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THE METHOD OF SCIENTIFIC MODELLING AND THE LIMITS OF ITS APPLICATION IN THE RESEARCH OF THE MIND

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Abstract. This article can be considered as an attempt to investigate the complex problem of the epistemic essence and typologization of models in science, as well as an attempt to determine the scope and boundaries of the modeling method in the research of the human psyche. The solutions to these issues led the author of the article to believe that the methodological analysis of the development of models in various sciences is far from complete and will continue in the coming years. The author connects the prospects of such an analysis with the logical clarification of a number of concepts and approaches related to the nature of models in science and the modeling method in general.

A separate part of the article is devoted to the genesis of the idea of modeling the functions of consciousness. In particular, in this context, the article analyzes behaviorism, the models of which do not meet the requirements of the principle of completeness. A special place is also given to the idea of computer modeling of consciousness and its justification in the form of functionalism in psychology. The spread of functionalism in the article is associated with the use of the concept of machine modeling of rational functions proposed by A. Turing and his followers. At the same time, the author of the article dwells on the critical analysis of functionalism from the standpoint of emergent naturalism of J. Searle. In this context, it is shown that the creation of effective computer programs in itself is not a sufficient basis for the absolutization of the functionalism approach. The main argument of this article is aimed at substantiating the fact that any attempt to create a strong AI cannot be successful, since the internal causal relationship between the human brain and its psyche remains unclear. Thus, the application of functionalism should be accompanied by an understanding of its scope and boundaries.

Key words: model in science, modeling method, machine modeling of consciousness functions, functionalism in psychology, artificial intelligence.

1. Modeling and models in science. The analysis of the content of numerous scientific and philosophical articles devoted to the method of modeling in science suggests that the term "model" (from Latin modulus – sample) in its modern use is quite polysemic. This ambiguity can be explained in two ways. On the one hand, the breadth and variety of subject areas in which the method of scientific modeling is used; on the other, the fact that scientists themselves, as a rule, do not deal with the problem of comparative analysis and classification of scientific models. These issues have traditionally been the area of interest of philosophers of science, who have been discussing the problems of models for at least a century. At the same time, there is no generally accepted classification of models today, which indicates differences in the understanding of their epistemic status (For example, Tolk 2015, p. 87–106).

A comparative analysis of various points of view on the nature of scientific models allows us to distinguish two dominant trends in them: (i) in some works the two–dimensionality of models is justified, (ii) in others, on the contrary, the property of their multidimensionality is revealed. In case (i), the ambivalent essence of models is revealed: that in such areas as physics, chemistry, engineering, etc., they are usually expressed in the form of various formulas and symbolic systems, which are essentially compact records of correlations identified between certain parameters of real objects. These types of two-dimensional mathematical models include stationary and non-stationary (independent and time-dependent), continuous and discrete, deterministic and stochastic, unambiguous or probabilistic, etc. models (For example, Кубланов 2004, p. 15). Among them, for example, a model of the general circulation of the atmosphere based on the Navier-Stokes equations; or – a model of the DNA double helix; or – models of the general equilibrium of markets, etc. Thus, it can be concluded that in the part of analytical works devoted to the study of the problem of the epistemic essence of models, they are mainly understood as compact symbolic (primarily mathematical) representations (imitations) of the revealed patterns in the behavior of objects in the real world (Forster, Myung 2000).

In the approach (ii) to the problem of the specificity of scientific models, the authors, on the contrary, point to their multidimensionality. For argumentation, references are made to numerous full–scale and technical models, of which there are many in the history of science, especially in natural science and engineering sciences. At the same time, multidimensional models include both living and inanimate objects of nature, including mice, rats and even stuffed animals in various museums, as well as various models of technical devices, including imitation games and children's toys. It is argued that research activities with such simulating objects allow us to represent patterns in the functioning of many complex real objects, such as, for example, objects of microbiology or human physiology. As a vivid illustration of one of these multidimensional scientific models, we can call an interactive three-dimensional atlas that displays the various stages of human embryo development from the moment of conception to two months. This model, developed by a group of Dutch scientists, was published in (de Bakker 2016).

As for the problem of typology of models in science, the analysis shows that their classification is carried out on different grounds, depending on how the authors understand the ontological and epistemological nature of objects and methods of their modeling. For example, the criterion of some classifications is the type of simulated objects (natural, technical, logical, pedagogical, atomic-molecular, etc.), for the development of others – technologies and their applications (mathematical, graphic, structural, functional, explanatory, test, heuristic, computer, economic-mathematical, statistical, etc.), for the third – mixed species – forming features (Bokulich 2003, p. 609–627). In this connection, of course, the question arises about the fundamental possibility of constructing a universal classification of models. As an answer to it, I think we can once again refer to the above argument. The main difficulty in explaining the differences in the classifications of models in science is that one has to mentally cover an extremely wide range of subject areas of their application. This circumstance is the basis for the assertion that the prospect of developing a "rigidly" coordinated typology of scientific models is unlikely. At the same time, there is no doubt that in accordance with the requirements of taxonomic and mereological logical divisions, existing classifications can be coordinated within an integrated system. This is an important perspective, since a comparative analysis of existing classifications shows that they are not always even logically consistent with each other (For example, Models in Science 2006, 2020).

The above considerations regarding the differences in classification and understanding of the ontological and epistemological essence of scientific models indicate that the methodological analysis of their development and use in various sciences will continue. Moreover, this analysis should not be considered as an end in itself, it is a methodological need: optimization of the modeling method according to various criteria is important for the further development of prospects for its application in scientific research, in particular, in the field of cognitive psychology and artificial intelligence. It seems that new modeling studies in science will be multi-subject, i.e. they will be aimed at finding different perspectives and aspects of the development and use of models. Among these aspects are: (i) methodological (study of the processes of model development in their correlations with the types of research problems and objects); (ii) semantic aspect (differentiation of semantic functions of the use of the concept "model" in different sciences); (iii) the ontological aspect, i.e. clear identification of denotations (real or imaginary) with which models in science relate; (iv) epistemological aspect (studies of how models used change perceptions and understanding of real subject situations); (v) systemic aspect (demonstrating how models are interfaced with various scientific theories and hypotheses).

2. The general structure and elements of the modeling process in science. Based on the results of the analysis of the content of discussions on the complex problem of scientific models, here, first of all, it is advisable to clarify a number of concepts related to their nature and the method of modeling in general. Let us assume that the need for models arises in any science, especially in those studies that are aimed at objects of reality that are inaccessible to their direct study. Models in science will be understood as a necessary resource for the indirect study of any objects that are not directly perceived, or such objects that cannot be accessed for ethical reasons. Objects of this kind are found both in the study of the physical world, for example, atmospheric conditions, the Earth's crust, underwater currents, micro- and mega-world phenomena, and in the study of animal and human organisms, their mental states, social and political situations, past events, etc.

Under the term "scientific modeling method" we will understand a set of principles (guidelines) implemented in the form of a sequence of stages of cognitive actions aimed at some classes of special (modeling) ***Oa*** objects that are selected (or invented) as similar in some respects to various sets of real ***Ob*** objects (originals, prototypes). ***Oa*** sets thus provide simulations of some ***Ob*** features; these features can be selected by researchers (***Rs***) in terms of essential properties, structures or elements of ***Ob***. As for the choice of ***Ob*** themselves, it is determined by the problems and goals of research.

Analyzing the use of the term "scientific modeling method" in the scientific literature, we note: usually this term is used in an expansive sense – as an indirect way of obtaining information, the interpretation of which gives knowledge of the object under study. For comparison: the meaning of the concept of "method" fixes a clearly formulated rule regulating a certain order of specific cognitive operations. Given this circumstance, it is important to keep in mind that modeling in the real practice of scientific research is not actually a method. In reality, the phrase "method of scientific modeling" refers to a research strategy that includes several stages of cognitive actions.

(1) The first stage of the process of creating models in science can be described as follows. Let some researcher (including a research team) ***Rs***, solving a scientific problem, plans cognitive actions with a set of ***Ob*** objects selected in accordance with the scientific problem being solved. Based on his initial knowledge of Z_i^0 about the set of ***Ob***, as well as by analyzing the results of various ***Tbg*** studies previously conducted by other authors, ***Rs*** can choose (or invent) some other set of ***Oa*** objects. This set is such that it is considered as analogous in a strictly defined relation (properties, elements or structures) to the set ***Ob***.

In order to establish such a correspondence (analogy) between the original ***Ob*** and ***Oa*** objects with different properties, connections, structural similarities, etc., ***Rs*** undertakes search actions, including using the analogy method and heuristic principles (Forbus et al. 2017). Success in finding (or inventing) ***Oa*** is recognized if ***Rs*** turns out to be able to formulate a fundamental model (idea) M_0, i.e. some hypothetical initial statements Z_{0i} about the set of ***Oa***, as well as statements X_i that reflect the relationship between ***Oa*** and ***Ob*** (Giere 2010, p. 269-281). From a logical point of view, this also means that from the initial hypothetical statements Z_{0i} about the set ***Ob*** and X_i are deduced (logically follow) the initial statements of Y_0i, which should be checked at the next stages of modeling and expressed in the form of ***Yi.*** Let's write it symbolically: $Z_{0i}x_i \vdash Y_0I \vdash Yi$. In this entry, the symbol $\vdash$ reads: "from statements … deduced …", or "… logically follows …". The totality of Z_{0i}, X_i and Y_0i determines the initial content of the principal model M_0, i.e. the hypothetical design of the future model ***M***. In general, M₀ expresses a complex system of relations and connections between ***Oa*** and ***Ob***, which allows, as a result of studying ***Oa***, to obtain new statements ***Yi***, the totality of which determines the content of ***M***. This content is further interpreted as statements by Z_i about the expected properties of ***Ob***. It can be said that following such a methodological principle legitimizes the use of the similarity principle as a methodological basis for determining the epistemic relations between the set of ***Oa*** and reality in the form of a set of ***Ob*** objects.

Since the function of modeling ***Oa*** objects in research is to perform the function of a substitute (representative) of the ***Ob*** class (original objects), ***Oa*** objects are necessary in cases where direct study of ***Ob*** is impossible, for example, due to their inaccessibility to direct perception. At the same time, since individual objects combined into sets of ***Ob*** can have a large number of different properties, when searching for or inventing ***Oa***, the following two circumstances must be taken into account. Firstly, from the point of view of research purposes, the set of ***Oa*** should reproduce all the essential properties of ***Ob***. This requirement – "***Oa*** must have all the essential features of ***Ob***" – is called the principle of completeness. Secondly, when searching for or inventing ***Oa***, it is also necessary to abstract from some properties of ***Ob***. Thus, the properties of the ***Oa*** object classes turn out to be, on the one hand, idealized due to the principle of completeness, and, on the other, simplified and approximate. Such ontological ambivalence of "analog objects" (i.e. ***Oa***) may lead to the fact that when studying ***Ob*** by modeling, one has to choose (or invent) several sets ($\boldsymbol{Oa_i}$). Accordingly, more than one model (i.e. m_i) can be developed.

(2) At the second stage, through the efforts of ***Rs***, in accordance with $\boldsymbol{M_0}$, cognitive actions with a set of ***Oa*** are realized (***Oa*** can also be reduced to an individual subject a). The ultimate goal of these actions is to gain knowledge, i.e. the true statements of $\boldsymbol{Z_i}$ about the ***Ob*** class. The research activities of the second stage are divided into two types: (1) obtaining statements – ***Yi*** models about ***Oa*** subjects; (2) transition by means of special rules of interpretation ***Yi*** to statements $\boldsymbol{Z_i}$. The rules of transition from ***Yi*** to $\boldsymbol{Z_i}$ are specially developed for each specific model study, which ensures the interpretation of ***Yi*** about the introduced objects of ***Oa***, and also allows you to obtain on their basis a set of statements of $\boldsymbol{Z_i}$ (knowledge) about the original objects of ***Ob***. Thus, the set of ***Oa*** at the second stage of the model study is studied as an independent class of objects; without them, scientific understanding and explanation of the corresponding class of ***Ob*** objects is impossible. A variety of methods are used as means of studying ***Oa***. In the most developed sciences, for example, "model" experiments occupy an important place in research of this kind. They have become widespread not only in the exact sciences, but also in experimental psychology (*Крылов 2010*). Such experiments can take various forms: often, for example, purposefully change the conditions of functioning of ***Oa***, and the ***Yi*** obtained in this case are compared and systematized.

(3) The third stage can be called analytical. It basically boils down to a comparative analysis of all new statements obtained in the course of research, ***Oa*** and their interpretation as a model ***M*** for the formation of knowledge about the original ***Ob***. Let's explain this: the whole set of statements is divided into three subsets: $\boldsymbol{X_i}$, $\boldsymbol{Y_i}$, $\boldsymbol{Z_i}$. Each of them displays the properties of ***Oa*** in its own way or is related to them. Thus, the specificity of the statements $\boldsymbol{X_i}$ is that they are descriptions of the similarities and differences of the properties of ***Oa*** in comparison with ***Ob***. Without $\boldsymbol{X_i}$, it is impossible at the first stage to determine the content of $\boldsymbol{M_0}$, i.e. the principal model of ***Ob*** and the choice of ***Oa***, nor the further interpretation of the ***Yi*** complex as a model of ***M*** for obtaining $\boldsymbol{Z_i}$ – knowledge about the set of ***Ob***. At the same time, $\boldsymbol{X_i}$ can display the identity of some properties of ***Oa*** and ***Ob***, or be a description of the similarity of their structural elements, or an expression of mathematical equations symbolically representing the functions of objects ***Oa*** and ***Ob***, or their similarity. Another set of statements – ***Yi*** – is not identical to $\boldsymbol{X_i}$ and is a description of the results of studying the set of ***Oa*** by various methods. Among these methods, for example, are observations, testing, experimentation, mathematical descriptions, etc. The analysis of ***Yi*** obtained as a result of cognitive actions with ***Oa***, as well as their interpretation, suggest a transition from ***Yi*** terms in the model ***M*** to terms forming statements $\boldsymbol{Z_i}$, i.e. to the expression of the knowledge obtained about ***Ob*** – o the class of originals (prototypes) modeled by the class ***Oa*** (where ***a*** are individual objects-models relative to individual objects ***b***).

The statements **Z_i**, as well as **Yi**, are not identical to **X_i**. When the previous stages of the model study are carried out successfully, **Z_i** are logically deduced from the conjunction of statements **$X_i \& Yi$** and determined by their interpretations. If the **Z_i** checks are successful, then it means that the choice (or invention) ***Oa*** and the development of the model ***M*** were adequate with respect to the studied set of ***Ob***; or, to put it another way: ***Ob*** is the original model of ***Oa***. In this case, the introduction into the structure of the theory of ***T*** of conjunctions of statements **$X_i \& Yi$** as various kinds of premises or conclusions (**$X_i \& Yi \rightarrow Z_i$**, etc.) provide the validity of **T**, which allows us to further construct various descriptions and explanations of the laws of the properties of the set Ob.

(4) The fourth stage is verification: it boils down to verifying the content of ***M***, i.e. to searching for confirmations of **Z_i**, since **M** is an imitation of ***Ob***. These model knowledge (***M***) only replaces as analogies some essential features of ***Ob***. This is necessary because if ***M*** were identical to the original, it would cease to be a model. In addition, if all the essential features of ***Ob***, when imitated in ***Oa***, would differ from the original, then ***M*** would also not be a model. Thus, in model studies, the study of some features of the simulated set of ***Ob*** objects is always carried out at the cost of refusing to study other aspects of the same set. The verification of **Z_i** leads to an adjustment of ***M*** taking into account those properties of ***Ob***, from which they were abstracted or idealized at the first stage when choosing (or inventing) ***Oa***. Shortcomings, ***M***, identified after the first cycle of ***Ob*** modeling, due to insufficient knowledge of its properties or errors in the development of ***Oa***, are usually corrected in subsequent modeling cycles.

3. The genesis of the idea of modeling the functions of consciousness. The history of science shows that models as a means of studying and understanding various real objects have been used by people since ancient times. At the same time, modeling has been used exclusively for studying nature and creating technology for at least 2,000 years. However, the growth of knowledge and scientific interest in new problem areas has led to attempts to model some functions of consciousness since the Renaissance. In this regard, it is important to note the work of the philosopher and logician Raimond Lull (1232/35-1315) “Great Art” (“Ars Magna”) (Yates 1954, p. 115-173). It was the first to express the concept of a mechanical model as a complex device (a “mechanical computer”) capable of simulating the functions of the mind. Moreover, the idea of the “Ars Magna” device included not only mechanical imitation of arithmetic operations, but also imitation of logical schemes of syllogistic reasoning. It remains to be regretted that R. Lull failed to fully implement this project “in hardware” due to the lack of skill of the mechanics of that time.

The category of logic machines similar to “Ars Magna”, although not so large-scale, can also include various computing devices created in the Late Renaissance, such as abacus (XV-XVI century.), slide rule (early XVII century.) and arithmometers. Examples of the creation of all these devices (especially “Ars Magna”) indicate that by the first half of the XVII century. in science, a primary interest in the imitation of intellectual functions had already been formed and the first experience of searching for ways of such imitation had accumulated. In this regard, we can talk about the genesis of the research ideal of creating artificial intelligence (AI). There is no doubt that the first tests of the realization of the AI ideal in the form of computational mechanical models played an important heuristic role in the further development of the modeling of consciousness functions and the methodology of scientific research. Thus, the history of science shows that the heuristic potential of “Ars Magna” was significant not only for Renaissance thinkers, but also for many great researchers in the field of logic and epistemology of later eras. Among them: M. Montaigne, B. Pascal, R. Descartes, G. Leibniz, I. Newton, etc. (For example, Steihaug 2020).

The direct connection of R. Lulli's ideas with the works of Blaise Pascal (1623-1662) and Gottfried Leibniz (1646-1716) is especially obvious. It was the ideas of R. Lulli that inspired B. Pascal, who designed a machine for performing arithmetic operations. Later, the concept of creating a mechanized model of inferences was theoretically developed by G. Leibniz in his work “On the Art of

Combinatorics”. It was on the basis of the principle of combinatorics that he created and improved his main technical invention: an adding machine that performed all 4 actions with multi-digit numbers. (Pascal's first arithmometer could only add and subtract) (Fidora, Sierra 2011, p. 36-38). The last and final version of the device was made in 1710, but G. Leibniz made a description of it already in 1673 at a meeting of the Royal Society of London. At the same time, he tried to combine his discoveries in the Analysis of Functions and in computer technology into a new integral science (Jones 2016, 56–87). Today we call it “Artificial Intelligence”.

Speaking about the first attempts to model some functions of the mind, it is important to note that for a long time they were developed exclusively as mechanical computing devices – a slide rule, an adding machine, calculating and solving mechanisms, etc. This fact indicates that the research ideal of theorists and inventors of mechanical calculating devices was to carry out simulations and to optimize exclusively the intellectual function of human consciousness with the help of technical devices. Interest in understanding and modeling other mental functions received an impulse of development only in the twentieth century.

4. Models of behaviorism. In the twentieth century, J. Watson and E. Thorndike proposed a new ideal for the scientific study of consciousness. They focused the research of a person's mental life on describing the facts of his behavior, which could be logically linked with an understanding of the functions of the human psyche. This ideal was important in the sense that it provided researchers of the psyche with an objective scientific approach. He was generally accepted by B.F. Skinner, but proposed a new strategy for a holistic understanding of the psyche through the use of a model that was previously known in physics as the “black box model”. This model was used to recreate the mechanism of functioning of any complex system, the internal structure of which is unknown. B.F. Skinner drew attention to the fact that the “black box” can be promising within the framework of the behaviorism approach to the study of the psyche. Influencing a person, or animals, for example, rats, from the outside, it is possible to record their responses. On this basis, it was proposed to build behavioral models that allow not only to explain the processes of the human psyche, but also to predict mental reactions to various situations. The established tradition of modeling the psyche has been called “psychology of the black box” (Skinner 2014, p. 46–90).

The advantage of the “black box psychology” model is that it provides for the study of a person without making any ontological commitments regarding the nature of the psyche itself. Such abstraction, as already noted above, is inevitable in the framework of any application of the modeling method in science, including in psychological research. Modeling in psychology necessarily involves simplifying the studied subject situations, which is due to the fact that neither emotions, nor will, nor thoughts are almost inaccessible for their objective study. Therefore, consciousness in the “black box models” is explained by searching for and describing correlations between stimuli on humans (or animals) and behavioral responses to these stimuli. Thus, in one of the versions of behaviorism – in the logical-linguistic behaviorism of Gilbert Ryle – only one subclass of mental states was analyzed – dispositional states, i.e. beliefs, intentions, motives and desires (Ryle 2009, p. 101-130, 137 – 174). From the point of view of Mr. Ryle, to be in a certain mental state means to be in a certain behavioral state or in a predisposition to such behavior (Ryle 2009, pp. 292-303). At the basis of such models, for example, in the G. Ryle model, explaining the mental phenomena of a person, there are statements about a person's response to stimuli from the external environment (S→R). Thus, behaviorist models of human mental states are certainly objective, but they are also limited, since many mental phenomena are out of the focus of research in them, access to which is possible only in the form of introspection.

5. Factor models of personality. Among the models developed in the field of psychology, a specific place is occupied by the so-called “factor models of personality”. They were mainly developed between the second half of the 1940s and the 1960s. The most famous of their two versions: “PEN

H. Eysenck" and "R. B. Cattell's 16-factor model". Each of these models was the result of an analysis of empirical ways of describing personality traits of many individuals (including on the basis of their self-descriptions). To construct the models, data from self-reports (answers to questionnaires, using predicate scales), data on the behavior of a relatively large number of participants studied, as well as expert assessments of external observers of the behavior of the subjects were used (Eysenck 1992, p. 667-673; Cattell 1984, p. 121–174).

The usual sample consisted of several hundred people; this was the case, for example, when developing the 16-factor model of R. B. Cattell. The processing of the received lists of words and phrases characterizing a person's personality traits was made out in the form of various questionnaires, which underwent a secondary check for the presence of these traits in the examined people. Then the generalization of the selected personality traits into factors was carried out by highlighting correlations with each other. At the end, with the help of sequential application of factor analysis, the number of generalized factors of the 2nd and 3rd order was brought to a small list (3, 5 and 16 factors, respectively 10).

Of course, the question arises about the objectivity of factor models of psychology and how they differ from models of physics or biology? It seems that this question can be answered as follows: They differ from models of physics or biology, as much as a person as an integral psychophysiological self differs from his physical, biological and mental components. At the same time, it is important to note that the development of factor models has largely determined what psychologists and philosophers now understand by the term "human personality".

6. The idea of computer modeling of consciousness. An analysis of the history of modeling the functions of consciousness suggests that functionalism occupies a particularly important place in it: today it is regarded by many as the main methodological approach in scientific psychology. Its origins should be connected, on the one hand, with the influence of behaviorism and factor models, and, on the other, with the success in using computing machines (computers) in modeling some functions of consciousness. Among these attempts, the most important are the works of the British mathematician Alan Turing (1912–1954).

In the early 30s of the twentieth century, while studying the prospects of using mathematical logic for practical purposes and reflecting on Godel's incompleteness theorem, he justified the possibility of replacing the universal formal arithmetic language with logical schemes of simple hypothetical devices in it. A. Turing in an article published in 1937 gave a fundamental description of the imaginary device of a logical machine: "We can compare a person calculating a real number with a machine that is capable of fulfilling only a finite number of conditions A_i and q_i, which will be called "m-configurations". The machine is equipped with a "ribbon" (analogous to paper) passing through it, and divided into sections (called "squares"), on each of which a "symbol l" can be applied. Write a number or letter instead of 0. It can also shift to the right and overwrite 1 with another digit or letter. Thus, by changing its m-configuration, the machine can effectively memorize some characters that it "saw" (scanned) earlier.» (Turing 1937, p. 231–232). In essence, in his article A. Turing talks about various schemes of formal calculations as actions. He showed that depending on the conditions and "configurations", it is possible to obtain their various models, which can be implemented in devices. Subsequently, these various models became known as "Turing machines".

A. Turing proved that any device capable of shuffling the simplest symbols according to the algorithm, for example, "0" and "1", can perform any mathematical calculations. Thus, the Turing machine is an imitation model of formal reasoning. It is capable of simulating logical schemes of thinking by means of numbers, the general essence of which can be expressed in the form of a fundamental formal logical scheme: if such and such input data ($\boldsymbol{A_i}$ and $\boldsymbol{q_i}$) are obtained, then such and such ($\boldsymbol{a_i \rightarrow a_i^l}$) state of the machine arises; or if the machine is in this ($\boldsymbol{a_i \rightarrow a^l_i}$) state, but no input data is received ($\boldsymbol{a_i \equiv 0}$), then it goes into a new state: $\boldsymbol{a_i^2 \rightarrow a_i^3}$, etc. This algorithm in the language of symbolic logic is displayed formulas implicative discourse: $\boldsymbol{a_i \rightarrow a_i^l \& a_i \models a_i^l}$; $\boldsymbol{a_i \equiv 1 \rightarrow a_i^l \equiv 1 \& \ a_i \equiv 1 \ \models a_i^l \equiv 1}$; $\boldsymbol{(a_i \equiv 0 \rightarrow a_i^2) \rightarrow a_i^3 \& a_i^3 \equiv 0 \ \models a_i^2 \equiv 0 \ldots}$ etc.

The device of the Turing machine is extremely simple. The complex of its elementary operations is much simpler than the very first computers. The Turing machine has two input channels (ai, qi) for information supply and three output channels (***ai+1***, ***qi+1***, ***Di+1***). Processing of information and issuing commands to record the sign and shift of the tape is performed by a logical device (***LD***).

Fig.1 Schematic diagram of the Turing machine device

If we approach the Turing machine from the point of view of the foundations of its schematic diagram from an epistemological point of view, the basis is the hypothesis that mental acts (processes) are special human states, which, on the one hand, depend on the effects on us ("at the entrance") of various sensory stimuli, and, on the other, – expressed in the form of intellectual reactions ("at the exit"). Thus, thought processes (states) are formally defined as cause-and-effect relationships between stimuli on a person and his reactions ("at the exit") to incoming information. This gives reason to call a person and his intellectual activity (in principle, any other organism or device) metaphorically "a system capable of processing information.» The order of the functions of any such system is recorded in the form of a computer program that simulates the variety of its states, depending on the stimuli "at the input". For example, utterances are functions of a person as a system processing information. At the same time, the machine model of thinking can, in principle, be implemented on various physical structures.

In 1936–1938, John von Neumann got acquainted with the ideas of A. Turing and continued the development of machine models of thinking. The last one wrote: "Turing showed that all machine computing is based on a very simple mechanism. Since the Turing machine (and, consequently, any computing machine) is able to determine the further course of action based on the results of previous operations, it is able to make decisions and model arbitrarily complex hierarchies of data (Neumann 2012). The works of J. von Neumann, as well as the ideas of the participants of the Dartmouth Summer Research Seminar on Artificial Intelligence (Dartmouth College, 1956) became the basis of a new field of research called "Artificial Intelligence" (AI). The basic thesis of AI adopted at the Dartmouth Seminar: "Every aspect of learning or any other property of intelligence can be described so accurately that that you can create a machine to simulate it.» He fully met the general goal of AI set at the seminar – to achieve machine intelligence (Solomonoff 1957, p. 56–62).

The results of the research of the computer systems theorist A. Turing, in particular, the famous article "Computing Machinery and Intelligence" written by him after the war, prepared for the philosophical magazine "Mind" in 1950, had a huge impact on the formation of the most influential tradition of the study of consciousness, called "functionalism". A. Turing demonstrated the logical possibility of "machine intelligence", i.e., a model that is understood as a device that simulates mental activity. A. Turing's strategy was confirmed by the results of the test, which later became known as the "Turing test". The test conditions were formulated as follows. (1) The states of a computer running a certain program are determined by checking the relationship between the input data (the question to which the correct answer must be found) and the output data (the correct answer). (2) If the machine manages to find the answers to the questions correctly and it is impossible to distinguish the answers of a person from the answers of a computer, then it is recognized that the machine passed the test successfully.

7. Functionalism as a methodology for modeling the psyche. Functionalism is a research approach that has been recognized since the 60s of the twentieth century as a scientific methodology for the study of the psyche. The spread of functionalism, firstly, was due to the fact that it overcame the lack of behaviorism, which is characterized only by the analysis of the behavior and dispositions of people (or animals) as reactions to stimuli from various environmental factors. Secondly, as already noted, the experience of using the concept of machine modeling of rational functions proposed by A. Turing and his followers was adapted to functionalism. Advances in AI are considered in functionalism as an important way of testing and practical use of psychological theories.

In methodological terms, the essence of functionalism is to search for correlations between data on stimulatory effects on the "inputs" ("in put") of the organism and data on its "outputs" ("out put"). In addition, he is characterized by a close interest in the study of any mental states of the body (emotions, volitional acts, expectations, etc.), provided that an objective check of their functioning is possible. We are talking about the verification of ideas about these states: it is checked how they are expressed at the level of "outputs" – in behavior, language narratives, facial expressions, pantomimics, etc. The resulting descriptions of correlations of dependent and independent variables can be used as a basis for the development of software descriptions of machine models or robots that simulate the functions of consciousness (For example, Putnam 1975, p. 408–428).

If we consider functionalism from the standpoint of analytical philosophy, then it can be characterized as follows. In ontological terms, functionalism does not require the identification of the states ($P_{\varphi i}$) of the psyche with either neuro-physiological or with some spiritual structures of the human body. In other words, when describing and explaining mental states in mental predicates $P_{\varphi i}$, there is no need to reduce these states to the brain or other neurophysiological structures $ob_{\varphi i}$ of a person (or other organisms). From the point of view of functionalism, the mental properties of $P_{\varphi i}$ should be considered only as functions (actions) of $Ob_{\varphi i}$ (i.e. $P_{\varphi i}(Ob_{\varphi i})$). Thus, functionalism is methodologically more universal and less dogmatic compared to various versions of monistic physicalism, behaviorism or dualism (Putnam 1960, p. 138–164). For example, unlike "identity theory" ("eliminative physicalism") or "reductive physicalism", in functionalism mental states are complex states that are considered as a set of emergent properties of the whole organism; they are the functions of an integral system, and not the properties of some components of the body (brain and central nervous system or disembodied spirit).

It is especially important that functionalism differs methodologically favorably from behaviorism, despite the similarity with the latter. If behaviorism correlation between behavioral reactions $Q_{\varphi i}$ people ($Q_{\varphi i}(Ob_{\varphi i})$) and various factors S_i the external environment are considered as the basis for the explanation of the mind, the functionalism behavioral condition $Q_{\varphi i}(Ob_{\varphi i})$ considered in their correlations with external stimulus effects (i.e. $S_i \rightarrow P_{\varphi i}(Ob_{\varphi i})$), and correlations with deeper States of holistic human self ($F(Ob_{\varphi i})$), including with "background" (initial) mental states $P_{\varphi i}(Ob_{\varphi i})$, from which behaviorism is abstracted. Thus, the most important difference between behaviorism and functionalism is that in the latter mental states ($P_{\varphi i}(Ob_{\varphi i})$) they are understood not as acts of behavior, but as their causes. In symbolic notation, this thesis looks like this: $S_i \& F(ob_{\varphi i}) \rightarrow P_{\varphi i}(Ob_{\varphi i})$.

It seems that the focus of functionalism is the idea of the possibility of circumventing the solution of the problem of the parity of the structures of the psyche and body. The principle of ontological neutrality ensures the impartial objectivity of functionalism – the basis of a research program (or paradigm) for the creation of scientific psychology. Within the framework of this program, the question "What is consciousness?" the answer may follow in the form of another question: "How does consciousness function?". In functionalism, descriptions of sensations of pain, hunger, anger, expectations, etc. states ($P_{\varphi i}(Ob_{\varphi i})$,) are replaced by mappings (including symbolic) states of all organisms. From the point of view of functionalism, it is only important how mental states are expressed (objectified), performing a particular functional role, as well as the regularity with which these functions are repeated. The results of cognitive actions to identify psychological regularities result in the construction of behavioral models, the interpretation of which is the basis for the nomination and verification of statements about the similarity of psychological models and the real mental life of people.

8. The boundaries of functionalism in the modeling of consciousness. Despite all the advantages of functionalism, which are obvious in comparison with behaviorism, in the last 25 years this approach has been subjected to critical analysis. Among the analytical works on the problems of functionalism, the texts of John Searle (1980) and David Chalmers (1996) are especially significant (Searle 1980, p. 417–424). In their works, the sharp edge of criticism is directed precisely at the adherence of functionalism to the "principle of neutral monism". In this article, as an example, we will briefly touch on one of them – the concept of J. Searle.

J. Searle, a representative of analytical philosophy, introduced several important concepts into the discussions on the methodology of functionalism: "emergent naturalism", "strong artificial intelligence", "weak artificial intelligence", and also proposed a thought experiment that led to a revision of the boundaries of the application of functionalism in research of the psyche. Analysis of J. Searle's critique of functionalism and his thought experiment can be represented as a description of two sequences of actions. Firstly, they boil down to the acceptance of 2 hypotheses: (1) "If the concept of "strong artificial intelligence" is correct (***Tr***), then there is a computer-type transliteration program that allows a person who speaks only one of the European languages (***Q***) to understand Chinese written texts by entering them into a computer that provides an adequate translation of these texts into this European language (***R***)*"*; this hypothesis can be written as the formula: ***Tr → Q&R.***

Hypothesis (2) can be expressed as follows: "If, without knowledge of the Chinese language (***N***), in accordance with the algorithm developed by programmers, the translation of the text from Chinese into European (***R***) is provided, then the translation of the text from Chinese into European is recognized as correct (***S***), i.e. corresponding to the algorithm of programmers, as well as the translation is considered adequate provided that it is understood (***T***) by a European who does not know Chinese characters"; the hypothesis can be written as the formula: ***N&(Q&R)→S&T.***

Secondly, in accordance with the idea of J. Searle, the accepted hypotheses can be tested through a thought experiment called the "Chinese Room". According to this experiment, an imaginary room in which a certain person is located can serve as an analogue of a computer operating in accordance with a program written by programmers and capable of imitating the human function of understanding Chinese. It simulates the actions of a computer, using instead of lexical signs of the European language, hieroglyphic signs and formal rules for establishing correspondence between them. This person does not know any Chinese characters and, when receiving a question in Chinese, acts according to instructions; he manipulates hieroglyphs. The rules define the manipulation of Chinese characters only formally, i.e. syntactically; there is no information in the instructions about the possible semantic meanings of these characters. The instruction is structured so that after all the answers to the questions are made, they are converted into hieroglyphs of the answers. In fact, the instruction is a kind of computer program (algorithm), and the person in the room executes the algorithm in the same way as if a computer did it.

In the "Chinese Room" thought experiment, a situation is assumed when an observer sends a meaningful question to the room (for example, "What color do you like?") and receives a formally adequate answer (for example, "blue"). At the same time, the person in the room answered the question purely according to the instructions, since he does not own hieroglyphs, and cannot learn how to use them without knowing their semantic meanings. In other words, he does not understand either the meaning of the question or the answer he has chosen (according to the instructions). But the observer, in turn, can be sure that there is a person in the room who knows and understands Chinese characters.

Analysis of the results of the thought experiment allowed J. Searle to draw attention to the limitations of the scope of the functionalism approach. He meant that computer models developed on the basis of the results of this approach can pass the Turing test, but this does not mean that the formal correctness of the results (***S***) of the application of the functionalist description of people's mental states ensures an adequate understanding of their true nature (i.e. ***T***). Therefore, hypothesis (2) has not been tested in a thought experiment. Thus, the hypothesis "If the concept of "strong artificial intelligence" is true (***Tr***), then there is a computer-type transliteration program that allows a person who speaks only one of the European languages (***Q***) to understand Chinese written text" should be rejected as false.

Conclusion. Analysis of the history of the use of the modeling method in the study of the psyche and consciousness allows us to join the consensus that models perform a number of important epistemological functions. In particular, with their help, it was possible to simulate some aspects of such processes and properties of the psyche as logical thinking, memory, learning ability, etc. However, it does not follow from this that functionalism as the main approach in modern psychological research provides a complete understanding of a person's mental life. It has its limitations, which are associated with the unresolved problem of the relationship between the neurophysiological and mental levels of a single human self.

References:

1. Bakker, B. S. et al. (2016) An interactive three-dimensional digital atlas and quantitative database of human development. Science, 25 Nov., Vol 354, Issue 6315.
2. Bokulich, A. (2003) Horizontal Models: From Bakers to Cats. in Philosophy of Science, 70(3)
3. Cattell, R. B. (1984) The voyage of a laboratory, 1928–1984. Multivariate Behavioral Research, pp. 121–174. https://doi.org/10.1207/s15327906mbr1902&3_2
4. Eysenck, H. J. (1992) Four ways five factors are not basic. Personality and Individual Differences. Vol.13, Issue 6.
5. Fidora A., Sierra, C. (eds.). (2011) Ramon Llull: From the Ars Magna to Artificial Intelligence. Artificial Intelligence Research Institute, IIIA Consejo Superior de Investigaciones Científicas. Barcelona, Spain, P.36-38. This book is electronically published at http://www.iiia.csic.es/library
6. Fishwick, P.A. (1995) Simulation Model Design and Execution: Building Digital Worlds. Upper Saddle River, NJ: Prentice Hall.
7. Forbus, K. D., Ferguson, R.W., Lovett, A., Gentner, D. (2017) Extending SME to handle large-scale cognitive modeling. To appear in Cognitive Science. https://groups.psych.northwestern.edu/gentner/papers/ForbusFergusonLovett&Gentner_inPress.2b.pdf
8. Forster, M., Myung, J., Browne, M. (2000) Special Issue on Model Selection. In Journal of Mathematical Psychology. Elsevier. March.
9. Giere, R. N. (2010) An Agent-Based Conception of Models and Scientific Representation. Synthese. Publ: Springer. Vol. 172,
10. Jones, M. L. (2016) Reckoning with Matter: Calculating Machines, Innovation, and Thinking About Thinking from Pascal to Babbage. Publ.: University of Chicago Press.
11. Modeling. Cognitive Science. (2017) Volume 41, Issue 5.
12. Models in Science. Stanford Encyclopedia of Philosophy. First publ. 2006; revision 2020
13. Neumann, J. (2012) The Computer and the Brain. Yale University Press.
14. Oberkampf, W. L., DeLand, S. M., Rutherford, B. M., Diegert, K. V., & Alvin, K. F. (2002) Error and uncertainty in modeling and simulation. – Reliability Engineering & System Safety 75(3). No. 75 (3).
15. Putnam, H. (1960) Dimensions of Minds. In Sidney Hook (ed.), NY Uni. Press. NY.
16. Putnam, H. (1975) The mental life of some machines. In Mind, Language and Reality. Vol.2. Philosophical Papers, Cambridge Uni. Press.
17. Ryle, G. (2009) The concept of mind. Hutchinson's Uni. Library. Routledge. L., NY.
18. Searle, J. R. (1980) Minds, brains, and programs. Behavioral and Brain Sciences. Vol. 3, Issue 3, Cambridge University Press.
19. Skinner, B. F. (2014) Science and Human Behavior. The B. F. Skinner Foundation.

20. Sokolowski, J. A., Banks, C. M. (2009) Principles of Modelling and Simulation. Hoboken, NJ: John Wiley and Sons.
21. Solomonoff, R. (1957) An Inductive Inference Machine. IRE Convention Record.
22. Steihaug, T. (2020) Computational Science in the 17th Century. Numerical Solution of Algebraic Equations: Digit–by–Digit Computation. University of Bergen Library. Bergen Open Research Archive. https://bora.uib.no/bora-xmlui/handle/11250/2976922
23. Tolk, A. (2015) Learning something right from models that are wrong – Epistemology of Simulation // Concepts and Methodologies in Modeling and Simulation. Springer–Verlag.
24. Turing, A. M. (1937) On Computable Numbers, with an Application to the Entscheidungsproblem. In Proceedings of the London Mathematical Society, Volume s2-42, Issue 1.
25. Yates, F. A. (1954) The Art of Ramon Lull: An Approach to It through Lull's Theory of the Elements. Journal of the Warburg and Courtauld Institutes.Vol.17, No.1/2. Publ. By: The University of Chicago Press. https://www.jstor.org/stable/750135
26. *Krylov, A. K. (2010) Rol modelnogo eksperimenta i fraktalnogo analiza dannyh v psihologicheskom issledovanii [The role of model experiment and fractal data analysis in psychological research]. Eksperimentalnaya psihologiya v Rossii: tradicii i perspektivy.* https://psyjournals.ru/nonserialpublications/exp_collection
27. Kublanov, M. S. (2004) Matematicheskoe modelirovanie. Metodologiya i metody razrabotki matematicheskih modelej mehanicheskih sistem i processov: Uch. posobie [Math modeling. Methodology and methods for developing mathematical models of mechanical systems and processes: Textbook.]. Part I. M., MGTU GA.