. Saveliev. The Origin of the Brain

The origin of neurons and nervous systems remains one of the greatest mysteries in the evolution of life. How did such complex structures come about? Since the Darwin time, the long-standing interest in this issue has been continuously providing suggestions for another new look at the evolution of neurons, in particular, the study of the features of the cells of ancient creatures that stood at the origins of living matter, and the newer ones that have already passed a multimillion-year path of improvement [1, 4, 16]. The main question is when and in what form the first neurons appeared [40].

It is also important to understand the mechanism of the formation of organic molecules, since life developed in interaction with inorganic components of the environment. There are no direct data for the analysis of the physicochemical conditions necessary for the origin of life, i.e. on the types and presence of inorganic cations that are necessary for the emergence of a system that synthesizes protein. However, there are data from paleogeochemistry, petrochemical indicators of the content of these main life-forming elements, sodium and potassium, in various sediments and rocks from different periods of the history of Earth [28]. Life and environment are two parts of a single system. The evolution of biota is closely related to changes in the physical environment on a planetary scale, and together they make up a single self-developing system [46, 8, 19]. Living things arose from inanimate substances in the course of prebiotic evolution, the result of which was the emergence of organic compounds from inorganic ones with the necessary influence of external factors [27]. The

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culmination was the emergence of the original living cell, which has a minimum of components that ensured life and the possibility of its continuation. Modern studies in Artificial Life suggest that a "minimal life", the proto-organismic physicochemical system, should be based on three constituents implementing the interrelated functions of a proto-container, proto-metabolism and a proto-gene [34]. The question of emergence of mind is also widely discussed, and it looks as we still lack convincing data to arrive at a reliable solution. One may connect mind's "starting point" with the emergence of life itself, or with the formation of nervous systems, or place it somewhere in between. Since one may raise almost no objection to the connection between mind and generation and use of signs, we see a certain perspective for the development of the concept of proto-semiosis [40] as a minimum condition for the emergence of mind, or at least the proto-mind, no matter how one may interpret the latter term.

One of the most important conditions for the emergence of living matter is its physical separation from the environment with the help of a membrane that would not only protect it from the surrounding world, but also ensure the exchange of substances on which the preservation of life depends. Studies have shown that potassium ions usually dominate over sodium ions in surface rocks. It is assumed that the first cellular forms arose in "potassium" reservoirs, and not in the "sodium" ocean [28]. An indispensable condition for the intracellular electrolytic environment should have been the dominance of potassium ions. In reservoirs where sodium began to predominate, only cells that already had a plasmatic membrane with a functioning potassium-sodium pump could survive. Measurement of the concentration of ions in cells and in the extracellular fluid in modern animals shows that potassium ions are the main intracellular cation that provides the potential difference between the intracellular and external contents [30, 38, 17]. The conservatism of nature in relation to the basic principles of the operation of living systems manifests itself in the similarity of electrical processes that form the basis for the implementation of vital functions from the first forms of life to those presently living on Earth.

According to some theories of the origin of life on Earth, the first living creatures were the ancestral forms of modern cyanobacteria that created mats, the traces of which in the form of stromatolites have survived to the present day [43]. The idea that microorganisms exist in nature in the form of structured communities rather than individual free-floating (planktonic) cells was expressed by Costerton and coworkers [6]. The communities of cyanobacteria are the structures of various levels of organization, the architecture of which is based on different ways of functional unification of their constituent elements [45]. Microorganisms survived and developed because they formed communities, the associations that could withstand threats from the external environment, contribute to the preservation of the species [41, 31, 32). The interpretation of a microbial colony as an analogue of an integral multicellular organism was probably first expressed by J. Shapiro [39]. In addition, the tasks that arose before the community required the specialization of cells and the formation of specialized structures, which increased the viability of the microbial community [44]. S.G. Smirnov in the 80-ies considered a microbial colony as a spatio-temporal continuum consisting of cell clusters with different properties; at each stage of culture development one subcolonial cluster dominated [41]. In fact, a viable colony of microorganisms in terms of functionality and structural complexity is a prototype of the brain, consisting of many departments with a special internal structure and containing nerve cells of different types [7].

Further studies revealed the morphological and physiological heterogeneity of the cell composition of the colony, which manifests itself in the form of genotypic and population heterogeneity. Community heterogeneity is a supra-organismic property of bacteria that contributes to its adaptation to environmental conditions at the population level. The heterogeneity of a population is the result of the implementation of adaptive behavior inherent in a specific microorganism; it is a way of revealing new adaptive capabilities of the same bacterial genome [24]. Prokaryotes can change the level of heterogeneity of their populations, maintaining it adequate to environmental conditions. The morphological diversity of bacteria forms the basis of the adaptive behavior of microorganisms; this idea arose at the stage of early classical studies [3]. The formation of cells that are not identical in many traits is a consequence of random processes and leads to an increase in the phenotypic heterogeneity of cultures. The variety of cells of microorganisms results from the interaction of the external and

internal environment, as well as due to random fluctuations in biochemical and physiological signs. Heterogeneity increases the survival rate of the bacterial population in heterogeneous or changing environmental conditions, as well as when exposed to stress factors.

The discovery of the heterogeneity of the morphological composition led to the idea of cell specialization. The initial historical stage in the study of the specialization of bacterial cells is associated with the discovery of their diverse forms and states in pure culture (the doctrine of the cellular heteromorphism of bacteria). At the beginning of the 20th century, colonies of microorganisms living on surfaces were discovered, and it was also found that bacteria that form surface fouling exhibit new properties that were previously lacking in them (for example, resistance to the action of antimicrobial substances) [6]. N. D. Ierusalimsky showed the existence of various cell types at different stages of culture development along with vegetative cells: differentiating spores, dying cells, filtering ("invisible in a microscope") cell forms [13]. To date, both in natural populations and in laboratory cultures, about 20 types of cells with specialized functions have been described. In some cases, these are cells for which the molecular genetic mechanisms of cell differentiation have been described, in other cases specialization is obvious as a phenomenon, the function of some cell types has not yet been fully determined. Using electron microscopic autoradiography, morphological variants have been found to differ in functions and possibilities of reproduction. In addition, it has been shown that cells with common functions form structural and functional clusters [14, 49]. The cells differ in shape and physiological state. An analogy arises with morphologically diverse cells of brain structures - the shape and size of neurons are formed and fixed in evolution (for example, Betz pyramids are commanding for performing movements, much smaller stellate ones distribute synaptic flows). Golgi cells are the main inhibitory interneuron of the granular layer of the cerebellum, play a central role in the functioning of the cerebellar network, the central element in the cerebellum is the Purkinje cell, and each neuron receives up to 500 thousand synapses from the axons of granular cells [2, 12].

The diversified composition of a microbial population in the process of creating dynamic functional groups required information exchange based not only on slow chemical methods such as "quorum sensing", but also on fast electrical processes [26], generation of action potentials, their distribution, as it takes place in the nervous system of highly developed organisms. Experimental data are convincing that electrical activity is not only one of the components, but also a necessary organizer of the formation of microbial communities, morphogenetic processes, a way of realizing functions of specialized cells, a dynamic means of communication [11, 15]. The basis for this kind of activity is the presence of a variety of ion channels that penetrate the membrane of even the most "ancient" in origin microorganisms. The properties of the electrical activity of cells of microorganisms create the prerequisites for communication to implement the specialized functions and processes of the dynamic organization of morphogenetic structures required to perform life support tasks. We obtained the characteristics of electrical activity in experiments on microorganisms of various evolutionary ages.

Method

The experiments involved recording electrical activity using glass microelectrodes filled with 1 M or 2.5 M (for multicellular organisms) KCl. To work with the cyanobacteria Oscillatoria terebriformis, a physiological solution of the following composition was used [in grams per liter]: $NaHCO_3$ - 3, Na_2CO_3 - 17, K_2HPO_4 - 0.5, NaCl - 30, KNO_3 - 2.5, $MgSO_4$ - 0.2, $CaCl_2$ - 0.04, $FeSO_4$ - 0.01. A fragment of a biofilm that included *Geitlerinema sp*. and *Halothece sp*. was studied in the natural environment (water sample from the salt lake Dus-Khol, Republic of Tyva, Russian Federation). Hay sticks *Bacillus subtilis*, medicinal preparation of *Bifidobacterium*, unicellular eukaryotic yeast cells of *Saccharomyces cerevisiae* and amoeba *Amoeba proteus* were placed in a liquid medium for registration, and social amoebae (myxomycetes) *Dictyostelium discoideum* were placed on a wooden plate in a Petri dish or on a wooden plate. During registration, ciliates *Paramecia caudatum* were placed in a solution of the following composition: KCl - 4 mM, $CaCl_2$ - 1 mM, $MgCl_2$ - 5 mM, Tris-HCl - 1 mM. pH - 7.2. The physiological solution for working with the nervous system of the mollusc *Helix lucorum* consisted of NaCl - 80 mM, KCl - 4 mM, CaCl2 - 7 mM, $MgCl_2$ - 4 mM, Tris-HCl - 10 mM, pH - 7.2–7.5. The milk mushroom *Zooaglea* at the time of registration was in a liquid medium

containing milk and water in equal amounts. In some of the experiments, registration was exercised simultaneously with two electrodes placed at different loci of the object under study. More than 500 fragments of records of electrical activity belonging to the above organisms were analyzed.

Statistical analysis

Fragments of the recording of electrical activity were digitized and subjected to spectral analysis in the R 3.0 statistical processing environment (R Development Core Team). Spectral analysis was performed on the original recording by constructing a periodogram using the fast Fourier transform. To identify the features of oscillatory activity, autocorrelation analysis was carried out. To analyze the interactions, we used the calculation of the cross-correlation coefficient and coherence. The duration of the digitized chunks was 3 seconds.

Results

The introduction of a microelectrode into the object under study makes it possible to determine the level of its membrane potential. All cells of microorganisms that have been in the experiments, as a rule, had a negative charge and the membrane potential (MP) reached -65 mV (Fig. 1). The MP of microorganisms varied within wide limits, for example, in Paramecia it was not possible to determine it accurately enough due to the mobility of these creatures; in cyanobacteria, the MF level could depend on the position of the ME, which it occupies in a separate filament (if it is located along the course of the filament, then the MF stable, and if along its diameter, then oscillations are inevitable, up to the exit of the microelectrode (ME) from the cell). For comparison, the level of the resting membrane potential when working with neurons of the mollusk *Helix lucorum* remained stable for many hours [42].

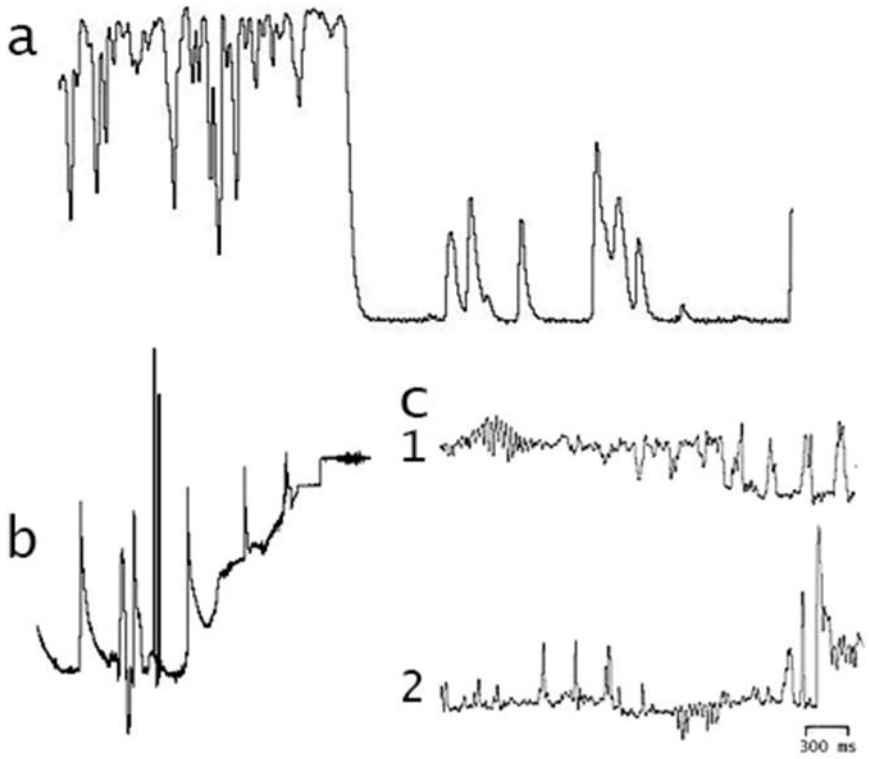


Fig. 1. Change in the resting membrane potential (MP) of individual units upon intracellular introduction of a microelectrode (ME). a - introduction of ME into the filament of cyanobacteria; b - exit of ME from the cell of the yeast *Saccharomyces cerevisiae;* c - introduction (1) and output (2) of ME in the social amoeba *Dictyostelium discoideum*. Calibration: 300 ms, 20 mV.

The introduction of a microelectrode into some microorganisms was technically difficult due to the microscopic size of these creatures and their rapid movement - for example, the amoeba. In other cases, the elasticity of the cell membrane could be an obstacle to the successful introduction of ME, for example, in yeast cells.

Microorganisms generate action potentials (APs). High-amplitude discharges of an individual cell were found in all investigated objects (see: Method). AP could be observed both with intracellular injection of ME (Fig. 2) and with its extracellular placement.

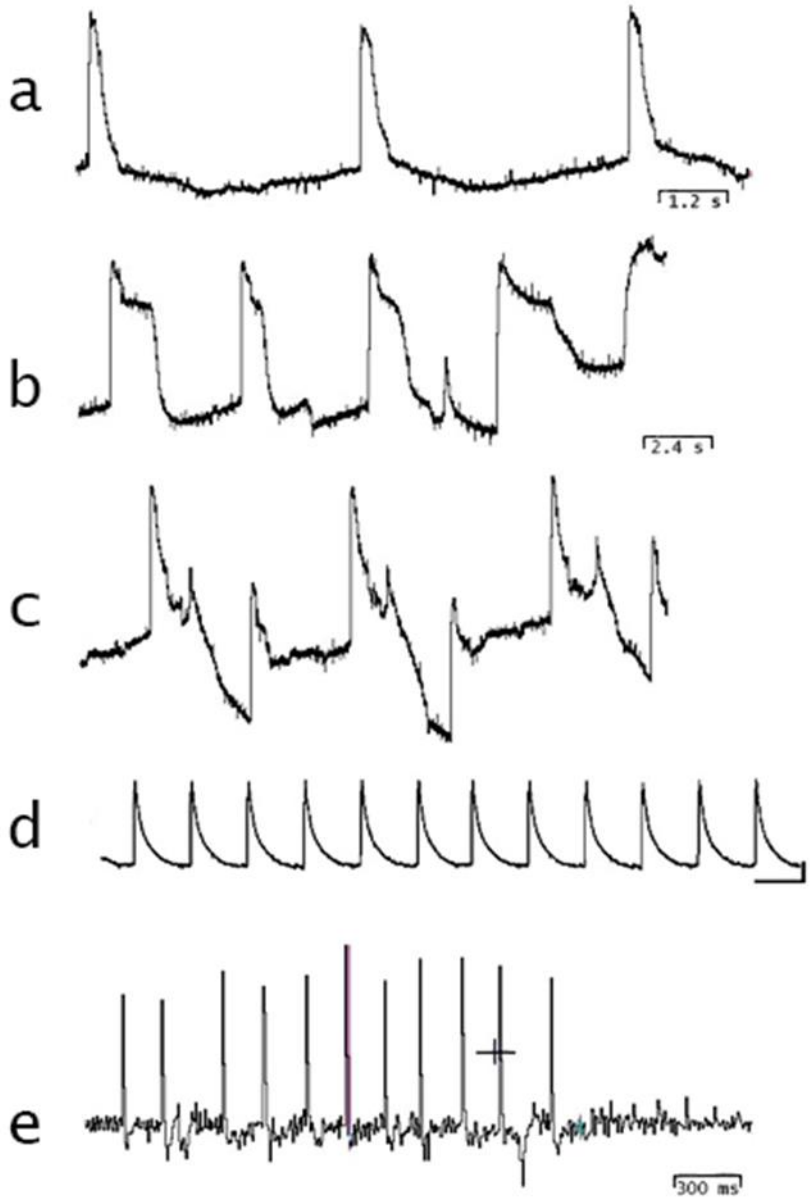


Fig. 2. Types of electrical activity of cyanobacterial filaments recorded by intracellular microelectrodes (ME). Calibration: a - 1.2 ms; b, c - 2.4 ms, d, e -300 ms; 20 mV.

The amplitude reached 50 mV (with intracellular registration); a feature of the AP of some microorganisms is the rate of development (Fig. 2). For example, in cyanobacteria, high-amplitude discharges to reach the maximum took an order of magnitude longer than in mollusks. The variety of electrical activity

recorded by intracellular electrodes from different elements of the same type of microorganisms indicates a variety of functional states of cells and, apparently, their different functional capabilities. For example, the electrical activity removed from single cyanobacteria differs not only in the rate of development, but also in the shape (Fig. 2, a-c), the organization of the temporal sequence of discharges (Fig. 2, d-e), and the absolute value of the amplitude.

Intracellular oscillatory electrical potentials of microorganisms form patterns - AP, distributed in a special way in time (Fig. 2, a, d, e, Fig. 3, a-c). For many cells of the microbial community, the active manifestation of the endogenic mechanism is normal: at least the following tasks can be distinguished that these cells solve: initiating movements, measuring time, coordinating the work of various cell ensembles located in spatially separated loci of the community, generators of rhythms of the functional state. The functional purpose of endogenous oscillations is different, therefore, the working modes of cells, the distribution of AP in time are different. The generation of certain discharge patterns creates the prerequisites for cell specialization.

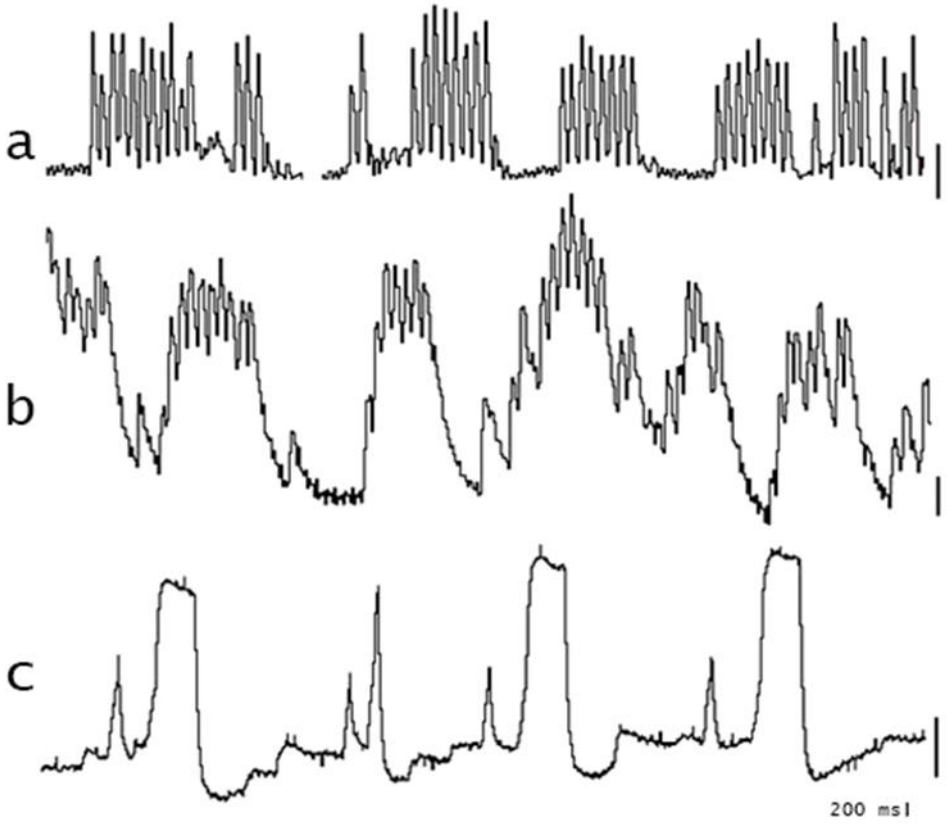


Fig. 3. Patterns of electrical activity of microorganisms: a - hay bacillus *Bacillus subtilis*; b - yeast cells *Saccharomyces cerevisiae*; c - ciliate *Paramecia caudatum*. Calibration: 200 ms, 20 mV.

The endogenous electrical activity of many cells may be synchronized, as shown by the registration of field potentials by means of macro-electrodes (Fig. 4).

Oscillatory activity has frequencies typical of the electrical activity of the brain of higher animals and humans. Periodograms have maxima at frequencies from 0.5 to 40 Hz, i.e. rhythms are present known as alpha, beta, delta and theta, which could be registered during the entire time of the experiment, i.e. 2-3 hours, or, on the contrary, disappear after 1-2 minutes. The oscillation amplitude varies from several μV to tens of μV (Fig. 4).

Simultaneous registration by several electrodes from different loci of the bacterial community showed that, depending on the conditions, the level of interaction between these regions can change significantly. The emergence of a common task enhances electrical activity and increases the interaction between organisms located in these places. This is reflected in the

.

Fig. 4. Electric field potentials recorded in microorganisms; a - from yeast cells of Saccharomyces cerevisiae, b – from Bacillus subtilis rods, c, d - from cyanobacteria Oscillatoria terebriformis. simultaneously with two electrodes from different loci of the fruiting body. Calibration: 300 ms, 20 μV.

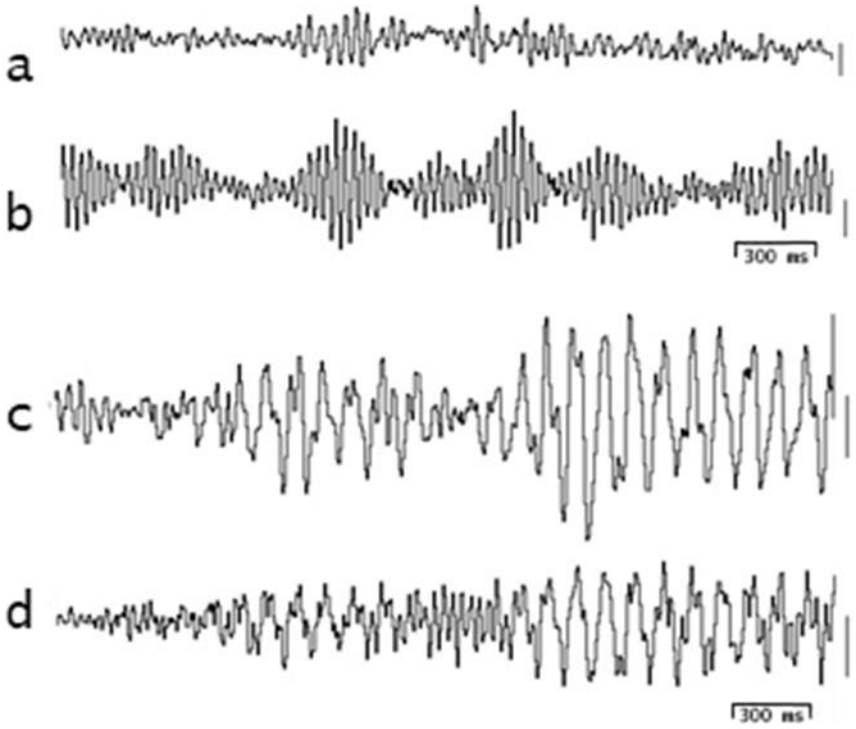
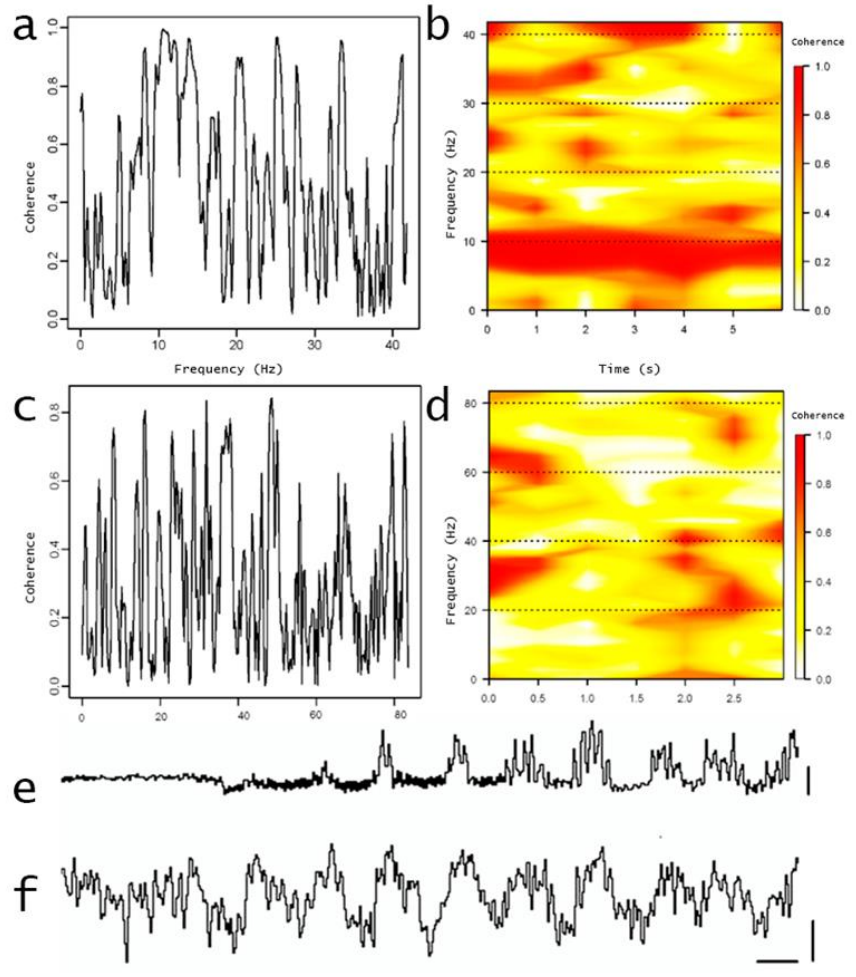


Fig. 4. Synchronization of electrical activity as recorded in two loci of the cyanobacterial biofilm at different stages of actions to preserve the integrity of the living space during active construction (a, b) and without interference in the process (c, d). a, c - graphs of phase-frequency coherence. The abscissa is the frequency in Hz, the ordinate is the coherence coefficient; b, d - time-frequency coherence at (a, c). The abscissa axis is the time in seconds, the ordinate axis is the frequency in Hz, the coherence coefficient (on the right axis); e, f are the field potentials recorded at the biofilm loci during active actions presented in (a, b). Calibration: 300 ms, 20 μV.



coherence coefficients characterizing the level of synchronization of electrical processes (Fig. 5).

The results were obtained reflecting the dynamics of communication in the cyanobacteria *Oscillatoria terebriformis*, in the social amoebae (myxomycetes) *Dictyostelium discoideum* when creating fruiting bodies, as well as in hay sticks *Bacillus subtilis* and yeast *Saccharomyces cerevisiae* cells when solving problems whose meaning in experiments was not controlled

The participation of organisms located in different parts of the colony in the performance of any socially significant task can be different, and this is evidenced by the analysis of the coherence of electrical activity recorded at the corresponding loci (Fig. 5). Do cells of the same locus participate with the same zeal in the "work"? Long-term registration from the same place of the colony of microorganisms shows a change in the dominant frequency (Fig. 6, a, b), which can occur both naturally, at certain time intervals, or chaotically. In this case, the presence of both "high" and "low" frequencies is preserved in the frequency spectrum of the periodogram (Fig. 6).

Apparently, this means that there is a change in active elements, i.e. high and low frequency oscillations are generated by different units. Consequently, the assumption about the "division of labor" in the bacterial community in the form of generators providing high-frequency and low-frequency oscillatory activity is confirmed in experiments.

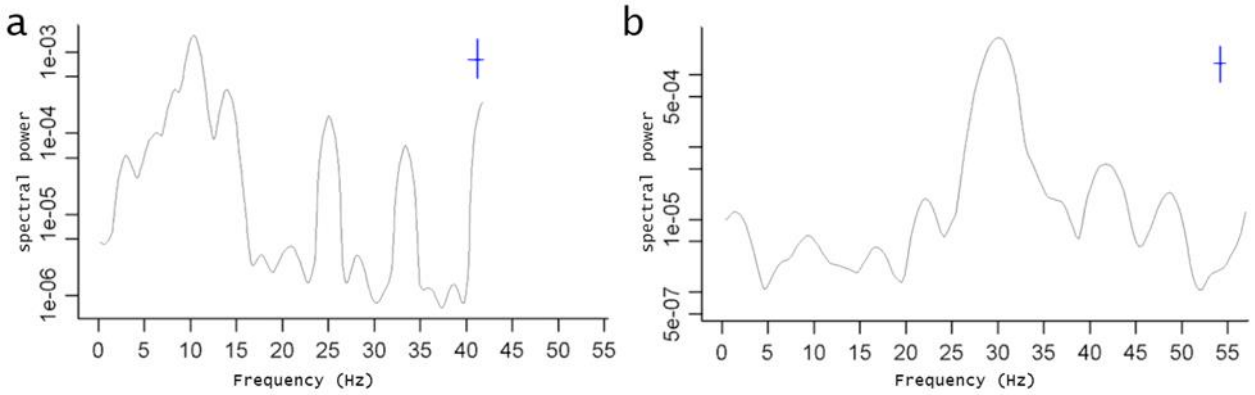


Fig. 6. "Division of labor" in a cyanobacterial film as registered from the same locus. The interval between registrations is 5 minutes. Designations: the abscissa axis – frequency in Hz; the ordinate axis – spectral density in a.u. The horizontal bar is the bandwidth, the vertical bar is the 95% confidence interval.

Discussion

Electrophysiological experiments were carried out, the purpose of which was to demonstrate, using objective indicators, the existence of qualities common to the most ancient microorganisms and nerve cells of highly organized animals and thereby strengthen the ideas about the common origin of both. Neurons and a complexly organized nervous system are a step up the evolutionary ladder from the same source.

Communication using electrical signals is very common in biological systems, and the electrical activity of microorganisms and highly organized creatures is very similar in its main forms of manifestation and physical characteristics. This may mean that the generation mechanisms have the same roots. The first intracellular electrical recordings from a living organism were obtained on a single-celled eukaryote, a paramecium, into which a glass microelectrode was inserted in 1934 to register the resting membrane potential [25]. It should be taken into account that the structure and activity of ion channels evolved long before the appearance of complex multicellular organisms on Earth [28, 25]. An example is the variety of ion channels existing on the cell membranes of prokaryotes. It was found that such classes of ion channels as sodium, chloride, calcium-dependent potassium, as well as ionotropic glutamate receptors, similar to those found in neurons, are involved in bacteria. The first information on the structure of the channels and their selective conductance was obtained in prokaryotes [5]. It is assumed that potassium ion channels work in bacteria, mediating electrical signals to coordinate biofilm metabolism: they conduct potassium waves propagating along the bacterial biofilm [33].

This depolarization wave coordinates the metabolic state of other cells located in different parts of the biofilm. Potassium channel blockade destroys this response.

Calcium as a bivalent ion was chosen by evolution as a signaling molecule for both prokaryotes and eukaryotes. All living prokaryotes have a low concentration of cytosolic free calcium (80-100 nM). These channels are indeed widespread in prokaryotic organisms, and are possibly the oldest ion channels [50]. In eukaryotes, the signaling system becomes more complex. This is primarily due to the development of intracellular organelles with their specific signaling calcium mechanism [47]. The complexity of calcium signaling in eukaryotes is also associated with the emergence of several types of calcium permeability channels, with different gate mechanisms. Electrically excitable channels use a voltage-related influx of calcium with the ability to transmit intracellular signals usually studied in neurons.

Volt-gated sodium permeability channels provide the basis for electrical excitability in animals [5]. Na-channels evolved from calcium channels and was probably permeable to Na^+ and Ca_2^+ ions. Like many other ion channels and receptors, sodium channels predate neurons. About 500 million years ago, in early chordates, sodium channels formed a cluster on the initial segment of the axon, and 50 million years later, with the evolution of myelin, sodium channels consolidated this property and accumulated in Ranvier's interceptions. Sodium channels show the impact of evolution on increasing the diversity of communication signals (electric fish), on defense against toxins (snakes, newts, fish, insects). It was found that bacteria can change the membrane potential in seconds, but what ion fluxes create these changes is not known. Scattered calcium sensors show that calcium current is induced by depolarization similar to action potentials. These results demonstrate the function of ion channels in microorganisms and provide a prokaryotic paradigm for spatial signaling activity in cellular communication.

It was shown experimentally that the cells of microorganisms have not only electrophysiologically expressed manifestations of metabolism in the form of changing membrane potential, but also rhythmic processes similar to those found in evolutionarily newer living things, the multicellular eukaryotes and in animals with a highly developed nervous system. Endogenous activity, which plays an important role in the organization and implementation of many functions of the nervous system of higher animals, appeared for the first time in prokaryotes, which are actually the same age as the Earth. Individual microorganisms have intracellular electrical activity similar to pacemaker endoneuronal oscillations in brain structures [42, 9]. The electrical oscillations can be rhythmic as in neurons of the time of the suprachiasmatic nucleus, periodically rhythmic as in neurons of the upper olive, generate patterns, like command neurons [20, 21]. The endogenous origin of the pacemaker activity of neurons and their independence from the cellular ensemble of various structures of the nervous system was proved in special experiments: on cultured Purkinje cells of the cerebellum, neocortex, upper olives and many other structures [23, 18, 22, 9]. All types of endoneuronal activity have precursors at the level of prokaryotic microorganisms [10].

Brain structures are morphologically heterogeneous and functionally specialized [36]. The predecessor of such an architecture of a biological substance responsible for the life of a given creature is apparently morphogenesis in prokaryotic colonies, biofilms and bacterial mats [44, 15, 29]. Microorganisms create the necessary temporary specialized structures to perform a variety of functions. S.G. Smirnov suggested that multicellular creatures took the path of creating concentrations of specialized cells, and of one type of cells, for example, a liver was gradually formed, a heart of another, muscle tissue of a third type, etc. In prokaryotes, there are also groups of cells specialized in performing different functions. Another type of specialization emerged, the "persistent" cells that resist antimicrobial drugs. The assumption about specialized members of the community is based on the results of electron microscopy. A number of studies show the morphological heterogeneity of microbial populations. Regularities were established in changes in the structure of microbial communities at different stages of development, manifested in a change in the ratio of different types of cells, i.e. physiologically active, resting, autolyzed and involutionary [36, 48]. The functional division of the cells of a microbial community is also supported by the data illustrating that in any population, along with bacteria that have an

ultrastructural organization characteristic of a given species, various morphological variants can be found that differ not only in structure, but also in physiological and genetic properties. Electrophysiological measurements prove that cells are functionally specialized in different ways. Specialization may be determined by frequency characteristics of the oscillators.

Conclusions

Brain neurons and individual microorganisms produce a resting potential of 0 to -65 mV, created by the asymmetric distribution of K + ions. Both neurons and individual microorganisms generate action potentials, in the development of which Ca ++ and Na + ions are involved. The presence of ion channels for these ions in neurons and microorganisms has been experimentally proved.

1. Both neurons and microorganisms have endogenous rhythmic activity.
2. The endogenous activity of cells may be synchronized and form field potentials with a rhythm of 0.5 to 40 Hz.
3. The electrical activity of microorganisms that form spatially separated loci of the microbial community is synchronized. The level of synchronization is characterized by coherence.
4. As in brain structures, in the communities of microorganisms clusters of morphologically and functionally specialized elements are created, one of the ways of communication between them is patterned electrical signals.
5. The structural and functional organization of microbial communities provide a prototype of the brain structure of evolutionarily advanced animals.

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Specifics of the Neuron Action Potential Frequency Dependence on the Intensity of the Excitatory Influence

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Abstract. A single formula linking the intensity of the stimulus with the strength of sensation has not yet been found. Neither the Fechner logarithmic dependence nor the Stevens power function can explain the specific dynamics of many psychophysical experimental data. And this is natural, because attempts to replace the multi-stage touch mechanism with a simple "black box" model are initially vulnerable: all stages of stimulus transduction in sensory systems should be separately considered. At the end of the 20th century, neurophysiologists agreed that one of the forms of coding of stimulus intensity is the frequency of action potentials (AP). In line with this paradigm and based on the universal Hodgkin-Huxley model applied to the conditions of a psychophysical experiment, the author developed a mathematical model of the primary receptor neuron. Calculations were made for a neuron with close to real geometric dimensions, physical and physiological properties. Calculations revealed characteristic areas of neuron activity: subthreshold, working, paradoxical and silent zone. A characteristic maximum of the "frequency of APs – stimulus" function was also discovered. Using the proposed model, the "saturation effect" and "cross" behavior of the "stimulus – sensation" curves revealed in psychophysical experiments are easily explained in individuals with different group characteristics of the nervous system. The calculation results showed that individual psychophysical differences are determined by types of combinations of the physical and physiological properties of the receptor. The presented mathematical model can be applied not only to sensory systems, but also to any neurons.

Keywords: stimulus, sensation, psychophysical experiment, receptor, neuron, frequency of action potentials.

In the present work, a primary neuron of a receptor is understood as a place on the sensory path of stimulus transduction, where action potentials (APs) first appear – the universal components of the language of the nervous systems of any living creature. Along with the "primary neuron of a receptor" term, other designations can also be found in the literature: "afferent neurons of receptors", "afferent nerve fibers of receptors", simply "sensory receptors", and others.

The proposed author's mathematical model of the primary receptor neuron is suitable for a quantitative description of the formation of APs in it both when the free nerve endings are directly acted on (for example, tactile or pain sensitivity), and when it is stimulated indirectly, for example, by the amount of the neurotransmitter released into the synaptic cleft (auditory or visual system). Both with direct and indirect action on the afferent neuron of the receptor, the frequency of AP arising in it is proportional to the stimulus intensity. However, as experimental data show (Willis, 2004), this proportionality is by no means direct, but satisfactorily described by a power function of the form (in (Willis, 2004), the formula is written in words):

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$$\nu = C(S - S_0)^n (1)$$

where ν is the frequency of the APs, Hz; C is a constant that takes into account the units of measurement of the stimulus S; S, S_o are the current and threshold values of the stimulus of the given modality; n is the power exponent, which may be less than, equal to, or greater than one for receptors of different modalities (Willis, 2004).

Expression (1) coincides with one of the forms of presenting the so-called power "Stevens law" (1957), which connects the intensity S of the stimulus and the sensory strength R (instead of the frequency ν, there is the sensory strength R in the Stevens formula (1957)). Stevens proposed approximating the psychophysical dependences R(S) by a power function in the middle of the 20th century instead of the approximations previously used everywhere since 1860 according to the so-called logarithmic Fechner's law (1860):

$$R = C(\lg S - \lg S_0) (2)$$

However, "up to now, *the basic psychophysical law* has not obtained universal and final recognition either in the form of the logarithmic dependence of Fechner (1860) or in the form of the power dependence of Stevens (1957) between the stimulus magnitude and the sensation intensity. The experimental data obtained by various researchers were not unambiguous: some speak in favor of the logarithmic law, others in favor of the power law" (Ratanova, 2008). It can be added to the quote that it is unlikely that, without knowing the physical mechanisms of the stimulus – sensation transformation, by simply approximating the experimental data by a simple formula, one can "find by chance" the basic psychophysical law connecting the stimulus intensity with the sensation strength. Moreover, a single "psychophysical law" for all sensory modalities without exception is also unlikely, because each sensory system of an organism has its own specifics of transforming stimulus into sensation. Therefore, further search for a simple empirical formula that connects the stimulus intensity with the sensation strength, the "basic psychophysical law", but does not take into account the physics of the process of transduction of stimulus into sensation, appear to be unpromising. Nevertheless, such search was undertaken after Stevens: for example, Zabrodin proposed combining the "laws" of Fechner (1860) and Stevens (1957) in a single formula in a differential form (Zabrodin, & Lebedev, 1977).

Thus, to identify an adequate formal dependence between the stimulus intensity and the sensation strength, it is necessary to analyze all the stages on the path of transduction of stimulus into sensation. Comparing the dynamics of the "stimulus intensity – sensation strength" curves obtained in psychophysical experiments at the macro level of organisms (Ratanova, 2008; Stevens, 1957) with the dynamics of the "stimulus intensity – frequency of AP impulses" graphs recently obtained at the neural level of receptors (Willis, 2004), the conclusion can be made about their equidistance: both of them are satisfactorily described by a power dependence (see above). Thus, *the stage of direct or indirect transformation of stimulus in the primary neurons of the receptor into APs is determinant on the entire path of its transduction into sensation*; that is why the present research was started with it.

Methods

In the middle of the 20th century, Nobel laureates Hodgkin and Huxley discovered a universal mechanism for the formation of APs in nervous tissue and developed its mathematical model (Hodgkin, & Huxley, 1952). In the author's works (Fokin, 2017), the general Hodgkin-Huxley model was applied to a particular case of a psychophysical experiment, the conditions of which allow significantly simplifying the original formulas. The thing is that, as a rule, the values of stimulus intensity in a psychophysical experiment are constant and have a short duration (for example, the duration of sounds in acoustic experiments is of the order of one second (see below).

"The research subjects were presented with sound tonal signals with a frequency of 1000 Hz of five intensities (from weak to very strong): 40, 60, 80, 100, 120 dB above a threshold level of 0.0002 bar, with the duration of 1 second, transmitted through the headphones in a random but identical for all research subjects order, 10 times each, with an interval of 12 seconds. In response to a sound of any intensity, the research subject had to press the button with the thumb of his/her right hand as quickly as possible (the reaction time was recorded by an electronic millisecond timer). ... Then the subjects made a quantitative (numerical) SE (*subjective evaluation – auth.*) of the loudness of sounds of the same five intensities. ... One sound (60 dB, average in intensity) was a standard

sound with the number 10 prescribed to it by the experimentalist, shown to the subject three times before the experiment and subsequently given for evaluation along with other sounds. Sounds of 1s were presented in random order and were evaluated by the subjects quantitatively (by numbers), based on the ratio in volume between the standard and the presented sounds. … He/she was told in advance about the intensity of sounds, how they would be presented, explained what his/her task was and how he/she should act" (Ratanova, 2008).

Therefore, when constructing a mathematical model of the primary neuron of a receptor for the conditions of a psychophysical experiment, one can take into account neither adaptation processes nor the change in the stimulus intensity over time. Such conditions of the psychophysical experiment made it possible to significantly simplify the differential equations of the Hodgkin-Huxley model and obtain their analytical solution for the frequency of AP impulses (Fokin, 2017).

According to the electrical engineering rules (Detlaf A.A., et al., 2007), the following equations can be written for the electrical circuit of an excitable Hodgkin-Huxley cell (see Fig. 1):

$$i_m = C_m \frac{dU_m}{dt};\ i_{Na} = (E_{Na} + U_m)/R_{Na};\ i_K = (E_K - U_m)/R_K;\ i_m + i_{Na} - i_K = 0$$

or:

$$C_m \frac{dU_m}{dt} + (E_{Na} + U_m)/R_{Na} - (E_K - U_m)/R_K = 0$$

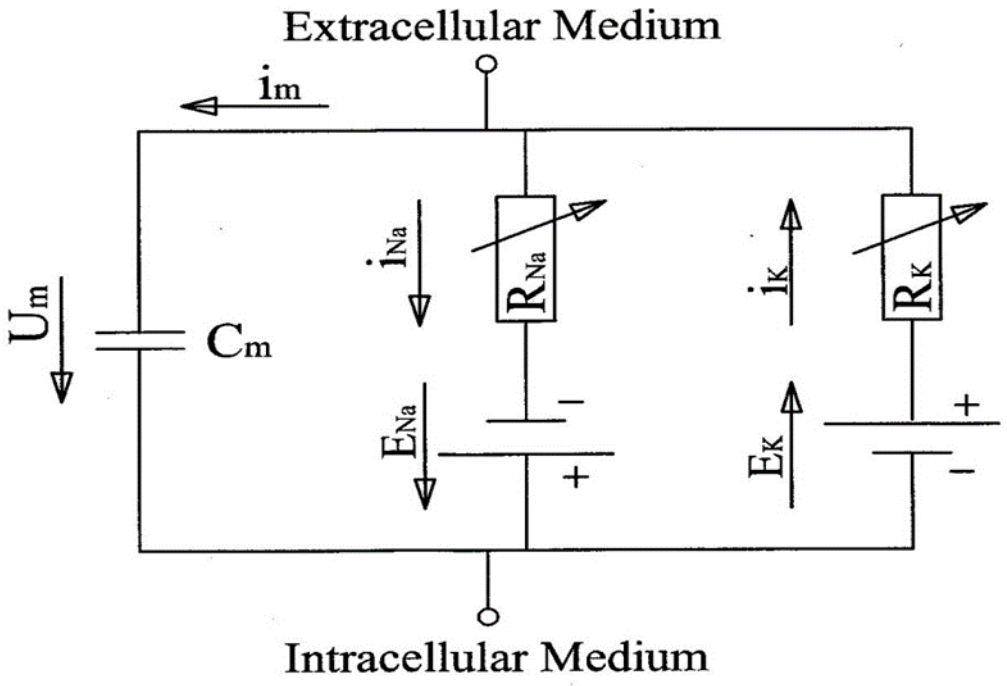

Figure 1. The electrical circuit of the membrane of the primary neuron of a receptor. As contrasted with the Hodgkin-Huxley scheme (1952), there is no "leakage" branch here; the leakage currents through potassium and sodium ion channels at rest are taken into account in the corresponding branches in the scheme. The directions of currents, electromotive forces (EMFs) and voltages are set according to the rules of electrical engineering (Detlaf, 2007). See the details in the text.

After some simple transformations we get:

$$\frac{dU_m}{dt} + U_m \frac{(R_{Na} + R_K)}{C_m R_{Na} R_K} = \frac{R_{Na} E_K - R_K E_{Na}}{C_m R_{Na} R_K}$$

The general solution of this type of differential equations with constant coefficients is presented in (Kamke, 2003). The coefficients in the above equation can be considered constant, because the capacity of the neuron membrane, sodium and potassium EMF are individually stable for each organism, at least for a long time, whereas the resistance of the membrane ion channels does not change during certain time intervals that make up the duration of AP. It is for these time intervals Δt_d, Δt_p and Δt_r (see Fig. 2, the description is given below) that the solutions below will be written. Substituting our initial data and simplifying the solution of the differential equation from (Kamke, 2003), we get:

$$U_m(t) = U_0 \exp\left(\frac{-t(R_{Na}+R_K)}{C_m R_{Na} R_K}\right) + \frac{R_{Na}E_K - R_K E_{Na}}{R_{Na}R_K}\left(1 - \exp\left(\frac{-t(R_{Na}+R_K)}{C_m R_{Na} R_K}\right)\right)$$

From this equation we can express the duration of any time interval during which its coefficients remain constant:

$$\Delta t = t_1 - t_0 = -\frac{C_m R_{Na} R_K}{R_{Na}+R_K}\ln\left(\frac{R_K(U_1+E_{Na}) + R_{Na}(U_1 - E_K)}{R_K(U_0+E_{Na}) + R_{Na}(U_0 - E_K)}\right)$$

According to the last formula and in view of the fact that the duration of all action potentials, except for the first and the last ones, is the same for each stimulus in the psychophysical experiment (see Fig. 2), we can write for the AP frequency:

$$\nu = \frac{1}{(\Delta t_d + \Delta t_p + \Delta t_r)} \qquad (3)$$

$$\Delta t_d = \frac{-C_m R_{res.K}}{(X_s+1)}\ln\left(\frac{X_s(U_t+E_{Na}) + U_t - E_K}{X_s(U_{cK}+E_{Na}) + U_{cK} - E_K}\right) \qquad (4)$$

$$\Delta t_p = \frac{-C_m R_{res.K}}{(X_{(s+p)}+1)}\ln\left(\frac{X_{(s+p)}(U_p+E_{Na}) + U_p - E_K}{X_{(s+p)}(U_t+E_{Na}) + U_t - E_K}\right) \qquad (5)$$

$$\Delta t_r = \frac{-C_m R_{(res.+rep.)K}}{(X_r+1)}\ln\left(\frac{X_r(U_{cK}+E_{Na}) + U_{cK} - E_K}{X_r(U_p+E_{Na}) + U_p - E_K}\right) \qquad (6)$$

$X_s = R_{res.K}/R_{(res.+s)Na}(S)$, is constant during Δt_d;

$X_{(s+p)} = X_s + X_p = X_s + R_{res.K}/R_{pNa}$, is constant during Δt_p;

$X_r = X_s \cdot R_{(res+rep)K}/R_{res.K}$, is constant during Δt_r;

where $\boldsymbol{C_m}$ is the electrical capacitance of the neuron membrane of the receptor, F;

$\boldsymbol{R_{res.K}}$ is the total electrical resistance of potassium ion leakage channels at rest; it remains constant throughout the duration of the AP $\Delta t_{ap} = \Delta t_d + \Delta t_p + \Delta t_r$, Ohm;

$\boldsymbol{R_{(res.+rep.)K}}$ is the total electrical resistance of potassium ion leakage channels and voltage-dependent potassium channels which open upon repolarization; it remains so for a period of time Δt_r, Ohm;

$\boldsymbol{R_{(res.+s)Na}(S)}$ is the total electrical resistance of sodium ion leakage channels and stimulus-dependent sodium channels which open upon the depolarization of the neuron membrane under the influence of the stimulus S; it remains so throughout the duration of the AP $\Delta t_{ap} = \Delta t_d + \Delta t_p + \Delta t_r$, Ohm;

$\boldsymbol{R_{pNa}}$ is the total electrical resistance of potential-dependent sodium ion channels, opening upon the depolarization of the neuron membrane of the receptor after the membrane potential reaching a threshold value, U_t, and closing upon the neuron membrane potential reaching the peak value, U_p; it remains so for a period of time Δt_p (see Figure 2), Ohm;

$\boldsymbol{E_{Na}}$, $\boldsymbol{E_K}$ are the sodium and potassium EMFs corresponding to the equilibrium sodium and potassium potentials, mV; for test calculations, it is set: E_{Na} = 60 mV; E_K = −90 mV;

$\boldsymbol{X}$ with the indices – ***potassium-sodium membrane parameter or translated stimulus*** (new terms and quantities) equal to the ratio of the total electrical resistance of single

potassium ion channels of the neuron membrane to the total electrical resistance of individual sodium channels regardless of the mechanisms of their opening/closing at the current time: $X(t) = R_K(t)/R_{Na}(t)$; $X(t)$ depends on the stimulus intensity S, the transfer function of the neuron, its physiological properties and time. The term "*translated stimulus*" or "*translated action*" for X was chosen due to the fact that during the transduction process, the physical intensity of any stimulus is "translated" into the universal language of the nervous system – into the APs of the primary neurons of the receptor, the frequency of which is specifically determined by the value of X_s. The quantity X_s itself is formed under the action of a real physical stimulus; and it is, so to speak, the first part of its "translation" into the language of the organism. Thus, the "*potassium-sodium membrane parameter*" is another name for X_s, it is a kind of universal stimulus, on which the frequency of the AP of the primary neuron of the receptor depends.

It is clear that, in the psychophysical experiment, for each $S_i(t)$ = const, $X_i(t)$ will remain constant periodically during three characteristic time intervals (Δt_d, Δt_p, Δt_r), which constitute the total time of the AP Δt_{ap} (see Figure 2):

1) Δt_d – when the membrane potential changes from U_{cK} (*closure potential of the potential-dependent potassium channels*) to U_t (*threshold potential of the neuron*); in this case, X_s is determined by the constant resistances of the sodium and potassium leakage channels (at rest) plus the total resistance of the stimulus-dependent sodium channels that have opened under the action of the stimulus S = const, and is denoted by X_s;
2) Δt_p – when the membrane potential changes from U_t to U_p (*the maximum value of the membrane potential of the neuron*); in this case, $X_{(s+p)}$ is determined by the resistances listed in item 1 plus the total resistance of the potential-controlled sodium channels that have opened at U_t;
3) Δt_r – when the membrane potential changes from U_p to U_{cK}; in this case, X_r is determined by the resistances listed in item 1 plus the total resistance of the potential-controlled potassium channels that have opened at U_p (the potential-controlled sodium channels were inactivated in this case).

Here, the AP frequency is calculated without taking into account the first and last impulses and therefore does not depend on the resting potential, U_{res}, but depends only on the threshold value of the membrane potential, U_t, and the closure potential of the potassium channels, U_{cK} (see Figure 2). The thing is that, under the stimulus preserving its action, the membrane potential of a stimulus-dependent cell, as a rule (Kamkin, & Kiseleva, 2004), does not have time to decrease to the resting potential (U_{res}) during repolarization for each AP, each new depolarization begins slightly higher than U_{res} (see Figure 2). It is this point of transition from repolarization to depolarization, i.e. from the decrease to the growth in the membrane potential in the process of AP generation under the action of an adequate stimulus constant in time, that was conventionally called the "potential of closing the potential-dependent potassium channels" – U_{cK} . It should be noted here that for the proposed mathematical model of a stimulus-dependent cell, the specific value of U_{cK} , selected between the resting potential, U_{res}, and the threshold potential, U_t, is not important in the sense that it does not influence the qualitative dynamics of the dependence $\nu(X(S))$, but determines only the numerical value of the frequency of APs: the higher the potential for closing the potassium channels, the higher the frequency of AP impulses ν.

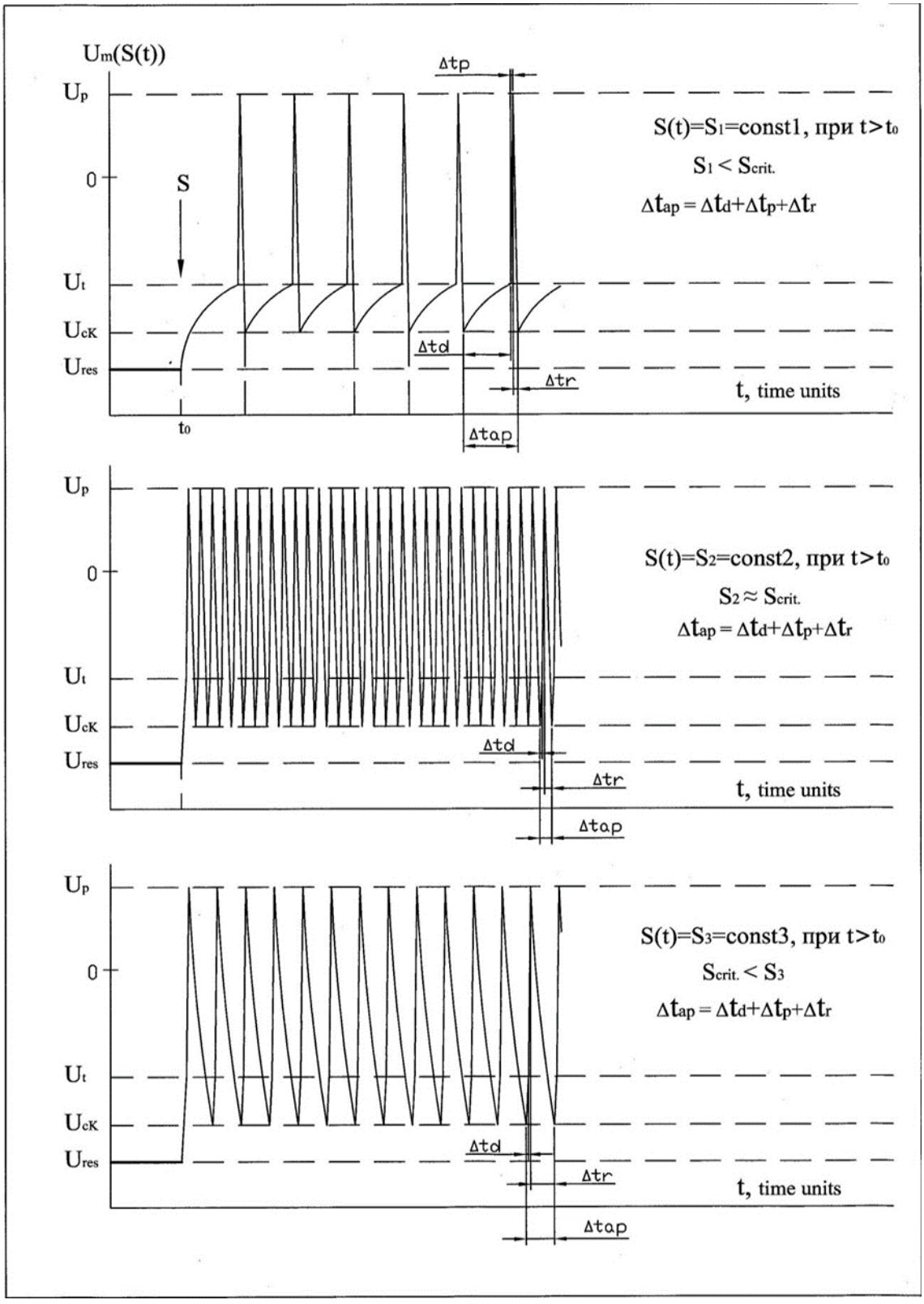

Figure 2. Dynamics of temporal change in the membrane potential of the receptor depending on the value of the adequate stimulus $S > S_{res}$: for $S < S_{crit.}$, the impulsing frequency of APs increases with the growth of the stimulus due to the predominant decrease in the duration of the depolarization component of AP – Δt_d; for $S > S_{crit.}$, it decreases due to the predominant increase in the duration of the repolarization component of AP – Δt_r.

As already discussed in (Fokin, 2017), due to the fact that, in reality, the stimulus-dependent sodium and voltage-dependent sodium and potassium channels do not open/close *at the same time*

(Ikeda *et al*., 2018), U_t and U_{cK} are some conventional values of the membrane potential at which it is observed: for U_t, an inflection on the curve $U_m(t)$ in the depolarization region; for U_{cK}, the decrease in membrane potential (repolarization) is changed to its growth (depolarization). In reality, the "lengthiness" in time and the heterogeneity over the membrane surface of the opening/closing of the stimulus-dependent and voltage-dependent ion channels will lead to some dependence of U_t and U_{cK} on the stimulus intensity. These nuances were not taken into account in the present study, but they can be taken into account in the development of the model. Now it will be assumed that U_t and U_{cK} in the above formulas are constant for a given primary neuron of a receptor.

Thus, instead of simple empirical formulas of Fechner (2) or Stevens (1), proposed in the past to describe the relationship between stimulus intensity and sensory strength *for the whole organism*, the authors have obtained a more complex expression of the "basic psychophysical law" *even at the receptor level* (3-6). In addition, it turned out that during the transduction of any analog external stimulus into, so to speak, "digital" AP pulse frequency, non-linearity inevitably occurs and there is even a maximum on the calculated curve $\nu_{ap}(X(S))$, see Figures 3, 4. This is caused by the fact that, with an increase in the stimulus intensity, the characteristic time intervals $(\Delta t_d, \Delta t_p, \Delta t_r)$, from which the period Δt_{ap} of the AP is composed, behave differently: Δt_d decreases; Δt_r increases; Δt_p changes slightly (see Figures 2-4 and formulas 3-6, 4*-6*).

Theory and calculation

For clarity, let us carry out a test calculation of the dependence $\nu_{ap}(X(S))$ with real physiological parameters. Based on the characteristic sizes of neurons (20 μm) and the cable properties of their membranes (Katz, 1966), for test calculations, the resistance of sodium and potassium ion channels were calculated (Fokin, 2017): $R_{res}.Na = 1.196 \cdot 10^9\ \Omega$; $R_{res}.K = 8.547 \cdot 10^7\ \Omega$; $R_{(res.+rep.)K} = 6 \cdot 10^6\ \Omega$, $R_{pNa} = 4.274 \cdot 10^6\ \Omega$. In this case, the resistance ratio, of course, will be inverse to the ratio of conductivities of the corresponding channels: $R_{res}K/R_{res}Na = 1/14$. Resistances turned out to be so "uneven", because they are interconnected with each other and with the surface area of the cell, i.e. its membrane. The membrane electric capacity was also taken to be characteristic for the nerve tissue (Katz, 1966): $C_m \approx 62.68$ pF (for details see Fokin, 2017a).

For the test calculations, the following values of the characteristic membrane potentials and EMFs were taken: $U_{res} = -80$ mV; $U_{cK} = -65$ mV; $U_t = -45$ mV; $U_p = 35$ mV; $E_K = -90$ mV; $E_{Na} = 60$ mV. The signs of potentials and EMFs are set here according to the generally accepted notion that, at rest, the intracellular environment is electronegative with respect to the extracellular one. However, formulas (2-4) were obtained in accordance with the sign rules of electrical engineering (Detlaf, & Yavorskii, 2007, p. 252) based on an electrical circuit similar to that from (Hodgkin, & and Huxley, 1952, p. 501) provided that the "leakage" branch is taken into account in the corresponding branches of sodium and potassium currents (Figure 1). Therefore, in formulas (3-6), the values of the characteristic potentials and EMFs should be inserted with the following signs (Fokin, 2017): $U_{res} = 80$ mV; $U_{cK} = 65$ mV; $U_t = 45$ mV; $U_p = -35$ mV; $E_K = 90$ mV; $E_{Na} = 60$ mV. After substituting test values to formulas (3-6) and simple simplifications, the following expressions are obtained:

$$\Delta t_d = -\frac{5.357}{(X_s + 1)} \ln\left(\frac{105X_s - 45}{125X_s - 25}\right) \qquad (4*)$$

$$\Delta t_p = -\frac{5.357}{(X_{(s+p)} + 1)} \ln\left(\frac{25X_{(s+p)} - 125}{105X_{(s+p)} - 45}\right) \qquad (5*)$$

$$\Delta t_r = -\frac{0.376}{(X_r + 1)} \ln\left(\frac{125X_r - 25}{25X_r - 125}\right) \qquad (6*)$$

The time intervals Δt_d, Δt_p, Δt_r in formulas (4*-6*) are expressed already in milliseconds.

Figure 3 shows the dynamics of change of the factors in formulas (4*-6*) depending on the translated stimulus, X_s. The factors in front of the logarithms in all three formulas decrease monotonically with increasing X_s – dash-dotted curves in Figures 3a, 3b and 3c, whereas the logarithm values (continuous lines) behave in different directions. The logarithm in the first time interval (Δt_d, formula 4*) decreases hyperbolically with increasing X_s; in the second (Δt_p, formula 5*), decreases very slowly and almost linearly; in the third (Δt_r, formula 6*), increases steeply closer to the maximum value of

X_s. Besides, the logarithm in formulas (4, 4*) determines the lower threshold value of the membrane potential: for the values of the translated stimulus $X_s < 0.4286 \approx X_t$, the AP will not be formed, because the membrane potential never reaches its threshold value; in this test example, it is $U_t = -45$ mV, whereas the value of the expression under the logarithm sign will go beyond its domain of definition: it will become negative, which makes no sense.

In formulas (6, 6*), the logarithm determines the upper limit of the translated stimulus (in the test example, it is $X_{slim} \approx 2.85$, whereas $X_{rlim} \approx 0.2$, respectively), above which the formation of

AP pulses also ceases, but for another reason: the membrane potential never reaches the potential for closing potential-dependent potassium channels during repolarization; the value of the expression under the logarithm sign will also go beyond its domain of definition – it will become

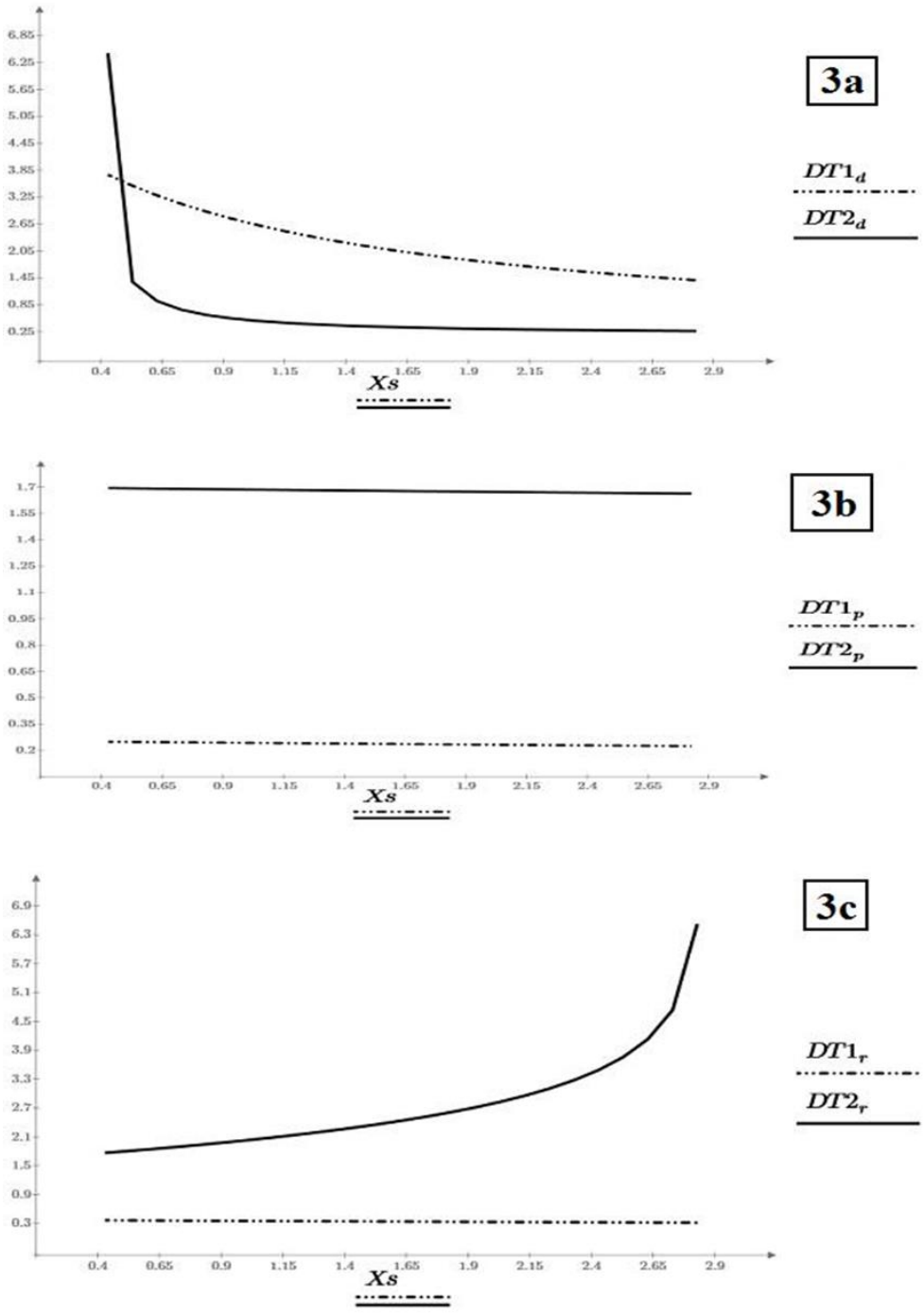

Figure 3. *Dynamics of change of factors in formulas (4*-6*) depending on the translated stimulus, X_s: 3a – formula (4*); 3b – formula (5*); 3c – formula (6*). Continuous lines denote the values of the corresponding logarithms, dash-dotted lines represent the factors in front of the logarithms. For other parameter values in formulas (4-6), the qualitative run of the curves will be the same as in Figures (3a-3c). negative, which makes no sense. The dynamics of the dependence of all three time intervals $\Delta t_d, \Delta t_p, \Delta t_r$, constituting the time of the AP Δt_{ap}, on the translated stimulus X_s is presented in Figure 4.*

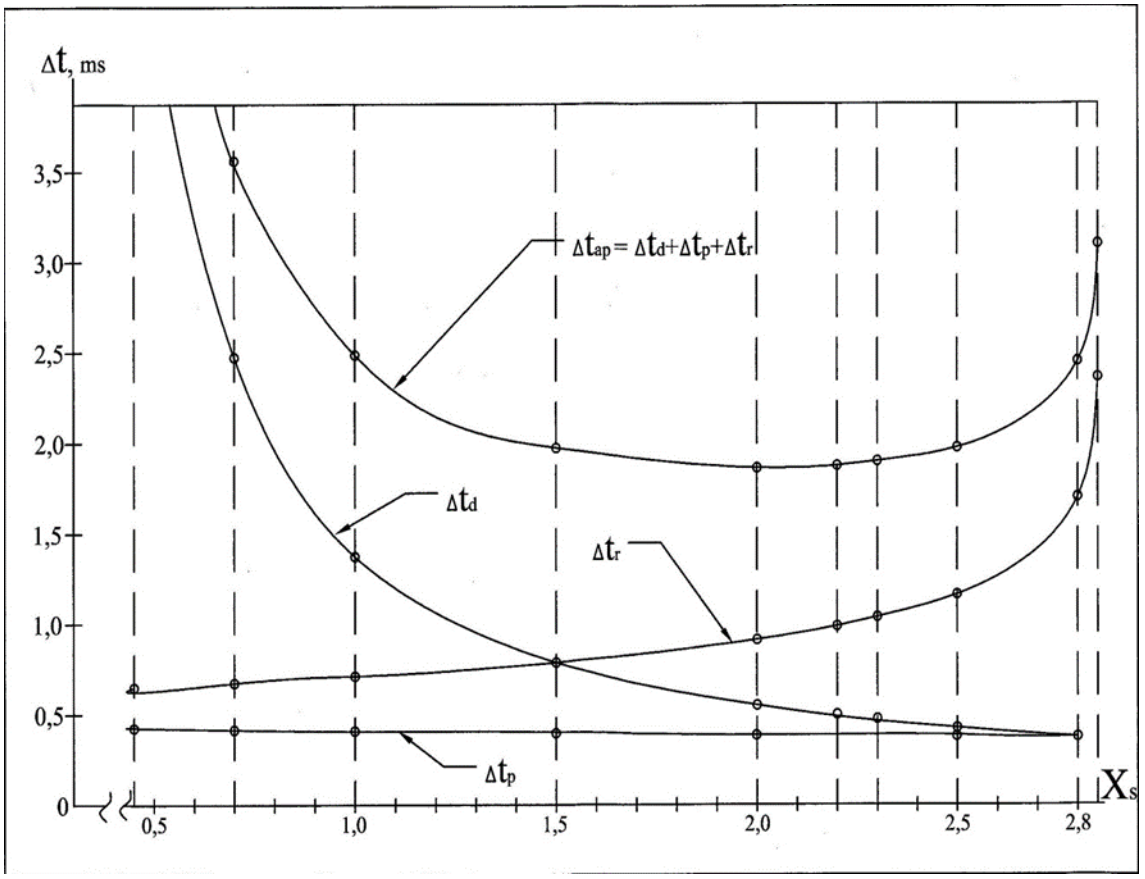

Figure 4. The duration of the AP impulse, Δt_{ap}, and its components: depolarization – Δt_d, peak – Δt_p and repolarization – Δt_r, depending on the magnitude of the stimulus expressed through the dimensionless potassium-sodium parameter X_S of the membrane (translated stimulus).

The dependence $\Delta t_{ap}(X_S)$ has a minimum due to the fact that, for large values of the ongoing stimulus, the remaining open stimulus-dependent sodium channels decelerate the repolarization process. The contribution of each of the factors in the formulas (4* -6*) is shown in Figure 3.

Since the frequency ν_{ap} of AP impulses is inversely proportional to their periods Δt_{ap} (see formula 3), the dependence $\nu_{ap}(X(S))$ will have a corresponding maximum. The characteristic curve $\nu_{ap}(X_S)$, constructed according to the data of test calculation, is presented in Figure 5.

By changing the above physiological or rather physical parameters of the primary neuron of the receptor, one can obtain at the output not only different thresholds of susceptibility to an adequate stimulus, but also different slopes of the curve $\nu(X(S))$, different coordinates of the maximum on it, and other individual features of sensory sensitivity discovered in psychophysical experiments at the macro level of the organism. For example, a change in only one parameter of the model – the potential of closing the potential-dependent potassium channels, U_{cK}, from –65 to –80 mV will lead to narrowing the range of $X_s(S)$ by almost three times: from 2.85 (Figs. 3, 4) to 1.02 (Fokin, 2017), whereas the maximum of the dependence will shift much closer to the pessimum zone.

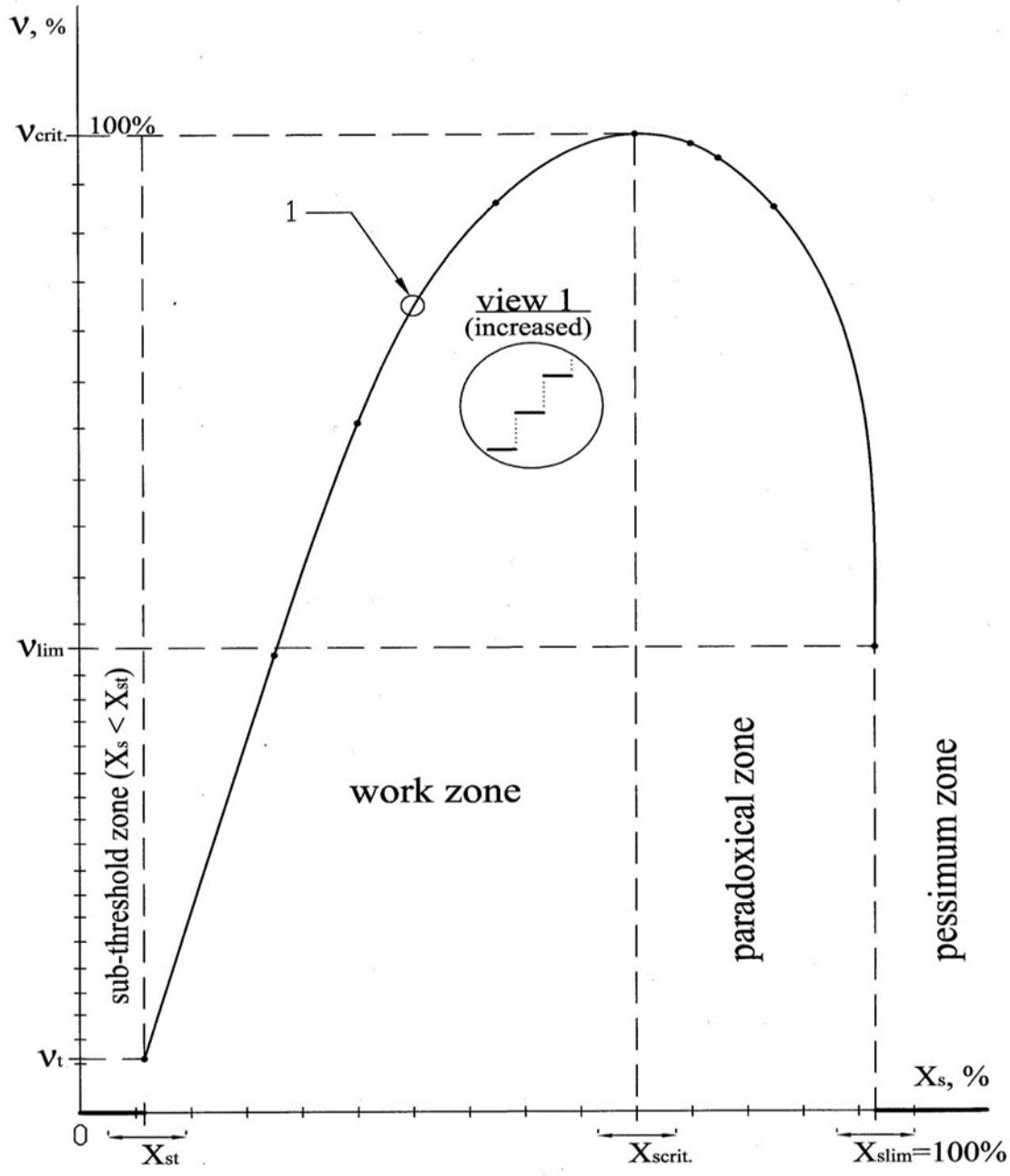

Figure 5. The calculated graph of the dependence of the frequency of APs $\boldsymbol{\nu}$ on the intensity X_S of the translated stimulus, in the conditions of the psychophysical experiment: each X_S = const during a short period of time (~ 1s). The curve $\boldsymbol{\nu}(X_S)$ is not smooth (analog), but "stepwise" ("digital") – see view 1, because the membrane resistance changes discretely when opening/closing individual sodium or potassium channels. In the subthreshold region and the pessimum zone, the neuron does not respond to the APs stimuli, although for different reasons (see the text and Fokin, 2017a for details).

Results and discussion

The theoretical maximum of the dependence $\nu_{ap}(X(S))$ under natural conditions, when the intensity of external stimuli, as a rule, is in the working range of values (see Figure 5), is difficult to detect unless one specifically sets such a goal.

However, psychophysical experiments in the area of high stimulus intensities (Ratanova, 2008) indicate its presence, at least, for the individuals with a "weak nervous system" (according to the terminology of Pavlov (1952) and the motional technique of Nebylitsyn (1966)). For example, it is known that the difference in sensations stably correlates with differences in such a physiological indicator of the organism as the amplitude of the evoked potentials of the cerebral cortex. So, experiments showed that "for some people, with an increase in the stimulation intensity, the amplitude of the evoked potentials increases all the time, while for others in the same range of intensities, at some point, when the stimulation intensity increases, the amplitude growth stops or even the amplitude decreases" (Ratanova, 2008, p. 96). However, psychophysicists have searched for the explanation of this phenomenon not at the level of receptors, but at the level of the central nervous system. An assumption has been put forward concerning the existence of a central mechanism for controlling intensity or a sensory "filter", the purpose of which is to protect the nervous system from the effects of superstrong stimulation. Depending on the sensitivity of the nervous system, this mechanism is activated in different people at different levels of stimulation intensity, which explains the observed differences (Petrie *et al.*, 1960).

Not denying the possibility of the existence of a hypothetical "central control mechanism", through which the signals from receptors are modified in order to achieve the best adaptive result for each particular organism with its inherent psychophysiological parameters, it should be noted, however, that *the above differences between individuals can be formed already at the receptor level*, because it is at the receptor level that the nonlinearity of the conversion of the stimulus intensity to the sensation strength is physiologically formed (see Figure 5). For a final clarification of this issue, additional experiments are necessary at the neurophysiological level, which make it possible to reveal the presence or absence of a maximum on the curve $\nu_{ap}(S)$.

Another indirect confirmation of the correctness of the proposed mathematical model of the primary neuron of a receptor is the experimental data of psychophysicists, indicating significant individual differences in the slope of the "sensation strength – stimulus intensity" curves $R(S)$ in the individuals with different sensitivity thresholds (Ratanova, 2008). Contrary to the theoretical hypothesis of Nebylitsyn-Ilyin (Nebylitsyn, 1966; Ilyin, 2004), the experimental curves $R(S)$ do not shift equidistantly to the right along the abscissa axis with increasing sensitivity threshold, but intersect already in the first half of the range of the stimulus values due to different slopes (Ratanova, 2008; Figure 6_{RT}, 6_{SE}).

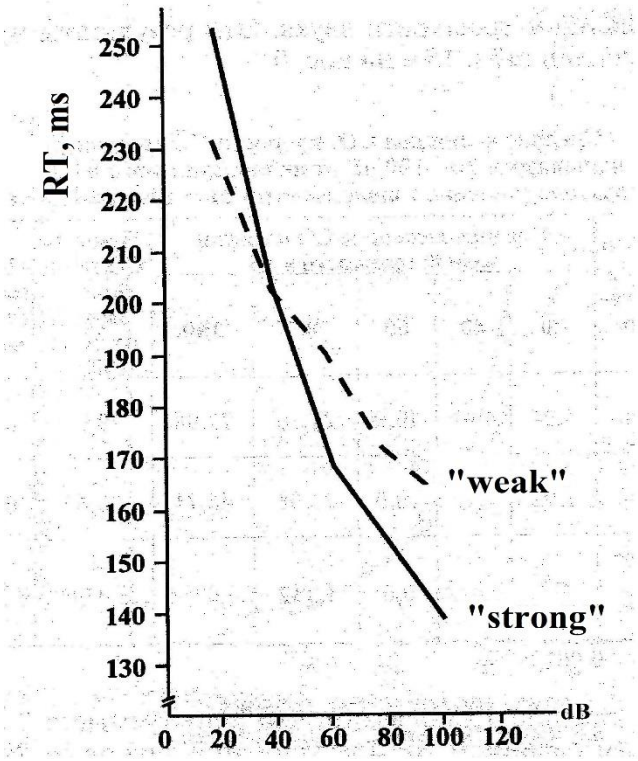

Figure 6$_{RT}$. "Cross" dynamics of experimental dependences of reaction time (RT) on the loudness of the presented sounds in subjects with a "strong" and "weak" nervous system according to Pavlov I.P. Source: (Ratanova T.A., 2008).

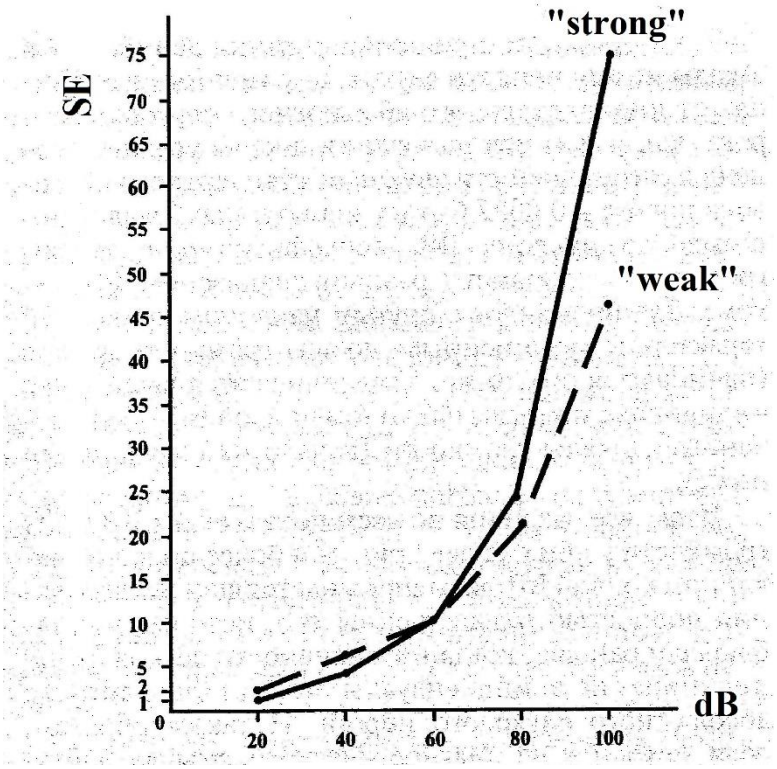

Figure 6$_{SE}$. "Cross" dynamics of experimental dependences of the subjective evaluation (SE) of the loudness of the presented sounds in subjects with a "strong" and "weak" nervous system according to Pavlov I.P. Source: (Ratanova T.A., 2008)

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The model proposed in the present paper can explain the above phenomenon already at the receptor level. For example, with an increase in the threshold value of the membrane potential U_t of the primary neuron of the receptor from -50 mV to -40 mV, which corresponds to a decrease in its sensitivity, the curves $\nu_{ap}(X(S))$ calculated using formulas (3-6) will have different slopes and intersect already in the first half of the range of values of the translated stimulus $X_s(S)$ (see Fig. 6).

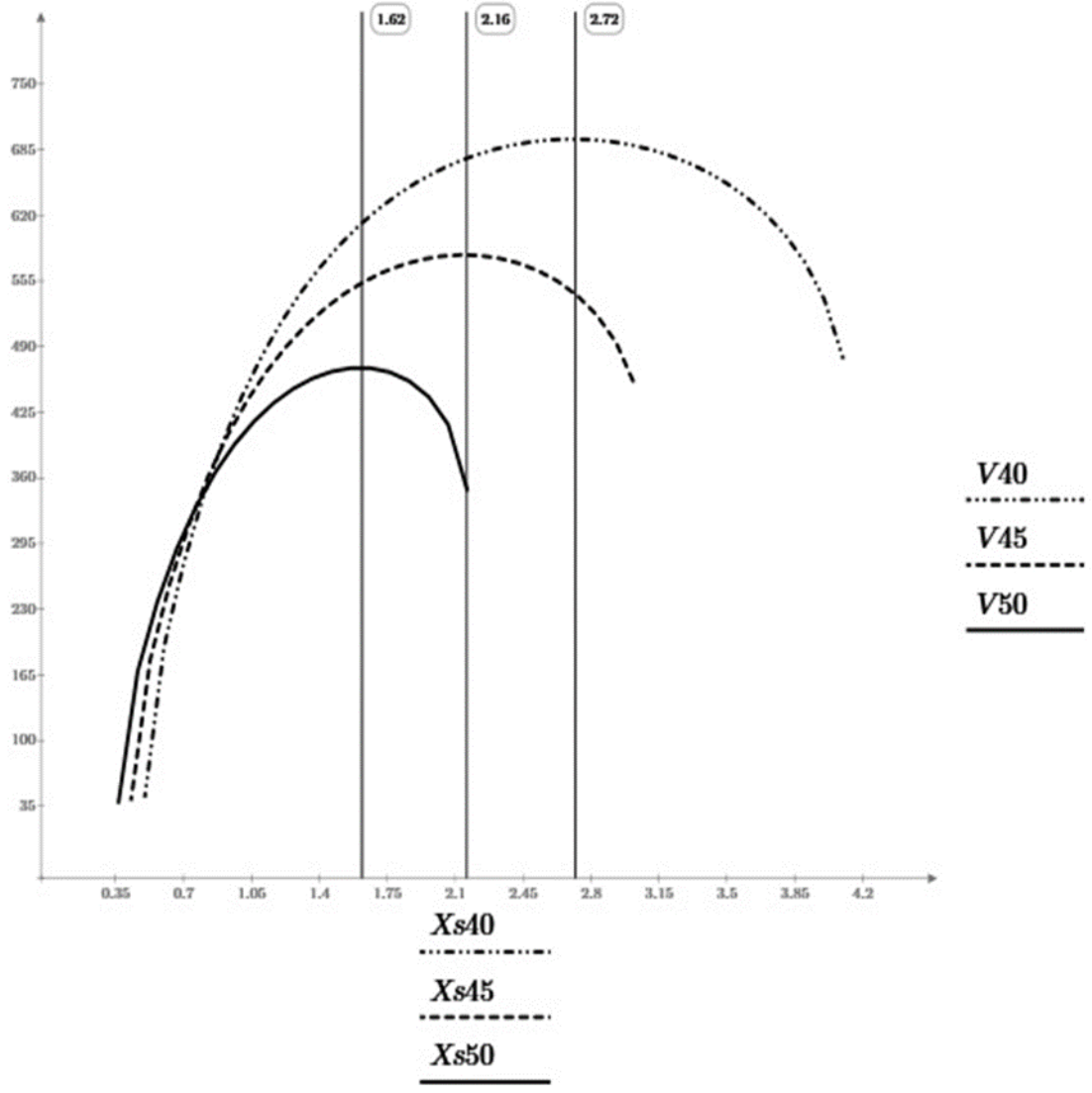

Figure 6. Calculated dependences of the frequency of impulses of the AP receptor (V) on the magnitude of the translated effect (X) and characteristic differences in their dynamics for organisms with weak (V50) and strong (V40) nervous systems (according to Pavlov's terminology (1952)). V40, V45 and V50 are AP impulse frequencies at the threshold receptor membrane potentials (U_t) of -40, -45, and -50 mV, respectively. Moreover, it is conventionally accepted that a threshold potential (receptor response threshold) of -50 mV characterizes a weak nervous system, while -40 mV, a strong one (a difference of about 20%).

Since the frequency of impulses of the AP receptor V and the magnitude of the translated action X are the "sources" for the formation of sensation strength (R) depending on the stimulus intensity (S), one can observe a qualitative agreement between the calculated V(X) and experimental R(S) dynamics, obtained by psychophysicists for various receptors taking into account the strength-weakness of the nervous systems (NS) of the research subjects (for example, Ratanova, 2008, pp. 189-191 – for acoustic receptors). The calculated dependences are extended due to the paradoxical region characteristic of individuals with a weak nervous system, although not shown on the above experimental graphs, but described in detail in the monograph (Ratanova, 2008, pp. 92-106, 140-147).

It should be noted here that the result shown in Figure 6 is obtained only under a simultaneous proportional change in both the threshold values of the membrane potential U_t and the closure potential of the potential-dependent potassium channels U_{cK} such that, for example, their ratio always equals 1.4 = U_{cK}/U_t. The numerical value of the ratio is not important here, the main thing is that, when the value of U_t changes, the value of U_{cK} changes proportionally. If one changes only the response threshold of the primary neuron of the receptor U_t, leaving the closure potential U_{cK} of the potassium channels constant, then the curves $\nu(X_s(S))$ will not intersect. The dependencies will simply equidistantly shift to the right along the abscissa axis as in the theoretical Nebylitsyn-Ilyin model (1966-2004), which contradicts the experimental data of psychophysicists (Ratanova, 2008). The above calculation options indirectly predict that the sensitivity threshold value of the primary neuron of the receptor is somehow connected with the value of the closure potential of its voltage-dependent potassium channels. To confirm or refute this circumstance, additional neurophysiological experimental studies of primary neurons of receptors with different response thresholds are necessary

Transition from the dependence $\nu(X_s)$ to the dependence $\nu(S)$

Now let us consider the relationship between the translated stimulus X_s and the real physical stimulus S, because without this link the desired dependence $\nu_{ap}(S)$ remains undetermined. Obviously, with the linear dependence $X_s(S)$, although the curves "AP frequency – intensity of the translated stimulus", $\nu(X_s)$, and "sensation strength – intensity of the physical stimulus", $R(S)$, are shifted with respect to each other, they are equidistant in form.

However, there are data supporting more complex $X_s(S)$ relationships. Thus, experimental psychophysical curves $R(S)$ were obtained not only convex in the direction of growth of R, similar to the calculated curves $\nu(X_s)$, but also concave or almost linear (Stevens, 1957; Ratanova, 2008). Even for the simplest case of the direct impact of the stimulus on the primary neuron of the receptor, for example, during tactile or painful sensations, it is unlikely that one can write down the dependence $X_s(S)$ in one equation, because, most probably, the curve $X_s(S)$ has a characteristic S-shape. For more complex receptors, for example, the auditory one, it is necessary to take into account the specifics of the stimulus transformation at each stage of its path to the primary neuron. That is, it will be necessary to write down several equations, each of which may have its own coefficients that differ among different individuals.

The dependence $X_s(S)$ in the conditions of a psychophysical experiment is actually the dependence of the total electrical resistance of the stimulus-dependent sodium channels of the neuron membrane on the stimulus magnitude: $X_s = R_{res.K}/R_{(res.+s)Na}(S)$, which can be successfully identified using modern microbiological methods. For example, in (Kamkin, & Kiseleva, 2004), an experimental dependence was obtained of the incoming sodium current strength on the elongation of a cardiomyocyte when it is stretched by various forces. The value of the potential difference between the extra- and intracellular media was the same for all variants of stretching. Since, according to Hooke's law, the elongation of the tissue in the elastic region is directly proportional to the tensile force, whereas, according to Ohm's law, the current strength at constant voltage is inversely proportional to the resistance, for the cardiomyocyte, the dependence $R_{(res.+s)Na}(S)$ was actually determined, where the tensile force acts as a stimulus. The same can be reproduced not with stretching, but with pressure on the pain or tactile receptors. The same manipulations can also be carried out with thermoreceptors, light-sensitive receptors, etc. Further, after determining the physical model of the influence of stimulus intensity on the electrical resistance of the membrane of the primary neuron of

receptors and its mathematical expression, the obtained experimental data are substituted into it and the limits of individual coefficients can be calculated. Thus, one can differentiate between:

a) individual features that are manifested during transduction of the stimulus at all stages of its path to the primary neuron of the receptor;

b) differences determined by individual variations of the electrochemical properties of the neuron itself.

The authors have already decided on the mathematical model of the primary neuron of receptors; some features of the stages of stimulus transduction are considered below.

As a rule, the electrical resistance of the membrane of a stimulus-sensitive cell decreases with increasing intensity of action due to opening of stimulus-controlled sodium ion channels (Fokin, 2017):

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$$X_S(S,\Psi) = \frac{R_{resK}}{R_{resNa}} + \frac{R_{resK}}{R_{sNa}(S,\Psi)} = \frac{R_{resK}}{R_{resNa}} + \frac{R_{resK}}{R_{1Na}} \cdot N_{sNa}(S,\Psi) \qquad (7)$$

where $\boldsymbol{R_{sNa}(S,\Psi)}$ is the electrical resistance of sodium channels opened under the stimulus action, Ohm; Ψ is the matrix of individual properties of the neuron, also affecting the dynamics of changes in electrical resistance. For S = 0, no stimulus-dependent sodium channel is opened, and R_{sNa} is equal to the resistance of the lipid layer of the membrane, which is several orders of magnitude greater than R_{resK} and, accordingly – matrix of individual properties of the neuron, also affecting the dynamics of changes in electrical resistance. At S = 0, not a single stimulus-dependent sodium channel was opened and R_{sNa} is equal to the resistance of the lipid layer of the membrane, which is several orders of magnitude greater than R_{resK} and, accordingly, $R_{resK}/R_{sNa}(S=0) \rightarrow 0$, whereas $X_s(S=0) = R_{resK}/R_{resNa} = X_{res}$.

$\boldsymbol{R_{1Na}}$ is the electrical resistance of a single stimulus-dependent sodium channel of the neuron membrane of the receptor, Ohm. To date, the electrical conductivity of many types of cation channels has been experimentally measured and amounts to about 10-35 pS (Kamkin, & Kiseleva, 2004), which corresponds to electrical resistance of ~ 0.1- 0.3 TΩ;

$\boldsymbol{N_{sNa}(S,\Psi)}$ is the number of opened stimulus-dependent sodium channels of the neuron membrane of the receptor when a constant stimulus of the magnitude of S is applied to it, pcs.; Ψ is the matrix of individual properties of a neuron that affect the dynamics of the opening of sodium channels during stimulation.

The ratio R_{resK}/R_{resNa} of "|leakage resistances" can be designated as the potassium-sodium rest parameter – X_{res}; for the test neuron, it will be equal to: $X_{res} = R_{resK}/R_{resNa} = 1/14 \approx 0.07143$ (see above). The other notation in (7) is the same as in the previous formulas.

The expression for the potassium-sodium parameter X_s of the membrane in formula (7) in terms of the stimulus-dependent total resistance R_{sNa} can be conveniently used to obtain the experimental dependences $X_s(R_{sNa}(S))$, because in such experiments, the total electrical characteristics of the membrane are operated with (Kamkin, & Kiseleva, 2004). However, the integrated characteristic $R_{sNa}(S,\Psi)$, obtained experimentally, will not tell anything about the mechanisms of the process, nor about the criteria for individual differences, although it will be useful for testing theoretical models.

The expression of X_s through the number of newly opened sodium channels when the cell is effected will help to understand the mechanisms of the corresponding processes and the possible causes of individual differences at the level of perception of the stimulus. For example, a mechanical effect on a cell is perceived by its cytoskeleton (Kamkin, & Kiseleva, 2004). Moreover, if the magnitude of the mechanical stimulus does not go beyond the elastic region of operation of the cytoskeleton of the stimulus-sensitive cell, for example, cardiomyocyte (Kamkin, & Kiseleva, 2004), then, upon the removal of the impact, the electrical resistance of its membrane returns to its original state, i.e. is completely restored. Thus, even if the full form of the dependence $N_{sNa}(S, \Psi)$ is unknown, one can still definitely say that for different elastic properties of the cytoskeleton of cells, the number of opened stimulus-dependent sodium channels in their membranes will be different for the same stimulus value. This means that the threshold value S_t of the stimulus will also be different, of course, provided that X_{st} is the same for them. Here, the threshold value S_t of the stimulus is understood to be such its value, under the action of which such a number of

sodium channels opens that is necessary to achieve the threshold potential (U_t) of the primary neuron of the receptor. Thus, one can already explicitly select from the array of internal individual characteristics of the neuron Ψ one of its components, which is responsible for the elastic properties of the cytoskeleton. By analogy with the coefficient responsible for the elastic properties of a spring in physics, it can be denoted by the Latin letter "k" and called "stiffness of the cytoskeleton". A cell can deform under the action of tensile, compressive, or shear forces. If the values of the impacts are in the elastic region, then, according to Hooke's law, the strain value Δd will be directly proportional to the applied force – in this case, the stimulus S:

$$\Delta d = S/k \quad (8)$$

For any of the above types of deformations, mechanosensitive sodium channels will open in an amount proportional to the displacement of its cytoskeleton (and membrane, respectively) from its resting position, i.e. proportional to Δd. Thus, it can be written:

$$N_{sNa}(S, \Psi) = \frac{S}{k} F(S, \Psi_1) \quad (9)$$

where k is the stiffness of the cytoskeleton of the membrane of the primary neuron of the receptor, [unit of the impact S/unit of the deformation Δd]; as will be shown below, the notation form indicated in (9) will be valid for many sensory modalities, therefore a generalized name for k is proposed – "*stimulus perception coefficient by the neuron surface*":

$F(S,\Psi_1)$ is a function taking into account the influence of all other individual parameters of the neuron on the dynamics of opening of sodium channels, except for k; Ψ_1 is a matrix of the individual properties of a neuron that affect the dynamics of opening of sodium channels during stimulation even without taking into account the stiffness coefficient k of the cytoskeleton.

That is, the larger the stiffness of the cytoskeleton, the less the cell membrane will be deformed under the same magnitude of the stimulus, and, accordingly, a smaller number of stimulus-controlled sodium channels will open.

Formula (9) is written for the simplest case, when the impact is performed directly on the primary neuron of the receptor, for example, as in tactile or pain receptors. If there are "mediators" between the stimulus and the primary neuron, such as hair cells in the auditory receptor, then k will reflect the stiffness of the cytoskeleton of the hair cells, the electrical resistance of which also varies depending on the level of sound pressure deforming the hairs. In such complex cases, each stage of stimulus transduction should be considered separately in their sequence up to the primary neuron of the receptor. However, in response to deformations, only a continuous generator potential arises in the hair cells, which stimulates the release of the mediator into the synaptic cleft with the primary auditory neuron, and already in the latter, AP arises in an amount proportional to the concentration of the mediator in the synaptic cleft and the reaction rate constant. That is, in addition to the same stimulus for all individuals – the magnitude of sound pressure repeatedly converted along the way to the auditory neuron, there are also individual coefficients of the auditory neurons themselves – the rate constants of the reaction of the mediator with the corresponding receptors of the membrane. The greater the reaction rate constant, the faster the threshold will be reached for the onset of generation of APs by the auditory neuron at the same concentration of the mediator in the synaptic cleft, i.e. at the same sound pressure. Thus, the reaction constant will be one of the parameters that determine the threshold value of the sound volume. It is interesting that the formal dependence of the number of opened stimulus-dependent sodium channels on the stimulus intensity (the sound pressure value) and the constant of the mediator reaction rate in the synaptic cleft of the auditory neuron will be the same as in formula (9), only k will denote the reaction rate constant and *be in the numerator*, where S is the sound pressure level. Thus, the volume of perceived sound will depend not only on a single objective parameter of the stimulus – the sound pressure level, but also on a number of subjective parameters that are individual for each organism, which can be used to explain individual differences obtained by psychophysicists (Ratanova, 2008).

Formula (9) will also be valid for thermoreceptors and photosensitive receptors, but it will be necessary to consider the coefficients in each case separately. It should also be noted that many neurons of the nervous system are excited through chemical synapses, and as mentioned above, for this case, formula (9) is also valid.

Substituting (9) into (7) and taking into account previously accepted notation, one can obtain:

$$X_s(S,\Psi) = X_{res} + \frac{R_{resK}}{R_{1Na}} \cdot \frac{S}{k} \cdot F(S,\Psi_1) \quad (10)$$

By combining the constant individual parameters $R_{resK}/(R_{1Na} \cdot k)$ of the receptor into one constant K_R , one can obtain:

$$X_s(S,\Psi) = X_{res} + K_R \cdot S \cdot F(S,\Psi_1) \quad (10^*)$$

The identification of the explicit form of the function $F(S,\Psi_1)$ requires additional research that is beyond the scope of the present paper. A priori, it can be only said that $F(S,\Psi_1)$ will depend on the cell geometry, the number of stimulus-dependent sodium channels per unit area of its membrane, the maximum value of the stimulus, and other factors. While the form of the function $F(S,\Psi_1)$ remains unclear, it is excluded from formulas (10, 10*) and equated to unity. Further, the consequences of variations in the electrochemical parameters of the neuron (see the characteristics of the test neuron above) and the coefficient k responsible for the dynamics of the stimulus perception by the neuron surface are considered.

As mentioned above, formulas (10, 10*) are valid for many sensory modalities, therefore a generalized stimulus value will be used, expressed as a percentage of the maximum value – 100%. Obviously, for $F(S,\Psi_1) = 1$, the dependence $X_s(S,k)$ will be linear with respect to S with the constant parameter k for each calculation option. The function $X_s(S,k)$ will intersect the ordinate axis at the point $X_{res} = R_{resK}/R_{resNa}$ (for the test data, $X_{res} = 1/14 \approx 0.07143$) for any values of the stimulus perception coefficient k. Further, two calculation options are possible:

1) If the value of the coefficient k_e of stimulus perception by the neuron surface is known from the experiment, then substituting it and the threshold value X_{st} of the potassium-sodium parameter of the membrane into formula (10), one can express the threshold value of the stimulus S_t (X_{st} is calculated from formula (4) when equating the numerator of the expression under the logarithm sign in this formula to 0):

$$S_t = \frac{X_{st} - X_{res}}{K_{Re}}, \text{ where } K_{Re} = R_{resK}/(R_{1Na} \cdot k_e) \quad (11)$$

Next, for each value of the suprathreshold stimulus $S_i > S_t$, one can find the corresponding value X_{si} according to the formula (10*) and, substituting the obtained result into the formulas (3-6), one can find the array of the sought-for frequencies of the impulses of the APs $\nu_{api}(X_{si}(S_i))$, generated by the primary neuron of the receptor in response to the stimuli S_i.

1) If the value of the threshold stimulus S_t is known from the experiment, then substituting it and the threshold value X_{st} of the potassium-sodium parameter of the membrane into formula (10), one can express the coefficient k of stimulus perception by the neuron surface:

$$k = \frac{S_t R_{res}}{(X_{st} - X_{res}) R_{1Na}} \quad (11^*)$$

Further steps are similar to those described in item (1).

Test calculations were carried out using the second algorithm, i.e. several variants of the lower threshold values of the stimulus were set and each of them was combined with the variants of the threshold potential of the primary receptor neuron shown in Figure 5. Figures (6-8) present the most interesting results from the point of view of coincidence of the calculated dynamics $\nu_{ap}(S)$ with the dynamics $R(S)$, obtained in psychophysical experiments (Ratanova, 2008).

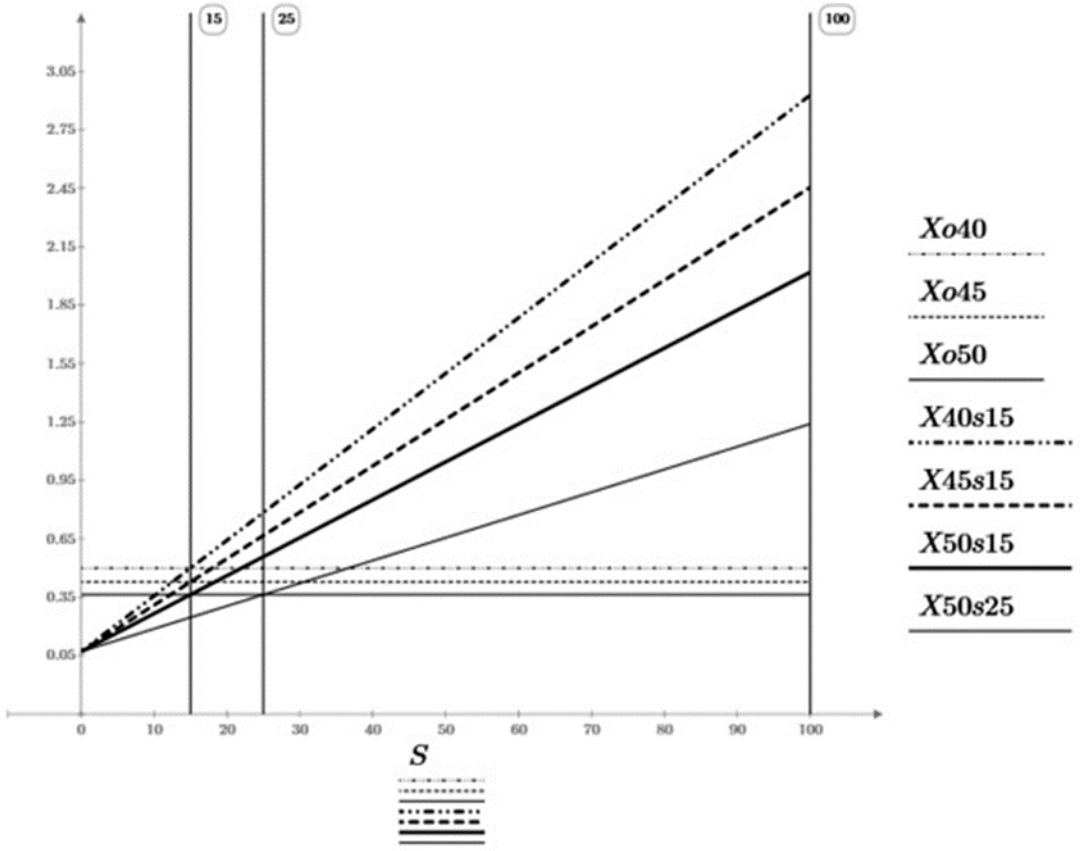

Figure 7. The calculated dependences of the translated stimuli X on the real physical stimulus S, expressed as a percentage of its maximum value S_{max}. The horizontal lines X_o40, X_o45, X_o50 are the threshold values of the translated stimulus in neurons with threshold potentials of −40, −45, and −50 mV, respectively. The inclined lines characterize the dynamics of changes of *X(S)* for different coefficients k of stimulus perception by the neuron surface for neurons with threshold potentials of −40, −45 and −50 mV (X40s15, X45s15, X50s15 and X50s25, respectively). For the three upper curves, the coefficients k are such that the threshold value of the physical stimulus S_t is the same ($S_t = 0.15 \cdot S_{max}$) for all three neurons with different threshold potentials (−40, −45 and −50 mV). It is also shown that an increase in k leads to a decrease in the slope of the graph *X(S)* and an increase in the threshold value of the physical stimulus: the line X50s15(S): $k \approx 0.01316 \rightarrow S_t = 0.15 \cdot S_{max}$; the line X50s25(S): $k \approx 0.02083 \rightarrow S_t = 0.25 \cdot S_{max}$. Moreover, the threshold potential of the neuron remains unchanged: $U_t = -50$ mV.

Regardless of the coefficient k of stimulus perception by the neuron surface, all lines *X(S)* start with the same value – the free term in the equations (10, 10*): $X_{res} = R_{resK}/R_{resNa}$, which for the test receptor is equal to $X_{res} = 1/14 \approx 0.07143$. The question concerning possible individual differences in X_{res} remains open. The greater k for mechanosensitive receptors, the smaller the inclination angle between the *X(S)* line and the abscissa axis, because k is in the denominator of formula 10 (it should be noted that for chemo-, light-, and heat-sensitive receptors, the dependence on the corresponding coefficients will be direct, see above). From a physical point of view, this means that a cell with a stiffer cytoskeleton has a greater threshold value of the physical stimulus S_t, of course, under the same threshold value of the membrane potential U_t (see Figure 7, lines X50s15 (S) and X50s25 (S)). A change in the threshold potential leads to a change in the lower threshold value of the translated stimulus X_{St}. The larger the value of $|U_t|$, i.e. the closer the threshold potential to the resting potential of the cell, the smaller the lower threshold value of the translated stimulus X_{St}, which is determined by equating to zero the numerator of the fraction under the logarithm sign in formulas 4 and 4*. This can be seen in Figure 6: the threshold value of the translated stimulus X_o40 ($|U_t| = 40$ mV) is higher than X_o50 ($|U_t| = 50$ mV). At the intersection of the

line *X(S)* with the level of the threshold value of the translated stimulus X_o, the value of the threshold physical stimulus S_t is obtained (see Figure 7).

Besides the lower threshold value X_{St} , the translated stimulus also has an upper threshold value X_{Slim} (see Figure 5), which is determined by equating the numerator of the fraction under the logarithm sign in formulas 6 and 6* to zero. In Figure 7, the levels of upper threshold values X_{Slim} are not shown; their values depend on the value of the threshold potentials in the same way as the lower ones: the larger the value of $|U_t|$, the lower the upper threshold value of the translated stimulus X_{Slim}. Obviously, the greater the angle of inclination of the line *X(S),* determined by the value of the corresponding coefficients of the stimulus perception (not necessarily mechanical, see above) by the cell surface, the smaller the critical value S_{crit} and the upper threshold S_{lim} of the physical stimulus corresponding to X_{Scrit} and X_{Slim} in Figure 5.

Recall that the sensation reaching its upper limit, after which its strength begins to decrease even with increasing stimulus intensity, is called the "satiation effect" by psychophysicists and is explained by the presence of hypothetical "central filters" that prevent too strong stimulation from being transmitted to the upper parts of the brain (Petrie *et al.*, 1960). The results obtained using the proposed mathematical model make it possible to go without the use of "central filters" by detecting the saturation phenomenon (the pair of X_{Scrit} and S_{crit}) for primary neurons with certain properties even at the receptor level (see Figures 5, 8 and 9). Note that the saturation effect is characteristic only for individuals with a weak nervous system (in the terminology of Pavlov (1952) and in the motor technique of Nebylitsyn (1966)), i.e. for those whose primary neuron of the receptor has a lower value of the lower threshold of sensitivity (a greater value in the absolute value, respectively): $U_t = -50$ mV (Figures 8, 9).

Even if not all of the research subjects experimentally reveal the saturation effect at the macro level of the organism, then it is hardly possible to observe the limit level of the stimulus (X_{Slim} and S_{lim}) in the natural conditions, because it has no adaptive significance, and, therefore, had to be eliminated by natural selection. However, one can try to detect the limit level of stimulation on individual neurons outside the organism, because it is not known whether it is excluded in principle, for example, by small slopes of the lines *X(S)* (see Figure 7), or the magnitudes of the stimuli in the natural conditions are too small to achieve it, but the primary neuron of the receptor will still retain its working capacity even for $S > S_{lim}$. This issue requires its solution at the experimental neurophysiological level.

It should be noted that when the stimulus reaches its lower threshold value S_t, the primary neuron of the receptor immediately begins to generate AP pulses with a certain, minimum possible frequency of the order of several tens of Hertz (Figure 8), which cannot be lowered due to the specific features of the analog-to-digital conversion (Fokin, 2017). However, the minimum possible frequency may differ for neurons with different values of characteristic potentials.

If one considers the frequency of AP of the primary neuron of the receptor as the basis for sensation formation, then the curves V40 (S15p40) and V50 (S25p50) in Figure 8 reflect *atypical* cases of their dynamics, because it was revealed in a number of psychophysical experiments (Ratanova, 2008) that highly sensitive individuals (low threshold S_t , curve V40 (S15p40)), as a rule, have a weak nervous system ($U_t = -50$ mV), whereas low sensitive (high threshold S_t, curve V50 (S25p50)), a strong one ($U_t = -40$ mV). That is, the above curves are exceptions to the general rule; and in the theory of Nebylitsyn (1966) and the early works of Ilyin (2004), there were no such exceptions at all. However, "atypical" individuals were sometimes still found in psychophysical scaling (Ratanova, 2008).

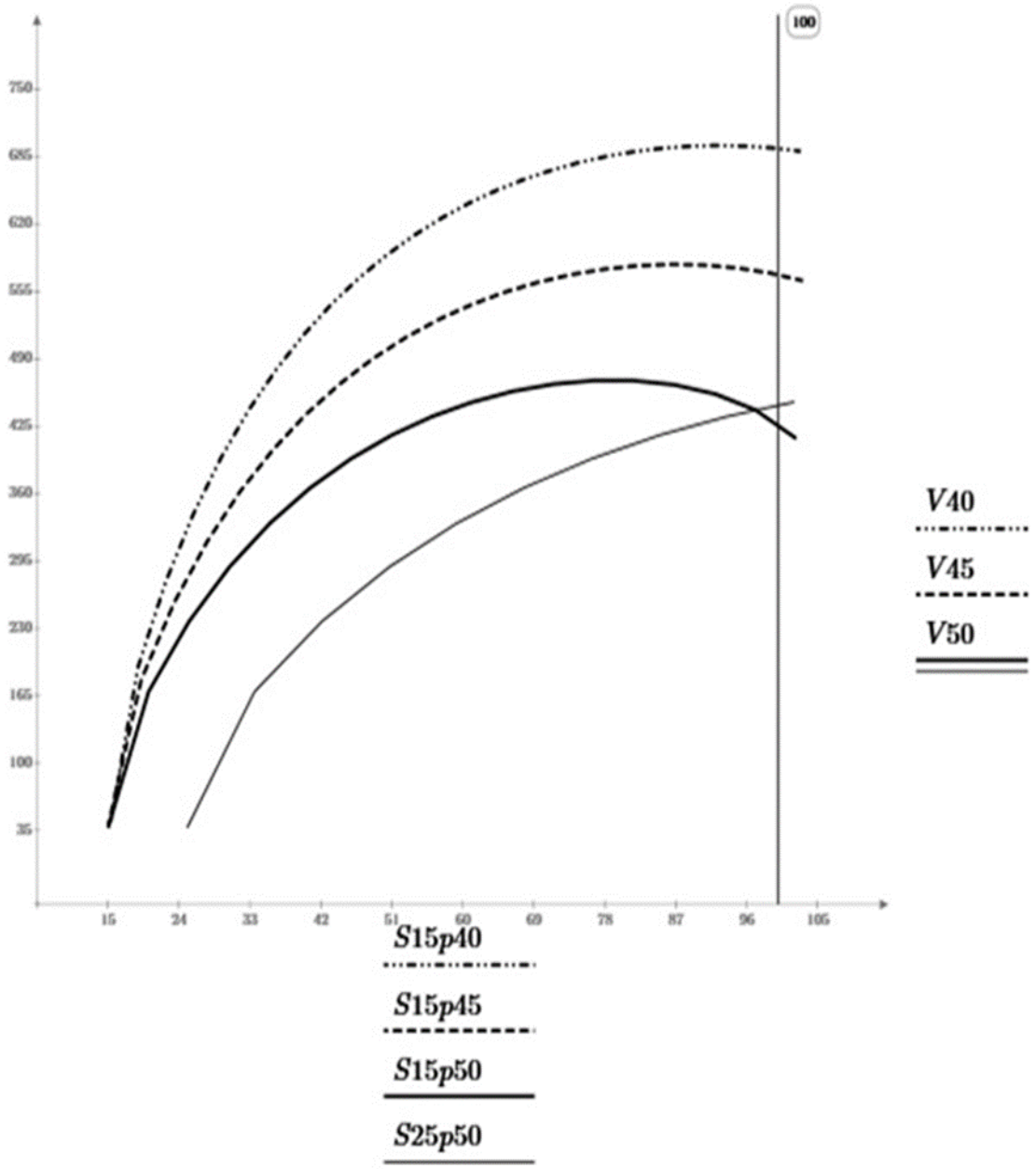

Figure 8. The calculated dependences of the AP frequency of the primary neuron of the receptor on the value $\nu_{ap}(S)$ of the physical stimulus for combinations of threshold values S_t of physical stimuli and threshold potentials U_t of the neuron, shown in Figure 6. It can be seen that for the same value S_t = 0.15·S_{max}, but different U_t= −40, −45, −50 mV, the curves $\nu_{ap}(S)$ do not behave identically. See details in the text.

In order for the curves V40 (S15p40) and V50 (S25p50) to become "typical", they need to be interchanged, which was done in other variants of calculation shown in Figure 8. Here, increased sensory sensitivity (S_t = 15, S15p50 in Figure 9) is manifested in the persons with a weak nervous system (U_t = −50, in Figure 9 it is denoted by V50), whereas the decreased one (S_t =19, in Figure 9 by S19p40), with a strong one (U_t = −40, in Figure 9 it is denoted by V40). The above curves $\nu_{ap}(S)$ intersect in the first half of the stimulus value range, which is typical for experimental psychophysical curves $R(S)$, "sensation strength in its dependence on the stimulus intensity

".

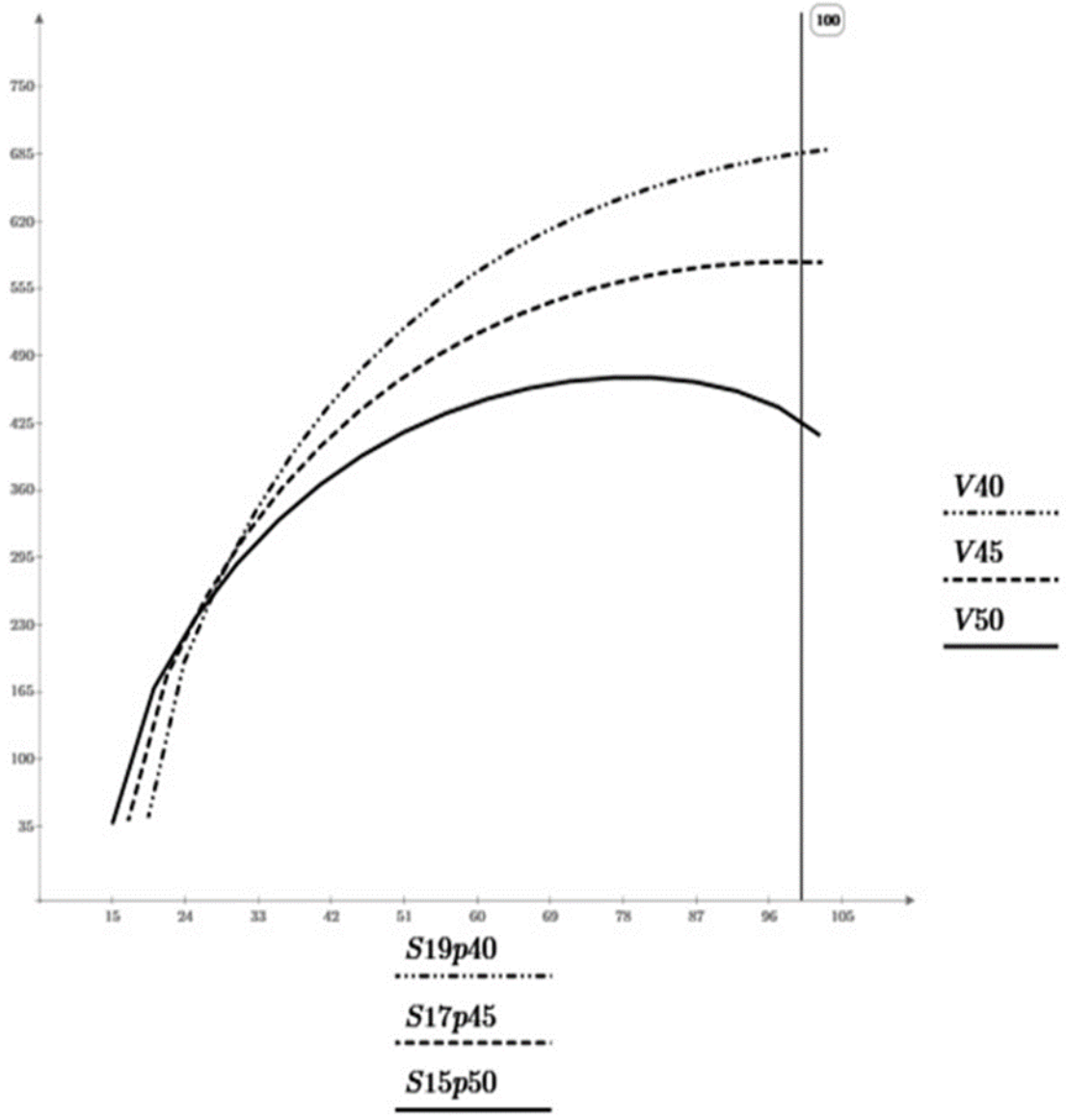

Figure 9. The calculated dependences of the AP frequency of the primary neuron of the receptor on the value $\nu_{ap}(S)$ of the physical stimulus for the following combinations of parameters: a) V50 (S15p50) → S_t = 0.15·S_{max}, U_t = −50 mV; b) V45 (S17p45) → S_t = 0.17·S_{max}, U_t = −45 mV; c) V40 (S19p40) → S_t = 0.19·S_{max}, U_t = −40 mV. The presented calculated curves $\nu_{ap}(S)$ correspond to the typical dynamics of changes in sensation strength due to the intensity of the physical stimulus, $R(S)$, for individuals with a strong (U_t = −40 mV) and weak (U_t = −50 mV) nervous system (according to classification of Pavlov (1952) and Nebylitsyn (1966)). See details in the text

.

Such "cross" dynamics could not be explained in any way either from the point of view of the "laws" of Fechner (1860) or Stevens (1957) or from the point of view of the Nebylitsyn-Ilyin theory (1966-2004). This happens because in the indicated theories, the type uniformity of transformation of the stimulus into the sensation within the "black box" model was postulated, whereas for different research subjects $R(S)$ differ only in the threshold S_t

.

Conclusions

In fact, as the proposed mathematical model shows, *there are several independent steps of regulating the dynamics of $v_{ap}(S)$ and R(S), respectively, two of which are considered in the present paper: the first is at the level of stimulus perception by the surface of the corresponding stimulus-sensitive cells, the second, at the level of electrochemical properties of the primary neuron of the receptor*. As a result of test calculations performed using the author's mathematical model with the real physiological properties of the neuron, the characteristic dynamics of the $v_{ap}(S)$ dependence agreeing with the experimental ones were obtained (Ratanova, 2008; Figures 6_{BP}, 6_{CO}), which indirectly confirms the adequacy of the proposed model.

In addition, the dependence $v_{ap}(S)$ already at the level of the primary neuron of the receptor has a characteristic maximum (see Figure 5), which allows explaining another experimental psychophysical phenomenon, the "saturation effect". It consists in the fact that after reaching a certain level, a further increase in the stimulus no longer leads to an increase in the sensation strength or even leads to its weakening (Ratanova, 2008). This cannot be explained with the help of traditional monotonous psychophysical dependencies. In fact, as the proposed mathematical model shows, even the dependence $v_{ap}(S)$ is not simple and monotonous, but consists of several "competing" equations (see formulas 3-6). Moreover, two of them have asymptotic limits that determine the lower and upper thresholds of sensory sensitivity (see Figures 3, 4).

The variant with the same stiffness coefficient k of the membrane cytoskeleton for all neurons with different threshold values of the membrane potential: U_t = −40; −45 and −50 mV is of interest. It is quite possible, although unlikely from a physiological point of view, that the membranes of all primary neurons of receptors of a certain modality are "manufactured" according to the same genetic program, not distorted by natural selection. Even if this is so and k_i = const, then, due to different threshold values of the membrane potential of the primary neuron, the lower thresholds of the sensitivity of the receptor to a physical stimulus will also be different. For the above test values of U_t and k_i = const, as shown by elementary calculations by formulas (4*, 11), the lower thresholds of sensitivity to a physical stimulus will differ from each other as follows: $S_t(U_t = -40\text{ mV})/S_t(U_t = -45\text{ mV}) \approx 1.2$, i.e by 20%; $S_t(U_t = -50\text{ mV})/S_t(U_t = -45\text{ mV}) \approx 0.82$, i.e. about 18%. The real limits of individual variability of cytoskeleton stiffness and threshold values of the membrane potential of primary neurons of the receptor should be revealed by the future neurophysiological experimental studies, but whatever their results, the author's mathematical model is capable of working with any initial data.

Perspective

Despite indirect confirmation of the adequacy of the proposed mathematical model of the primary neuron of a receptor by the results of psychophysical experiments at the macro level of the entire organism, experimental confirmation of it at the micro level of individual neurons and receptors is also required.

The proposed model requires further development, because many questions remain open: what is the form of the dependence $R_{sNa}(S,\Psi)$; at what stage of the dependence $v_{ap}(X_s(S))$ do stimulatory-controlled sodium channels end; what is the contribution of each stage of stimulus transduction on its way to the primary neuron for sensory systems with a complex structure and how can the stimulus transformations be formalized on each of them; is there a relationship between the threshold value of the potential of the primary neuron and the closure potential of the potential-dependent potassium channels and which factors determine it; what are the real dynamics of opening stimulus-dependent sodium and closing potential-dependent potassium ion channels of the primary neuron of a receptor and what is the error introduced into the model by the accepted assumption of the instantaneous opening/closing of these channels; and so on.

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Personality Types of Modern Russians: Myth or Reality?

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Abstract. The existence of personality types is one of the most extremely controversial issues. In contrast to the ideology of the "Big Five" or biological approach, we presume that the typology of individuality cannot be reduced to temperament types or personality ones, since reflects the effect of the interaction of multi-level properties of a person. This study focuses on the empirical identification of types of individuality and the description of their behavioral manifestations. One thousand and one hundred volunteers aged 19–35 (73% female), took part in the present study. We used a set of methods for assessing the multi-level properties of individuality: Temperament, Fundamental Personality Dimensions (PEN), Character Traits, Motivation, Cognitive Styles, Intelligence, Hardiness, Spiritual Personality Traits, Meaning in Life, Axiological Orientation, and Ways of Coping. Principal Component Analysis (Varimax rotation) reduced 81 variables into four main components, which were called Wisdom, Emotionality, Activity, and Sociability. Hierarchical Cluster Analysis allowed us to identify four groups of respondents who differ in the manifestations of the above-described integrative variables. We called these complexes of individuality traits as "Ordinary Man", "Spiritual Man", "Man of Mood" and "Man of Action". The significance of differences between groups was confirmed based on multivariate ANOVA.

Keywords: individuality, multi-level individuality properties, individuality types

Introduction

Individuality research has a long history. There are two well-known opposed strategies for exploring individuality. The first strategy (probabilistic) is based on the uniqueness of each person [1, 2]. The second (essential) comes from Plato's philosophy in explaining individual differences, emphasizing the priority of qualitative differences over quantitative ones, through typology. It is important that these types be obtained empirically and reflected the nature of different levels of individuality, that is, they would be an external and internal manifestation of the generalization of multi-level properties of individuality.

Individuality is often understood as a manifestation of the biological properties in man, for instance, Hippocrates and Galen, K.-G. Jung, E. Kretschmer and W. Sheldon, D.W. Keirsey, I.P. Pavlov and others. Indeed, the typology of temperament is well developed. However, there is another interpretation: individuality as a set of biological and social qualities of a person [3, 4]. In this case, personality traits and higher social manifestations of a person also relate to individuality. This approach is widespread in Russian psychology, but has recently been reflected in world science when discussing the personality [5, 6].

V.S. Merlin emphasized, "Man possesses the properties of all stages of the development of matter, ranging from chemical level to socio-historical one. In each of these properties there is, along with something common and typical for groups of people, something individual and

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unique" [7] (p. 58). Individuality consists of a number of levels reflecting the features of the development of matter: biochemical, somatic (the general constitution of the organism), neurodynamic (nervous system), psychodynamic (temperament), personal, socio-psychological, socio-historical ones. Between these levels, there are complex interactions that allow you to adapt successfully to a changing environment. Each level is formed and functionates according to its own laws, the relations between the properties of one level are rigidly determined, and between levels, they are plastic and changeable. The rigidity of ties, on the one hand, and plasticity, on the other, allow the body to adapt adequately to the situation and at the same time be generally stable and relatively constant in its behavioral manifestations.

V.M. Rusalov noted that the complex multi-level structure of individuality is a manifestation of the interactions of genetic and environmental factors mediated by activity of a man. Neurophysiological foundation of human mind and behavior are the temperament. Each property of individuality is formed under the influence of society as an amplification (continuation) of temperament properties or as their compensation [4].

One of the closest to the above-described understanding of individuality is the lexical personality models (for example, the Big Five Model, the Big Seven Model, Hexaco Model). The Big Five model coved five main domains of human personality such as neuroticism, extraversion, openness, agreeableness, and conscientiousness. However, G. Bedny, W. Karwowski, characterizing the "Big Five" obtained by factor analysis, note “factor analysis is a fundamentally atheoretical approach to personality that conflates motivation, attitude, temperament, and values. Moreover, the mathematics of factor analysis precludes identification of qualitative differences in personality types, the effects of complex moderator relationships among the variables, nonlinear relationships among variables and factors or consideration of unusual or unique standings on the measured variables” [8] (p. 457). Agreeing with this opinion, we stress that the Big Five, based on the human manifestations reflected in the language, erases the differences between temperament and personality, mixing the qualitative differences between these levels of individuality.

M. Gerlach, B. Farb, W. Revelle and L. Amaral, combining an alternative computational approach to clustering with available large data sets comprising the responses of hundreds of thousands of users of web-based questionnaires (International Personality Item Pool implementation of the NEO-PI-R8), found reliable evidence of the existence of at least four different personality types. Comparing more than 1.5 million participants, researchers stated that, “although the presented empirical evidence for the identified types is unambiguous, we still lack a theoretical understanding” [9] (p. 740).

We believe that the theoretical and empirical development of a typology should answer the question about the mechanisms of type formation. In contrast to the ideology of the “Big Five”, our appeal to the typology of individuality is due to the fact that individuality is determined from three sides: from biology, from the environment and from the activity of man himself [10]. Therefore, the typology of individuality cannot be reduced to temperament types or personality types, since reflects the effect of the interaction of factors, multi-level properties of individuality.

This study focuses on the empirical identification of types of individuality and the description of their behavioral manifestations.

Materials and Methods

Procedure

The collection of empirical data has been organized in accordance with generally accepted ethical standards. Participants were 1100 volunteers aged 19–35 (M = 23,74; SD = 5,39; 73% female). They filled out test notebooks in a large auditorium after classes. Testing was anonymous. Researchers helped participants if the questions arose. The average test time was 120 minutes.

Participants

The focus was on the widest possible audience to reflect more fully the population. Young people from different cities of Russia (Kostroma, Moscow, Perm, and Taganrog) and different specialties (teachers, engineers, customs officers, salespeople, physicians, designers, journalists, psychologists, managers, historians, linguists, programmers, etc.) took part in the study.

Measures

We used a set of methods for assessing the multi-level properties of individuality:

Temperament Properties (Ergonicity, Tempo, Plasticity, Emotionality, and Activity in Motor, Intellectual or Social spheres; General Activity and Adaptability) were measured with the help of shortened version of the Structure Temperament Questionnaire (STQ-S) [11]. Cronbach's Alpha for all the scales ranged from 0.55 to 0.84.

The *Fundamental Personality Dimensions* (Psychoticism/Soft-heartedness, Extraversion/Introversion, Neuroticism/Emotional stability) were evaluated with the help of Russian modified, validated, and shortened version of Eysenck PEN-questionnaire [12]. Cronbach's Alpha varied from 0.72 to 0.87 for the scales.

Character Traits scored with shortened version of the questionnaire that covered Hyperthymicity, Stuckness, Emotivity, Pedanticity, Anxiety, Cyclothymicity, Demonstrativeness, Excitability, Dystimicity, and Exalitveness [4]. Cronbach's Alpha varied around 0.6 – 0.91 for different scales.

Achievement Motivation, *Accessibility Motivation*, and *Value Motivation* were estimated with the help of Motivation Questionnaire [4]. The checking reliability revealed the high level of internal consistency of the scales: Cronbach's Alpha varied around 0.6 – 0.9.

The *Cognitive Styles* (Field Dependence/Field Independence, Narrow/Wide Range of Equivalence, Flexibility/Rigidity of Cognitive Control, Impulsivity/Reflectivity, Concrete/Abstract Conceptualization, Tolerance/Intolerance of Unrealistic Experience) were estimated with the help of the Cognitive Personality Styles Questionnaire (CPS-Q) [13]. Cronbach's Alpha for the scales was more than 0.60.

Intelligence (IQ level) was evaluated based on the indicators of speed and precision of solving simple logical problems (LOGOP) [14]. The checking reliability revealed the high level of internal consistency of the scale. Cronbach's Alpha was 0.90.

Hardiness was measured with the help of Russian adapted version of the Hardiness Survey [15] in adaptation by D.A. Leontiev, E.I. Rasskazova [16]. Cronbach's Alpha for the scales Commitment, Control, and Challenge was respectively 0.65, 0.79, and 0.79.

Spiritual Personality Traits were estimated with the help of the Spiritual Personality Inventory [17]. Cronbach's Alpha for the scales (Spiritual Virtues, Positive Outlook on Life, Spiritual Discipline, Goodness, Spiritual Service, and Moral Rectitude) ranged from 0.52 to 0.72.

Meaning in Life was evaluated with the help of Russian modified, validated version of Purpose-in-Life Test [18] by D.A. Leontiev [19]. Cronbach's Alpha for scales Purpose in Life, Life Process, Life Performance, Locus of Control "I", and Locus of Control "Life" was respectively 0.82; 0.77, 0.73, 0.63, and 0.67.

Axiological Orientation, namely, the orientation of a person towards such values as Collectivity, Spiritual Satisfaction, Creativity, Life, Achievement, Tradition, Material Well-being, Individuality, Profession, Education, Family, Social Life, and Leisure were studied using the of the Axiological Orientation Survey [20]. Cronbach's Alpha varied from 0.58 to 0.82 for the scales.

Ways of Coping such as Seeking Social Support, Focus on Solving Problems, Working Hard and Achieve, Worry, Invest in Close Friends, Seek to Belong, Wishful thinking, Not Coping, Tension Reduction, Social Action, Ignore the Problem, Self-Blame, Keep to Self, Seek Spiritual Support, Focusing on the Positive, Seek Professional Help, Physical Recreation were estimated based on Ways of Coping Questionnaire (WCQ) [21]. WCQ was validated for Russians by T.L. Kryukova [22]. Cronbach's Alpha varied around 0.43 – 0,82 for different scales.

Thus, the total list for statistical treatments included 94 indexes, of which 81 indicators were primary, non-aggregated variables. We used primary variables in the statistical processing.

Statistical Methods

We used Stat Soft Statistica v.10 and the R programming language environment (NbClust package) for statistical processing of the data. Principal Component Analysis (PCA) was used (Varimax rotation) to reduce the dimension of the primary variables. The number of factors was determined by the Scree plot. Hierarchical cluster analysis (Ward's method, Euclidean distances) was carried out based on the reduced variables. We revealed the number of clusters using the NbClust package, which allowed us to determine the optimal number of clusters based on an analysis of 30 criteria. Comparison of

mean values of primary variables in the identified groups was carried out using ANOVA (Scheffe post hoc test).

The results of analyzes with an excessively large amount of information were presented in the Supplementary materials.

Results

Factor structure of Individuality

Theoretically, we assumed that there could be no less than three Factors with certain common mental mechanisms of behavior regulation or types of generality of individuality properties, which probably based on (a) Extraversion, Neuroticism, and Psychoticism or (b) such temperament traits as Motor Activity, Intellectual Activity, and Social Activity.

Descriptive Statistics (KMO = 0.912; Bartlett sphericity values = 49126.538; df = 3240; $p < 0.001$) showed that we have sufficient grounds for applying Factor Analysis.

Principal component analysis allowed us to reduce 81 variables into four main components (Figure 1.), cumulatively explaining 38.4% of the variance of the primary scales. Percentage of explained variance for each factor was 11.8, 10.9, 9.6, and 6.4, respectively.

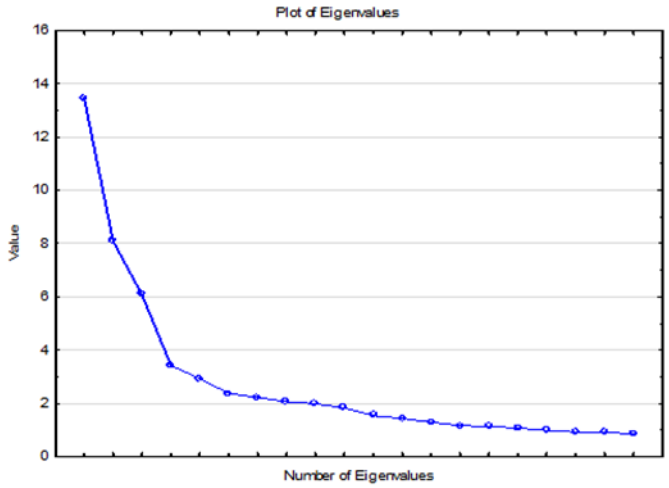


Figure 1. Cattell's scree test.

The first significant factor covered Psychoticism (-0.499);

- Purpose in Life (0.424), Locus of Control "I" (0.436), Locus of Control "Life" (0.417), Life Process (0.411), and Life Performance (0.408);
- Values of Achievement (0,829), Spiritual Satisfaction (0.824), Life (0.794), Collectivity (0.733), Individuality (0,684), Creativity (0.653), Material Well-being (0.646), and Tradition (0.616);
- Spiritual Virtues (0.550), Moral Rectitude (0.521), Spiritual Service (0.472), and Positive Outlook on Life (0.446);
- Working Hard and Achieve (0.591), Focus on Solving Problems (0.589).

This Factor appears to reflect such integrative dimension as Wisdom of man.

The second factor included both fundamental personality dimension Neuroticism (0.734) and temperament property such as Emotionality in Social (0.575), Intellectual (0.510), and Motor (0.404) Spheres;

- Cyclothymicity (0.638), Exalitvenesswere (0.599), Dystimicity (0.529), Stuckness (0.522), Emotivity (0.482), and Anxiety (0.472);
- Field dependence (0.459), Concrete Conceptualization (0.411), and Rigidity of Cognitive Control (0.410);
- Control (-0.667), Commitment (-0.643), and Challenge (-0.569);
- Life Performance (-0.524), Life Process (-0.517), Purpose in Life (-0.447), Locus of Control "Life" (-0.446), and Locus of Control "I"(-0.441);

- Not Coping (0.603), Self-Blame (0.559), Wishful thinking (0.522), Tension Reduction (0.504), and Worry (0.461).

Apparently, the second factors covered different aspect manifestations of the mood. We named this factor as an Integrative Emotionality dimension.

The third factor contained personality dimension Extraversion (0.481) and temperament property such as Ergonicity in Intellectual (0.579) sphere, Tempo in Intellectual (0.601) and Motor (0.416) spheres, Plasticity in Intellectual (0.508) and Social (0.422) spheres;

- Hyperthymicity (0,526) and Demonstrativeness (0.434);
- Achievement motivation (0.717) and Accessibility motivation (0.485);
- Abstract Conceptualization (0.662), Field independence (0.647), Flexibility of Cognitive Control (0.612), Tolerance of Unrealistic Experience (0.526), Reflectivity (0.504), Wide Range of Equivalence (0.460), and Impulsivity (0.433);
- Control (0.438).

Obviously, the third factor united the various attributes of productive activity. We called this combination of variables as an Activity Power dimension.

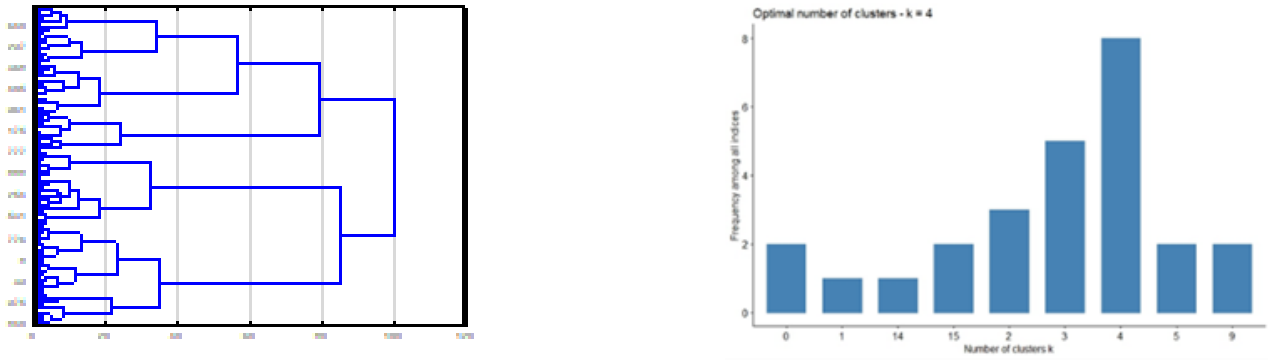
The fourth factor covered personality dimension Extraversion (0.655) and temperament property such as Ergonicity (0.664), Plasticity (0.522), and Tempo (0.508) in Social sphere;

- Hyperthymicity (0.507) and Demonstrativeness (0.499);
- Invest in Close Friends (0.664), Seek to Belong (0.561), Seeking Social Support (0.424), and Social Action (0.407).

Evidently, the fourth factor reflected the different aspects of the need for social contacts. We named this combination of variables as the Integrative dimension of Sociability.

Types of Individuality

Hierarchical cluster analysis allowed us to identify four groups of respondents who differ in the manifestations of the above-described integrative variables: Wisdom, Emotionality, Activity, and Sociability. The choice of four clusters for further analysis was due studying the indices that determine the optimal number of groups in cluster analysis. The method was implemented in the NbClust package for R (Figure 2).



(a) (b)

Figure 2. Results of the hierarchical cluster analysis: (**a**) Dendrogram; (**b**) Determination of the optimal number of clusters.

The significance of differences of indicators between the respondents of the four groups was confirmed based on multivariate ANOVA (Table 1).

Table 1. The results of the multivariate ANOVA (Scheffe post hoc test).

Effect	F	P	η^2
Intercept	141.54	<0.001	0.93
Clusters	12.79	<0.001	0.54

Note. η^2 - partial eta-squared, degrees of freedom for effect = 264, degrees of freedom for residual = 2910.

Discussion

The existence of personality types is one of the most extremely controversial issues. It is now widely believed that there are about five major personality domains that describe the psychological profile of a man [24]. However, M. Gerlach, B. Farb, W. Revelle, and L. Amaral based on a robust data-driven approach revealed four personality types across four large data sets [9]. Despite the fact that different methods were used, the data obtained in the present paper to a certain extent confirmed the existence of four personality types. We called these complexes of individuality traits as "Ordinary Man", "Spiritual Man", "Man of Mood" and "Man of Action".

We think that each complex is likely to have its own behavioral manifestations:

(1) "*Ordinary man*" is psychotic, emotionally unstable, with a low level of meaningfulness of life, spirituality, family and profession values, low intelligence. He does not aspire to anything (low rates of Achievement Motivation and choice of professional activity), but has a high need for communication (Social Activity) and heightened sensitivity to any critical remarks. He is field-dependent, intolerant and rigid. In difficult life situations, he resorted to coping "Social Activities", "Ignore the Problem", and "Seek Professional Help".

(2) "*Spiritual Man*" is distinguished by a high level of hardiness, meaningfulness of life, spiritual abilities. Facing a difficult life situation, he is focused on problem solving and productive work. "Spiritual Man" is an introvert, distinguished by high intelligence, and emotional stability. He is kind-hearted. He relies on his inner experience and easily withstands the influence of other people (Field Independence). He is able to "grasp" the essence of the problem or phenomenon (Abstract Conceptualization). Such a person is open to new experience (Tolerance) and easily switches from one cognitive function to another (Flexibility of Cognitive Control).

(3) "*Man of Mood*" is an introverted, emotionally unstable, and anxious, with mood swings for no apparent reason, focused on the dark and sad sides of his own life. He is characterized by low activity, hardiness, spirituality and meaningfulness of life. He does not strive for achievements, but the subjective significance of professional activity, family values, material well-being and spiritual satisfaction are important for him. He is field-dependent and resorts to coping "Self-blame" and "Keep to Self".

(4) "*Man of Action*" is extraverted, sociable, initiative, possessing an even mood and able to get along well with other people. He has a high achievement motivation and availability of professional activities motivation, a high level of meaningfulness of life, spiritual capacity and hardiness. He has a wide repertoire of coping (excluding "Keep to Self"). He is tolerant, has a high sensitivity to details.

Statistically the "Big Five" and "multi-level individuality" studies using PCA (EFA) seem similar; they methodologically differ greatly in their understanding of the qualitative differences in the multi-level properties of individuality.

We do not know yet about the mechanisms of type formation, and how they form complexes with these or other personality traits. If we try to examine the types through the prism of adaptation to enviroment, quite possibly, we can reveal that the "cores" of the types, which perform the function of regulating behavior, will be located at different levels of the individuality. Probably, the second type has a strong value-and-meaningful regulation. Undoubtedly, all these problems need further research.

Limitations: Several limitations of this study need to be recognized. First, the results obtained cannot be extrapolated to a population that falls outside the specified age range. Second, the study involved mostly Russian-speaking students, so it cannot be argued that the identified features are inherent in the population as a whole. In this regard, it would be interesting to study the stability of the identified types in different ages and through different cultures.

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Supplementary Materials: The following are available on the journal website, Table S1. The Results of a Principal Component Analysis of the Multi-Level Properties of Individuality; Table S2. Mean for 4 selected groups (T-scores).

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BOOK REVIEW

Sergienko E. A., Ulanova A. Yu., Lebedeva E. I. Theory of Mind: Structure and Dynamics. M.: Publishing House "Institute of Psychology RAS", 2020.

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Abstract. The monograph presents the current state of the study of Theory of mind and the original experimental work of the authors aimed at studying the understanding of mental states throughout human ontogenesis, including adult and old age. New aspects in the study of the theory of mind are discussed: its evolutionary precursor, early forms of this ability, expansion of research at the later stages of ontogenesis. The problems of the architecture of Theory of mind, the correlation of implicit and explicit models, cognitive and affective components, the nature of understanding mental states and the prospects for the development of this direction are analyzed.

Keywords: Theory of Mind, architecture, dynamics, understanding of mental states, ontogenesis, evolution, early development, childhood, adulthood and the elderly

The publishing house of the Institute of Psychology of the Russian Academy of Sciences has published a book by E.A. Sergienko, A.Yu. Ulanova, E.I. Lebedeva "Theory of mind: Structure and Dynamics". Theory of mind is as an understanding of own mental states (knowledge, intentions, desires, emotions, beliefs, etc.) and mental states of other people.

The monograph covers the history of the origin of the construct, the main approaches to the theory of mind, the results of contemporary research and original experimental research by the authors. The authors presented a holistic panorama of the theory of mind problem, covering such stages of human ontogenesis as preschool, primary school, adolescence, adult and old age.

Theory of mind is considered by the authors as one of the areas of cognitive psychology. At the same time, from their point of view, the status of this phenomenon has a pronounced specificity.

First, the research in this case is focused on the subjective mental states of a person, which allows us to talk about the belonging of theory of mind to the post-nonclassical type of scientific research. Second, the analysis of theory of mind involves the intersection of cognitive psychology with social psychology, psycholinguistics, developmental psychology, and neurosciences. Third, the phenomenon of theory of mind can be viewed as a cognitive structure, as a research paradigm, and as a theory of development

Fourthly, the theory of mind is considered as the basis of social cognition, because the understanding and recognition of mental states are studied in the context of social interaction.

Fifth, theory of mind is studied within the framework of the author's hypothesis about its

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level development and the existence of various types of mental models. All of these aspects of the problem are presented in chapters 1-3.

This monograph proposes a fundamentally new interpretation of the theory of mind as a form of conceptualization of the inner world of a person. The phenomenology of theory of mind is presented, according to the authors, in a wide range of manifestations, such as following the gaze of another person, understanding perspective, mindreading, understanding intentions and false belief, the idea of deception, etc.

Chapter 2 provides a variety of empirical data on specific aspects of theory of mind in preschool age. In particular, it describes the understanding of the false belief, the distinction between the apparent and the real, the assessment of perspectives, the understanding of desires, preferences and emotions, the specifics of the perception of advertising by preschoolers. Chapter 3 provides an empirical evidence in favor of the interpretation of theory of mind as the mental basis of the communicative success of children. Undoubtedly, a new line is the study of the narrative abilities of children at different levels of theory of mind's development, as well as the study of children's drawing and play in the context of the peculiarities of theory of mind in preschool age.

Chapter 5 provides the features of the development of theory of mind in children of primary school and adolescence, including the understanding of emotions and the development of mental vocabulary. Of particular interest are the sections devoted to the study of factors development of theory of mind (family, language development, cultural factors). An analysis of the consequences of the development of theory of mind in adolescence (in the form of an increase of social competence, as well as manifestations of bullying and aggressive behavior) is of undoubted theoretical and practical interest.

Empirical data regarding the development of theory of mind during adulthood (in particular, understanding of deception and the ability to manipulate other people), as well as in old age (changes of theory of mind during aging, associated with changes in its cognitive and emotional components) are analyzed in Chapters 6 and 7.

This collective monograph, dedicated to a new and so far, insufficiently studied phenomenon under the collective term "theory of mind", while undoubtedly being a large-scale and innovative work, allows us to raise some debatable questions.

First of all, the question arises whether or not theory of mind is found already in animals (starting with the birds up to the primates) and in children during the neonatal period (first 28 days) and infancy (from 1 month to 1 year). According to the authors, the ability to understand mental states can be performed on an unconscious level, starting to develop long before the development of speech and arbitrariness (executive functions?). Consequently, the ability to understand the social world cannot be attributed to the conscious level, and it is inherent in both animals and infants. This position is, in a sense, contradictory.

On the one hand, the ability to build a mental model of one's own state and the state of another person (in fact, solving the problem of dividing one's mental world with the mental world of another person) is inextricably linked with the development of symbolic functions and the simplest forms of reflection, including self-awareness. It is no coincidence that the authors study the formation of symbolic functions in preschool age as the basis for the development of theory of mind in their studies, and from the age of 3-4 years. On the other hand, it is hardly possible to talk about the presence of symbolic functions and, moreover, self-consciousness in animals (the exception, perhaps, are the higher primates, capable of the simplest forms of symbolic activity) and babies up to one year old. Similar is not always identical. For example, intelligence-like forms of behavior in animals and intelligence itself are phenomena that are different in their mechanisms. Perhaps one should distinguish between "reading of behavior" (as an earlier evolutionary biological phenomenon) versus "mindreading" (as a later socio-symbolic phenomenon).

Narrowing the scope of the concept "theory of mind" will make it possible to more clearly describe the mechanisms of this phenomenon, linking them with the formation of semiotic abilities. The latter determine the skills of using speech and constructing mental images as prerequisites for self-awareness As the authors note, it is not surprising that recognition of oneself in the mirror, as one of the basic indicators of the development of self-awareness, occurs only about 18 months, when the child has already mastered language communication and

in his development has reached the stage of symbolic intelligence (in the form of the ability to distinguish between the designation and the designated and, therefore, perform substitution actions a real object by a sign or by any other object).

In conclusion, it should be said that the problem of Theory of mind posed in the monograph and the systematized base of empirical data on this research topic will be of interest to a wide range of specialists in the field of cognitive, social, educational psychology, as well as developmental psychology and personality psychology.

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MEETING ABSTRACT

Human Abilities and Mental Resources in the World of Global Changes

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Abstract. The conference was held on November 30-31 in Moscow. Hosted by the Institute of Psychology, Russian Academy of Sciences, it passed in mixed format including offline and online presentations via Zoom. Among the conference's topics were: human abilities and mental resources and their development; variants of life in post-traumatic stress disorder and coping ability; digital technologies in psychodiagnostics; professional, spiritual, chemical abilities; modelling cognitive and communicative processes; the youth startup "Cognitive science and virtual reality" etc. The conference proceedings (in Russian with English abstracts) are available on the conference website: http://druzhinin.ipran.ru/

Keywords: Druzhinin conference, psychology of abilities, mental resources, Institute of Psychology, Russian Academy of Sciences

The conference is hosted by the Institute of Psychology, Russian Academy of Sciences on a quinquennial basis since 2005. This year was marked by the grown interest from the academic community stimulated by focusing on poignant topics revealed by COVID-19 pandemic. There were about 200 presentations of different form carefully selected while the number of applications for the conference exceeded 250. Besides Russian authors there were 12 contributions from Armenia, Belarus, Israel and Ukraine.

Director of the Institute of Psychology, member of the Russian Academy of Sciences, Dr D.V. Ushakov inaugurated the conference; then three keynote lectures took place. Member of Russian Academy of Education, Dr V.D. Shadrikov presented his view on the explanation in psychology; corresponding member of Russian Academy of Education, Dr A.V. Karpov drew a resource perspective on metacognitive determinants of personality's professional destructions; Dr M.A. Kholodnaya discussed theoretical and methodological implications of the psychological indicators' nonlinear nature for studies of mental resources.

The topicality of the main conference's focus is caused by urge for analysis of the state of affairs in psychology of human abilities and mental resources facing the digital transformation of ordinary people's existence as well as of entire domains of social life. Many of conference sections were also marked by socio-psychological challenges and mental health issues induced by pandemic restrictions and isolation, such as substitution of immediate social communications by its digital version and personal space deformation.

Thus, the phenomenology of difficult life situation experience is analysed in N.V. Tarabrina's perspective differentiating the everyday stress from the traumatic one. Researches show that the potential post-traumatic stress disorder as well as coping

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strategies depend largely on what Druzhinin have called "variants of life", term describing existential choice of individual life path.

Another concerned topic was the search of hardiness and resiliency resources by townspeople differing by living conditions. The urban environment may or may not provide such resources depending on where the respondent lives: in Moscow residents negative environmental factors are compensated by positive ones (good job, developed infrastructure, beautiful and comfortable living space etc.), they are proud of their city while young people from Siberian city of Surgut don't find it promising for further life and work.

Digitalisation of life also actualised many conference's topics, such as cognitive and social factors of respondents' interaction in reality and social media. Psychodiagnostics of abilities and mental resources has enriched by procedures and methods based on digital technologies. Intelligence research on macro level shows its important role in human capital and highlights the perspectives of AI technologies in education.

A heated debate unfolded over the scientific method issues in psychology. According to Dr A.V. Yurevitch scientific explication can be only reductionist one, assuming transition to another level of generalisation and thus transcendence of the studied system. While Dr V.A. Mazilov warns agains reduction of psychological to non-psychological, Dr Shadrikov points out that many scientific fields can have the same object, but approach it from different perspectives, thus combining their findings may be fruitful for the clarification of the issue's essence.

The great number of studies presented on the topic of general abilities was inspired by the work of Druzhinin who had opened many perspectives in the field. Just to cite examples, he had raised the intelligence and communication problem; proposed to divide mental properties into point, linear and multidimensional ones; coined the term "cognitive resource" defined as the number of elements that can be simultaneously presented in the person's mind. Numerous facts of splitting of indicators of intelligence and creativity give evidence in favour of their multidimensional models as more coherent to the phenomena's nature. Discussion between Dr Karpov, Dr Kholodnaya, Dr E.V. Volkova and Dr V.A. Tolochek pointed out the applicability of the equilibrium dynamic systems principle in psychology.

The topic of chemical abilities was first held in the framework of psychological conference, bringing together specialists in psychology, pedagogy, chemistry, genetics and medicine. The concept of sense of substance as the core chemical ability was vividly discussed as well as methods of its research. It has been demonstrated that specially organised educational environment is needed for the enrichment of individual experience of interaction with substances. Some findings presented on chemical abilities' genetic markers are inconsistent and need further investigation

Spiritual abilities studies presented at the conference gained attention as a new direction in scientific research. The psychological construct of spiritual abilities and their theoretical model was discussed as well as spiritual intelligence, spiritual personality, spiritual life, spirituality, wisdom, self-esteem, self-regulation, inner harmony, conscience, reflexion etc. Empirical studies were presented on spiritual and moral man's ideal, relationships of spiritual and moral qualities with empathy, self-regulation and personality's semantic sphere.

Modern approaches to modelling cognitive and communicative processes were also presented: to cite one example, an informational-Bayesian model of complex objects visual perception's language by V.M. Shendyapin. Amongst conference topics were also: general laws and individual variation of the formation and implementation of behaviour; analysis of history of abilities and giftedness research; development of mental resources and abilities in the modern socio-cultural context; professional abilities and personal professional self-realisation in modern organisation. The conference was hosted for the first time the youth startup "Cognitive science and virtual reality".

The conference proceedings (in Russian with English abstracts) were published in digital format and is available on the conference website: http://druzhinin.ipran.ru/

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Creativity in the Modern World

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Abstract. The Ponomarev conference was held on September 26 – 27 in Moscow (Institute of Psychology, Russian Academy of Sciences). The main idea of the conference is to create the foundation for interdisciplinary systemic research of creative process. Among the conference's topics were: prospects of computer modelling of creative process; the problem of the biological foundations of creativity and the dual cultural-biological determination of its evolution, etc. The general range of problems and the kinship of principled approaches to their solution allows us to look to the future with optimism and hope for the formation of united fundamental scientific approach to the study of creativity from mosaic theoretical models of creativity, the emergence of which was predicted by Y. A. Ponomarev. The conference proceedings (in Russian with English abstracts) are available on the conference website: http://ponomarev.ipran.ru/

Keywords: Ponomarev conference, interdisciplinary systemic research of creative process, Institute of Psychology, Russian Academy of Sciences

In the fall of 2020 (September 26 - 27), the Institute of Psychology of the Russian Academy of Sciences held one of the most unusual conferences in its history. The forum dedicated to the 100th anniversary of the birth of Yakov Aleksandrovich Ponomarev, one of the pioneers of creativity research, fell on the period of a pandemic and demanded from the organizers a non-trivial approach to its conduct. The format of the conference, despite the fact that it was initially dictated by difficult external conditions, in the end turned out to be successful for the implementation of the main meaningful idea: the organization of a dialogue among researchers of creativity working in various fields of science and locating in different parts of the world. The online format made it possible to implement a productive exchange of views on thematic platforms, and the videos posted on the conference website made it possible to get acquainted with all the events, which is very difficult in the framework of traditional conference formats, and to provide scientific communication that continued after the event. The main idea of the conference, as D. V. Ushakov noted in the opening speech, is to create the foundation for interdisciplinary systemic research of creative process.

The invited speakers discussed the current state and main trends in creativity research in different fields of science and different countries. Substantive overlaps in the reports of scientists who are far from each other in their subject areas were especially interesting. Thus, Michel Ollinger, a psychologist from Munich, and V. L. Dunin-Barkovsky, a physicist from Moscow, discussed in his reports the results and prospects of computer modeling of creative process.

Tod Lubart and A. G. Asmolov talked about the interaction between environment and person, the role of creativity in the interaction of person with environment and the formation of human psyche. Yu. I. Aleksandrov and Michael Woodley considered the problem of the biological foundations of creativity and the dual cultural-biological determination of its evolution.

The general range of problems and the kinship

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of principled approaches to their solution allows us to look to the future with optimism and hope for the formation of united fundamental scientific approach to the study of creativity from mosaic theoretical models, to the research of creativity from mosaic theoretical models, the emergence of which was predicted by Y. A. Ponomarev.

Many theoretical ideas of the participants came from Ya.A. Ponomarev theory of creativity mechanisms. In particular, the possible mechanisms of unconscious intuitive components of solving creative problems were considered. Special attention was paid to the key idea for this theory - the idea of a “by-product”. This idea suggests that one of the main mechanisms for a successful creative solution is a person's analysis of patterns found in the course of the solution that are not directly related to the problem being solved, which allows restructuring the representation of the problem and leads to an unexpected and instantly solution.

Along with fundamental scientific reports, the organizers provided for a series of master classes aimed at acquainted with the modern research tools. K. B. Zuev spoke about the prospects for using scientometrics as a tool that allows not only assessing the effectiveness of scientific activity, but also suitable for meaningful subject research. E.V. Pechenkova introduced the audience to the possibilities of using the method of functional magnetic resonance imaging in creativity research, and I.I. Ivancey discussed with the participants of his master class the prospects for using modern methods of data analysis (linear models with mixed effects).

The busy schedule included along with classical reports and interactive sessions, which involved discussion on the basis of materials presented in advance by the participants, made it possible to ensure productive work in all the declared thematic areas of the conference. The content of these areas was wide and varied: resources and potential of creativity, insight and problem solving, neurobiology of creativity, the problem of creativity in education, cognitive development and creativity, and others. The topics of the directions reflected the current state of creativity research and outlined the points of growth and integration of individual theoretical models and applied research in this area. A unique by-product of the conference was that the event did not end when it officially closed. The recording and materials of all reports can be found on the conference website (http://ponomarev.ipran.ru/), and discuss the presented material with the authors using e-mail addresses.

The conference proceedings were published in digital format and is available on the conference website: http://ponomarev.ipran.ru/

LEARNING FROM THE PAST

The "Learning from the past" section presents the works of Russian scholars that are inaccessible to English-speaking readers. The articles are not only of historical interest. The development of science is like a spiral, and the modern researcher can often learn a lot from the scientists of the past. The section opens with an article by B.F. Lomov.

Boris Fedorovich Lomov (1927 - 1989) was Russian psychologist, a founder and first director of the Institute of Psychology of the USSR Academy of Sciences, a popularizer of psychological science, a founder and first editor-in-chief of the Psychological Journal. The core of B.F. Lomov's systems approach is formed on the following six basic principles:

1. Mental phenomena should be perceived and analyzed from several aspects: as a qualitative unit, as an internal condition for the relationship and interaction of a subject with the environment, as a set of qualities acquired by an individual, and as a result of activities of the organism's microsystems. A holistic description of the mental phenomenon involves a combination of all of the above research paradigms.

2. Mental phenomena are multidimensional, and therefore they should be considered from different aspects and in different measurement systems.

3. The system of mental phenomena consists of many levels, the mind as a whole has cognitive, communicative, and regulatory dimensions, each of which is also differentiated into several levels.

4. The organization of human mental properties is like a pyramid. The main mental properties are at the top, the properties that underline them are at the bottom, and the facets represent different categories of mental properties.

5. The systems study of any mental phenomenon implies taking into account the multiplicity of its determinants: causal relationships, general and specific prerequisites for mental phenomena, mediating links, various external and internal factors. Depending on the conditions, the same determinants can act as prerequisites, an independent factor, or as a mediating link.

6. Mental phenomena should be studied in terms of their dynamics and development. Human life is a polysystems process. The mental development is emergence, is the formation and transformation of person's main traits and properties.

The systems approach was presented in a number of publications by B.F. Lomov. One of his last works "Systems Approach and the Problem of Determinism in Psychology" was published in the Psychological Journal in 1989. The article is republished with small abbreviations.

Systems Approach and the Problem of Determinism in Psychology

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Lomov B.F. Systems Approach and the Problem of Determinism in Psychology. Psikhologicheskii Zhurnal, 1989, 10(4), 19-33

Abstract. The current state of psychological science and the logic of its development led us to the need for new approaches in psychological research and to their synthesis based on systems principle. From these positions, the problems of the mental development of the individual are considered in the unity of his/her biological and social factors. The question of determinism in psychology is raised, the nonlinear nature of the determination of mental phenomena is stressed. The types of determinants in relation to the tasks of psychological research are highlighted, the problem of determinations is discussed. The possibilities of solving practical problems are analyzed, taking into account the potential of the systems approach in psychology.

Keywords: Systems Determination, Systems Approach, Types of Determinants, Scientific and Practical Methods.

In reascent years the logic of development of psychological science has led us to the need for new approaches in psychological research and to their synthesis based on systems principle. This, necessary, requires a rethinking of its problems, a new formulation of traditional problems, further development of the methodology and general theory of psychology. But at the beginning I should note the contradictions that objectively accumulated in it.

First. The contradiction between new problems, on the one hand, and the old approaches (old principles, general theoretical concepts and schemes, a system of specific scientific research and scientific-practical methods).

Second. Contradictions between different general theoretical concepts and the corresponding different schools. Studying the same or essentially similar phenomena, psychologists adhering to different schools describe and explain them in different ways.

For instance, adherents of the school of L.S. Vygotsky, A.N. Leontyev, A.R. Luria interpret the system of mental phenomena in the context of the conception of Cultural and Historical Development and the Psychological Theory of Activity. In the school of S.L. Rubinstein these phenomena are studied as a process based on the principle of the unity of consciousness and activity; in the school of D.N. Uznadze - in the context of the theory of attitudes, in the school of A.F. Lazursky & V.N. Myasishchev - in terms of the concept of psychological relations; in the school of B.G. Ananyev - in terms of the Comprehensive Theory of Man and his heterochronous development; in the school of B.M. Teplov - V. D. Nebylitsyn - in the context of the study of individuality and individual psychological differences. These approaches to the fundamental problems of psychology in the schools listed above are different. In particular, this refers to the problems of biological and social determinants in the human mental development, the relationship between the conscious and the unconscious in his/her behavior, to the interpretation of behavior, activity and social interaction (It should be noted, then, that some contradictions between

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different schools are only seeming).

Third. Contradictions between the internal logic of psychological science and the logic of its interrelationships with other sciences, or, in terms of Western science, between tendencies of internalism and externalism [4]. Obviously just like other sciences psychology has an internal logic of development; a change in problems under study, a change in approaches or paradigms, and the development of research methods obey this logic. But psychology cannot develop without close contacts with other sciences, both natural and social. The possibility of its formation as an independent science arose only when natural science and social science reached a certain level of development (psychophysics could not arise until physics reached a certain level, and social psychology could not emerge before the appearance of sociology). Psychology was formed and developed at the intersection of natural and social sciences. Taking a marginal (in this sense) position, it, as J. Piaget noted, is constantly being torn between physiology and sociology. The contradictions between internalist and externalist tendencies are especially clearly revealed when it comes to solving practical problems. In connection with the foregoing, the need for new approaches is maturing in psychology. In my opinion, many of the psychological problems posed by the present time (such as the dynamics and structure of social psychology, psychological stereotypes, prejudices, social illusions, psychological factors of radical economic reform, political reform, scientific and technological progress) can hardly be solved in the mainstream those approaches that have developed in previous years. One of the ways to overcome the noted above contradictions is the systems approach. The importance of new approaches was recognized in world psychology. At the XXIV International Congress of Psychology (Sydney,1988), various issues of methodology and general theory were widely discussed. The need was noted for the integration of psychological knowledge and the development of new theoretical concepts.

Discussions were held about the prospects of existing scientific schools, about the need to synthesize their achievements. It was emphasized, in particular, that such schools as Classical Behaviorism, Gestalt Psychology, Psychoanalysis, which played an important role in the development of psychology as a science, have already exhausted their heuristic possibilities a long time ago; the current Behaviorism, Humanistic Psychology and some other areas that have come to replace them also need critical rethinking. However, the main directions of research go outside the mainstream of these schools. The principal idea here is the creation of Integrating Psychology. Such a psychology would include the psychology of learning, psychology of motivation, personality psychology, and cognitive psychology [4].

Modern trends in Western psychology are based on different principles (or paradigms) compared to the classical schools. They are focused not so much on schools as on the subject areas of research and use achievements of different schools. For example, cognitive psychology can be viewed, in a certain sense, as a continuation of classical Experimental Psychology and Gestalt psychology. Its development was greatly influenced by the theories of J. Piaget (stages of cognitive development), J. Bruner (motivation aspects of perception, problems-solving strategies), W. Neisser (primary and secondary processes, cognitive schemes), J. Miller, E. Galanter and K. Pribram (plans and structure of behavior), P. Saugstad, K. Raaheim (convergent and divergent thinking); some ideas of S. Freud (memory, thinking, and imagination). As one can see, cognitive psychology is built on the basis of the synthesis of the achievements obtained in different schools; I can declare that this is a new type of scientific direction.

Attempts to synthesize the knowledge, accumulated in different schools, are also be observed in Russian psychology. I mean theoretical research aimed at identifying the relationship between the concepts of personality, activity and social interaction. On this basis, a tiered representation of human being as the subject was formed (K.A. Abulkhanova).

The desire to integrate psychological knowledge based on real problems rather than paradigmatic interests is, in my opinion, a promising trend, which corresponds to the inner need of psychological science.

What does the systems approach give or can give in this regard? I will not list its general provisions and principles; they are quite fully covered in the literature. I will only note the main thing: when studying this or that phenomenon, event, or process, one must consider it in several interrelated aspects:

- as a relatively independent unit possessing a qualitative certainty;
- as an element of some macrosystem in which

this phenomenon (event, process) must be included and the laws of which must be obey;
- as an integration of a number of microsystems that have their own specific patterns, which also manifest themselves in the phenomenon, event or process under study.

Any phenomenon has many dimensions; each of the above aspects reveals its specific dimensions. Hence, there is a need to clearly define the levels of what we are studying. Often discussions arising in psychology do not yield anything concrete because the disputing parties mean either different dimensions of the object in question, or different levels of its analysis. Another important consequence is that the systems approach requires the development of typology of the phenomena under study, since they inevitably act as multivariate. For instance, we are accustomed to the general formulation of the unity of consciousness and activity principle: consciousness is formed, develops and manifests itself in activity. But in reality, as K.A. Abulkhanova rightly notes: the relationships between them are diverse, from their almost complete coincidence to the contradiction between them. In other words, there are different types of relations between consciousness and activity, and they must to be studied. This also refers to problems of personality, social interaction and many others.

In general, the systems approach provides us a broader theoretical basis for the development of ever-changing problems of psychology, and thus it allows us to overcome the first of the indicated contradictions. It also allows us to resolve the contradictions not only between scientific schools, and between internalist and externalist tendencies in the psychological science. In fact, when it comes to the individual psychological traits, it is very difficult to understand them, limiting oneselves only to what has been accumulated in psychology, or to explain them by the laws of mental development. Here we need to go to another type of analysis. We must consider person's life in macrosystems to which he/she belongs, and, therefore, turn to those sciences that study these macrosystems. First of all, I mean the social and biological systems to which man belongs.

Man (individual) is a member of society. He/she is included in the systems of social, economic, civil, ethical, national, family, political, and ideological relations. The entire system of social relations that characterizes a given society at a given historical epoch forms a macrosystem for an individual development. It constitutes an objective basis for the formation for person's life goals, he/her social needs and motivation sphere, value orientations and attitudes, he/her subjective relationships to reality. For instance, it is hardly possible to understand how such psychological traits are formed in a person, which are usually called "a sense of justice" or "a sense of duty" without an analysis of the system of moral and legal norms of a given society, or "a sense of boss" without an analysis of production and distribution relationships. In this regard, psychology should turn to sociology, ethics, economic, legal and other sciences that study society. At the same time, the problems of social interaction between people and their joint activities (or the relationship between the individual and society) acquire special importance in connection with the study of human life in society. Unfortunately, these problems have not been studied for many years in psychology, although they were raised long ago (in particular, in the Bekhterev' works). In recent years, these problems have been actively investigated by A.V. Belyaeva, A.L. Zhuravlev, V.N. Nosulenko, V.V. Rubtsov and others.

However, man also belongs to the biological system. Unfortunately, the issue of biological determinants of mental development has not received enough attention in Russian psychology. Moreover, any attempts to address them were declared biologization. If still some research was carried out in this direction, despite the ideological prohibition, they investigated only to one type of living matter organization: organism or even only one of the subsystems of organism, i.e. the brain. Meanwhile, the types of organization of living matter are diverse. According to V.I. Vernadsky, there are four fundamental types of organization of living matter: organismic, population-specific, biocenosis and biospheric.

I believe that in order to solve the problem of the relationship between biological and social determinants of the person's mental development, it is necessary to go beyond the framework of only the organismic type and to consider the person's development in the system of the listed types of living matter organization. This can substantially enrich our understanding of the mind and patterns of mental phenomena. True, this will require addressing such problems as the individual, the population and Homo sapiens, man and humanity, the psychological problems of human ecology, place and role of a men in the biosphere development, which sure greatly complicates the problem. But it is precisely by entering the field of macrosystem

laws, that we can ascertain the principal problems of psychological science in a new way, and substantially enrich our psychological knowledge.

Another research aspect is also important for the development of psychology, namely, the analysis of microsystems that underlie mental phenomena. Studies of the mind as an organized entity allow us to distinguish three main subsystems: cognitive, regulatory and communicative. In particular, the cognitive subsystem was studied most intensively: perceptual, mnemonic, and intellectual processes. Microgenetic (or actualgenetic) studies of perception, revealing its phasic nature, the relationship of its sensory and motor, as well as conscious and subconscious components, belong to this type of research. It also includes research on the different types of memory, the dynamics of thought process, mental states and other mental phenomena. This kind of research necessarily leads to the study of neuronal processes, which in relation to the mind can be considered as a microsystem. A further advance in this direction is the study of biophysical and biochemical processes underlying mental phenomena.

Thus, the systems approach organically links the “outputs” in the field of studying both macrosystems and microsystems. This makes it possible to include the problems of different scales in a single subject area of psychology, i.e., from the most complex mass phenomena to elementary material processes that underlie the mind as a special reality.

The systems approach, obviously, is not yet a theory. An approach is only an approach, a method of cognition in the philosophical sense of the word. The systems approach is, in essence, the implementation of the principles of materialistic dialectics in relation to a specific science. It opens up new possibilities for the development of both general and particular (special) psychological theories. It also allows us to order existing theories.

It should be noted that the "theoretical edifice" of psychological science is a complex multi-storey structure. It would be wrong to imagine the general theory of psychology as a set of ideas and principles located on the same level. We mean the macro-, meso- and micro-levels of the analysis of mental phenomena, and, accordingly, different levels of theoretical abstractions, generalizations, and syntheses. I consider the question of the structure of the "theoretical edifice of psychology" to be most important, requiring special research.

The core of the theory of any level is the knowledge of the objective laws of the phenomena to which it belongs (although, of course, the theory is not limited to one level alone; it includes many other levels). When it comes to the laws, the problem of the determination of the phenomena under study becomes central. How and why does this or that mental phenomenon arises? How and why does it develop? How and why does it disappear or does turn into something else? These are the principal issues of psychological research. The problem of determinism in psychology is one of the most fundamental.

Throughout its history, this problem has not gone off the stage. Previously, many researchers believed that the principle of determinism applies only to the natural sciences. As for the person spiritual life, it did not find application: here complete freedom dominates; spiritual life, including mental phenomena, is not subject to objective laws; it is supposedly a special world that is not connected with objective reality; human behavior is goal-directed, and therefore there is no need to objective determination.

In the history of sciences many antinomies such as "matter and spirit", "need and free will", "objective reality and subjectivity", "causality and goal-directedness" have arisen. These antinomies have not yet found the satisfactory solutions. And at present, the attempts are also undertaken to consider mental phenomena as so they do not obey the principle of determinism.

The first attack against indeterminism in the understanding of mental phenomena was done in the middle of the last century (I do not mean philosophy, in which such attacks began much earlier). Psychophysics was perhaps the first scientific discipline that tried to reveal the logical connections between external influences on the senses and the corresponding sensations. At the same time, psychophysiology began to develop by studying the relationship between the brain functioning and various mental phenomena.

Both these disciplines dealt with specific phenomena. In psychological science new issues erose that required access to broader interpretations of the mind determination. At the beginning of twenty century, the so-called classical behaviorism and reflexology emerged. Representatives of these directions tried to regard various acts of behavior as reactions to external influences. The stimulus-response formula became a general principle of causal (more precisely, deterministic) explanation of

behavior. It doesn't matter if we mean American behaviorism or Russian reflexology, or Pavlov's scientific school. Certainly, this was a serious step towards the establishment of the principle of determinism in psychology. But the psychology science has to pay a very high price, since such an approach required to exclude all the phenomena of the so-called subjective world from the general scheme of analysis, to eliminate them. They were declared unscientific. The formula "stimulus- response" expresses the linear (one-dimensional) determinism of the Laplace type, borrowed from classical mechanics.

The accumulated experimental data and the results of observations have been more and more demonstrating the limitations of the "stimulus-response" formula. The need arose to return to the so-called "subjective" concepts. New approaches began to appear: the so-called "Subjective Behaviorism", the Functional Systems Theory, and the Theory of Activity (in its various forms).

The formula, proposed by S. L. Rubinstein, according to which external causes act through internal conditions, has played and continues to play an important role in the development of a deterministic understanding of the mind and behavior. This was an important step in the development of the principle of determinism. Concepts such as goal, motive, perception, thinking, and others began to be included in the analysis of human behavior. A strong blow against linear determinism was struck by studies that showed that any influence of external stimulus on a person does not occur strictly and unambiguously, but only with a certain probability.

Psychology has entered a new round in the spiral of development of scientific knowledge. It has returned to its old problems, but on a new level. Naturally, the question arises of where do the purposes, motives, and internal schemes of behavior come from? Is the process of their formation and development natural? If so, how should one approach toward the laws of their formation and development?

I believe, it is impossible to reveal these laws if we regard the individual' behavior as something that exists in itself. It is necessary to take behavior in the broader context of social and natural systems to which the individual belongs, in which he/she is included. In other words, we should move to another level of analysis, to the macrosystem level. Such an analysis makes it possible to understand why a particular individual sets certain goals, why certain motives arise in him/her.

Psychology is also interested in the forms in which these goals and motives appear in a particular individual. These forms are different. For example, the goal can act as a perceptual image, as an image-representation, and as a "logical structure" (a system of judgments and inferences). In what form will the goal appear depends on the specific conditions in which the individual has to act, and what are his/her mental features.

Therefore, while investigating goal-setting, the psychologist cannot limit oneself to only macrosystem analysis. He/she should also turn to the processes of perception, memory, imagination, thinking, emotional processes on the basis of which the goal is formed, while bearing in mind different levels (especially conscious and subconscious), that is, the psychologist should also carry out a microanalysis of the goal-setting process.

All of the above leads to the conclusion about the need for a critical rethinking of the concepts of determinism that were formed in psychology at the dawn of its development and are still urgent today. For a long time, the linear concepts of determination prevailed in psychology. The scholars tried to present human (and animal) behavior as a direct, unidirectional chain of causes and effects: "cause - effect", "new cause - new effect", etc. The most striking example here is classical behaviorism. He played a certain progressive role in the psychology development, since it permitted the transition from general speculation to scientific research, from introspection to experiment, but at the same time it showed that this path is a dead end. First of all, because it does not give the possibility of a deterministic explanation of the mental phenomena that could arise in similar conditions. Any psychologists who have to conduct experimental (or generally empirical) research are often faced with the fact that, no matter how carefully they achieve identical conditions, the results may be different, often directly opposite. So, one and the same individual in seemingly identical conditions, but in different tests and at different moments, behaves differently.

When psychologists try to determine logical connections, they usually use statistics, averaging the data obtained. In doing so, results outside the overall range are often discarded, assuming this are random outliers or artifacts. However, the average values do not always really reveal essential and necessary connections. Sometimes, on the contrary, they may hide these

connections. And what is viewed as an artifact sometimes may express these connections more fully and may lead to a deeper understanding of the phenomena under study. It should be emphasized that different, including contradictory, data, consequences, effects can arise in similar or even identical situations.

The problem of explaining of the variety of consequences under the action of the same causes is fundamentally unsolvable in case of a linear approach. But it can be solved with the systems approach. The linear approach relies only on external causes. In psychology, the approach that ignores the importance of internal determinants of personality development is still widespread. In practice, this approach is realized in the assertion that any child can grow up to be an outstanding person in science or art, one just needs to organize the appropriate external influences. That is why genetics was banned because it stressed the importance of internal determinants in the individual's development.

From the point of view of the systems approach, the determination includes determinants of different types. Causal relations are central to this system. However, determination is not limited to causal relations only. It also includes external and internal factors, general and special prerequisites as well as mediators. Causal relations are most essential, necessary, and repetitive. The other determinants do not generate, do not cause events, effects, but are regarded as consequences. They affect these consequences, by accelerating or slowing down their occurrence, by strengthening or weakening them, changing them in one direction or another.

Consider the types of determinants the listed above.

Causal relationships. There are several important points to note here.

1. Usually, psychologists try to look for direct connections between causes and effects. Such attempts lead to illusions, to errors like "Post hoc ergo propter hoc". An event immediately preceding some other event is not always the actual cause of it. It should be emphasized that in real life the effect may not arise immediately after the cause, but after a while. Freud was the first who paid attention to this statement. Analyzing the reasons for certain behavioral features of his patients and their subjective world, he tried to trace their life path, as if by removing layer by layer of what had been accumulated during their life. In the long run, he found a real reason that had been hidden deeply in the history of the individual's life. When one investigates human behavior, one usually tries to find some single event that might be the cause. In real life, information about events is accumulated in the individual's memory and the consequence is as a result of many events. When this information reaches some critical mass, a consequence arises. In this sense, one can observe cumulative causes.

2. The most important role in the organization of human activity and behavior is played by the processes of anticipation. A person organizes his/her behavior, keeping in mind not only the past and the present, but also the future. In my studies which I conducted together with E.N. Surkov, showed that anticipation is included even in the organization of unconscious movements, such as postural reactions, locomotion, and others. G.K. Sereda and A.K. Osnitsky demonstrated that memorization and reproduction also depend on anticipation. One usually thinks of memory as referring only to in the terms of the past. But it is not so. The predictions that a person makes are certain guidelines for memorization.

3. A person, as is well known, has a very wide range of possibilities for self-regulation. And this aspect strongly affects on causal connections. As O.A. Konopkin has demonstrated that human being is capable of regulating many aspects of his/her activity and his/her resources; the final effect of the activity considerably depends on this. D. Kovacs experimentally showed that person self-regulation allows him/her to overcome external influences.

4. Self-regulation allows us to change our internal states. But in the process of behavior and activity, he/she changes the environment, thereby changing the external determinants of his/her own behavior. In connection with the above, one can consider self-determination as one of the most important components in general system of determinants. In the course of human evolution, the role of self-determination increases. The systems determination of human development is not limited to these connections, it also includes other types of determinants.

External factors. As is known, the beginning of experimental studies of sensory processes is associated with psychophysics, which clarified the regular connections between the value of external influences and the sensations corresponding to them. The basic psychophysics law was formulated and the

concept of subjective scales was developed. In classical psychophysical experiments, the subject interacts only with the signal that he/she must perceive and evaluate, that is, the relationship "object - subject" is analyzed here. A different approach was proposed in the Institute of Psychology of the Academy of Sciences. V.N. Nosulenko conducted comparative studies of subjective scaling in two situations: when the subject works alone (a classical psychophysics experiment) and when he/she interacts with another subject.

Experiments showed that there are noticeable differences between the assessment scales obtained during social interaction and the individual assessment of the same signals. The influence of social interaction is expressed, in particular, in an increase in the similarity of the scales of different subjects toward the end of the experimental series. It is assumed that the subjects form a certain “common module”, which enhances the accuracy of the evaluative scaling. The evaluation of these scales changes even when the subject refuses to taking into account the partner's assessments, nevertheless his/her value judgment changes against his/her will, i.e., subconsciously. Similar results were obtained in studies of other cognitive processes: perception, memory, imagination and thinking (V. A. Koltsova, G. M. Kuchinsky, A. M. Matyushkin, N. N. Obozov). Evidently, cognitive processes obey their own laws; some of them are unknown to us. Whether or not the interaction of the cognizing subject with other people will be included in the "cognitive situation" and in what forms, depends on the specific circumstances. In this sense, social interaction in relation to cognitive processes can be considered an external factor that can accelerate their course, can increase the accuracy of their results, reduce some their stages, and can act in the opposite direction. The direction of this factor depends on the specific circumstances (in particular, on the interpersonal relations of communicating people, on the levels of their cognitive development, etc.).

Internal factor. Here I mean such events or processes that are organically included in the phenomena under study and which are immanently inherent in them. In relation to cognitive processes, the set (attitude) is such an internal factor, which is productively studied in the school of D. N. Uznadze. As is known, the concept of set was formed on the basis of the study of perceptual illusions (illusion of volume, pressure force, illumination, mass, etc.). The general experimental scheme of the effects of set on perception is as follows: the subject is presented with two different objects (e.g., of different weight) several times in a row, then the objects are replaced by other similar objects of the same weight. The subject perceived two similar object as different. It means that illusion (set) takes place. D. N. Uznadze came to the conclusion: “... in the mind ... there is a factor/state ... that can ... be qualified as an extraconscious mental process that under these conditions has a decisive influence on the content of consciousness... The peculiarity of this state is that it precedes the appearance of certain facts of consciousness or precedes them ... It would be more correct to call this state the individual set " [3]. When such set is formed, it becomes a powerful internal factor influencing cognitive processes and, in general, all mental processes and acts of behavior. It should be emphasized that modern psychology has accumulated a huge mass of empirical data that show the effects of such internal factors as apperception, set, stereotype, cognitive scheme, psychological attitude to the processes of perception, memory, thinking, imagination, and the entire system of mental processes, and on behavior in general.

General and specific prerequisites. It goes without saying, that any event does not appear suddenly. It must be prepared by the development of all other events preceding it. If something does not reach a certain stage in its development, it is not mature, then no reason will cause the effect. A premise is a kind of readiness to perceive the action of the cause. This is a kind of “soil” on which certain events will grow. Perhaps most often the problem of premises is addressed in the study of abilities. In the history of psychology (and perhaps science as a whole), discussions continue on the issue: where do abilities come from? Are they some natural properties of the individua, are they his/her innate quality? Are they acquired during life, or are they formed in activity? I believe that the approach of B.M. Teplov is most constructive. He believed that the abilities as individual’s psychological features, that allow him/her to quickly master certain types of activity, i.e., are formed during life. I would like to note that when psychologists consider the formation and development of abilities, they usually associated abilities with activity. And this is true, but this reveals only one side of the matter. The other is the interaction of the individual with the people around. In particular,

there is reason to believe that imitation is the most important factor in the formation and development of abilities. However, abilities are not formed at an empty place. The brain of a newborn and its body as a whole is not a blank board (tabula rasa) on which one can write whatever one wants. In this regard, Teplov proposed the concept of "makings". The makings are not yet a real ability, but only its prerequisite. Whether or not the makings will develop into an ability depends on the specific conditions of the individual's life. The relationship between makings and ability is ambiguous. Different abilities can develop on the basis of similar makings, and vice versa. I mean general prerequisites that are associated with the development of general human abilities and specific prerequisites that determine the originality of the abilities of each individual.

Other phenomena, related to the problem of prerequisites, are the properties of the nervous system that determine the formation of temperament, individual style of activity, and a number of other characteristics of human behavior and activity. At present they are regarded as formal-dynamic properties (V.M. Rusalov). When discussing the problem of the relationship between general and specific prerequisites, one inevitably comes to the problem of individuality, the uniqueness of each person. From the standpoint of linear determinism, this problem is, in principle, unsolvable. I maintain that only the concept of the systems determination makes it possible to get closer to its solution. The most difficult problem of psychology is to identify the general laws of human mental development and to reveal the specific regularities of their implementation in the individual's life.

Mediating links. The idea that behavioral acts include mediating links is not new (recall, for example, Tolman's concept of intermediate variables). Without going in the history of this idea in detail, I would like only to emphasize that mediating links are included in the determination of behavior, mental processes, and person's mental development. This idea was developed most fully and thoroughly in L.S. Vygotsky's school of Cultural & Historical Development. He demonstrated the role of signs and sign systems in the formation of so-called higher mental functions. As an example, one could cite the experimental studies of the development of memory in children carried out by A. N. Leontiev. The subjects were asked to memorize words and syllables. In some cases, direct memorization was required, while in others the subjects were proposed to use pictures as an auxiliary means of memorization. It would seem that the second task is more difficult than the first, since the subject is dealing here with a doubled number of objects. But experiments have shown that the results of direct and indirect memorization were fundamentally different. The data accumulated in the school of Cultural & Historical Development show that auxiliary means, being included in cognitive processes, change them qualitatively. Thus, mediating links become necessary elements of cognitive operations in the course of mental development.

Concluding the analysis of the problem of determination of mental phenomena from the standpoint of the systems approach, I would like to emphasize several points. First, when one investigates the mental laws, one must bear in mind different types of determinants; causes, external factors, internal factors, general and special prerequisites, and mediating links. Second, the set of these determinants forms a certain system. In this regard, one speaks of systems determination. Third, in the study of mental phenomena, any attempt to search only for a single determinant of this or that phenomenon is a dead-end. Any phenomenon is determined by a system of determinants. The relationship between determinants of different types is very dynamic and flexible. What acts in some conditions as a prerequisite (general or special), in other conditions can become a cause or factor (external or internal), a mediating link, and vice versa. The specific structure of the systems determination depends on specific circumstances. In my opinion, the concept of the systems determination allows us to approach towards to the solution of a number of fundamental problems of psychology, in a different way compared to traditional approaches.

Let us again return to the problem of biological and social determinants of mental phenomena and human behavioral acts. Sometimes the biological and the social are viewed as two successive parts of a single line of development. At the initial stages, the development of the individual is determined primarily by biological laws. Then social laws begin to "work". This position is most clearly expressed by V. Stern [2].

I believe that the concept of the systems determination makes it possible to overcome the

limitations of the concepts of the sequential change of biological and social or the concepts of two factors. In different circumstances and at different stages of mental development, biological and social determinants play different roles. In some specific situations, a particular social event is the cause of certain human actions; at the same time, its biological characteristics can act as a factor, prerequisite or mediating link. In other situations, the ratio of the determinants is different.

The second fundamental problem, closely related to the first, is the problem of human mental development (I mean, first of all, the problem of individuality). Most psychological studies try to find some single determinant that "acts" throughout the life of an individual, to present things as if person's development is determined from beginning to end by this "universal" determinant, to find, so to speak, "causa finalis." But from all what has been said above it follows that such an approach is hardly justifiably; at least now, at the modern stage of development of psychological science, it yields very little results. As was noted above, the relationships between different types of determinants are not rigid and unambiguous. They vary depending on the specific circumstances. In this regard, I mean **a change of determination** or a **changeable determination**. And this, in my opinion, is a very important statement arising from the essence of the systems approach. It allows us to put forward new approaches to the study of the laws of mental development. All the concepts available (or most of them) coincide. The individual's mental development includes certain stages (different authors use different terms: "phase", "period", "stage", "epoch", etc.). The essence of mental development can also be interpreted in different ways. It is possible to compare the classical theory of J. Piaget, the neo-Piaget theories of J. Pascual-Lyon, W. Fischer-M. Farrar, A. Demetriou-A. Euclid, R. Keyes and others, the concepts of B. G. Ananyev, A. N. Leontiev, D. B. Elkonin and find significant differences in their interpretations. But all these theories and concepts point to a more or less strict sequence of stages, each of which differs from the others, both qualitatively and quantitatively. I think that the transition from one stage to another is associated with a changeable determination. In essence, this idea can be traced in the concepts of B. G. Ananyev and D. B. Elkonin.

How and why does one stage transform into another? To this, perhaps, the main issue, in my opinion, it is impossible to give an answer if you follow the concept of linear determinism, i.e., if one tris to find some single universal determinant, or one universal reason. Hypothetically, the development picture can be presented as follows. When this or that stage comes to its end, a new situation arises. The developmental results achieved at this stage (for example, cognitive structures, knowledge and skills, value orientations, motives, etc.) are included in the system determination. They act as either internal factors, or prerequisites, or mediating links, that is, determinants for the next stage. At the same time, the forms of activity of a developing person, especially his/her social interaction, are broader: they include interactions with other people (for example, interaction "child - adult"); at the same time, the psychological relations among people also change consciously or unconsciously. The set of new circumstances creates a new situation: the systems determination changes, the determinants are recombined, and the possibility of a transition to a new stage appears. I think that the idea of changeable determination can clarify how and why a developing individual moves from one stage to another. The so-called critical periods in mental development are inherently associated with a change due to the systems determination. The first steps towards studying the change of determinants in ontogenesis was made in the studies of A.A. Mit'kin and E.A. Sergienko.

The same general theoretical scheme of the systems determination, which was discussed above, can also be applied in sociology and social psychology. The socio-psychological phenomena that arise in the course of development of social processes can play a different role as determinants of these processes. Very often, they act as a prerequisite of a particular social process. For example, public opinion and public sentiment are an integral part of the prerequisites for revolutionary changes in society.

Socio-psychological phenomena also act as an internal factor of social processes, accelerating or slowing them down. Thus, the prevailing attitudes, prejudices and social illusions have a strong influence on societal innovation processes. These phenomena also play the role of mediating links in social processes. The stereotypes of human behavior that emerge in the process of the formation and development of social relations give these relations a certain

stability. Finally, psychological phenomena act as the cause of social phenomena. A new idea, collective image, social mood can cause a particular social movement (for example, in the field of culture).

It seems to me that in the modern world, the role of social psychology as a phenomenon, as a necessary "component" of society's life is highly significant. A scientific analysis of the state and dynamics of social psychology in these conditions becomes extremely important. Social psychology has a complex structure; along with rational, logical, intellectual components, it also includes irrational components (prejudice, superstition, social illusions), image and emotional components. This is revealed especially clearly when one turns to the study of real-life events and try to understand the determining role of social psychology.

Thus, the problem of determinism in psychology has two inextricably linked sides. The first concerns the study of the determination of the mental phenomena, the second is dealing with the role of these phenomena in various real-life processes. The systems approach opens up new opportunities for their study. The application of the principles of the systems approach is important not only for solving theoretical problems facing psychology. They are of more importance for solving practical problems. I would like to note that one of the weakest links in our practical work is lack of practical tools, namely, the methods of diagnosis, forecasting of human behavior. And this is only possible if the methods are developed on the basis of knowledge of the laws of the mind. The psychological forecast of human behavior presupposes the development of definite methods of person assessment. I believe that the principles of the systems approach can be applied here too.

In my opinion, it is the systems methodology, which opposes all kinds of one-sidedness, simplified, linear schemes, opens up the broadest opportunities for creativity both in psychological theory and in practice.

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