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ARTICLE

Bernstein's Philosophy of Time: An Unknown Manuscript by Nikolai Bernstein (1949)

Mark L. Latash
The Pennsylvania State University

Vera L. Talis
The Institute for Information Transmission Problems (Kharkevich Institute)

The authors have presented an unpublished manuscript by Nikolai Aleksandrovich Bernstein written in the form of a diary in 1949. Bernstein focused on the concept of time as a coordinate in four-dimensional space and discussed a variety of issues, including the definition of time, its measurement, time travel, asymmetry of the past and future, and even linguistics. In particular, he offered a definition of life tightly linked to the concept of time. Overall, this manuscript offers a glimpse into Bernstein's thinking, his sense of humor, and his sarcasm, intimately coupled with the very serious attitude to scientific discourse.

Keywords: causality, determinism, history of science, linguistics

The name Nikolai Aleksandrovich Bernstein (1896–1966) is well known to researchers in many fields, including biomechanics, motor control, psychology, sport science, and neurophysiology. Among his major contributions are the invention of kimocyclography in the 1920s and 1930s, which made it possible to perform the objective quantitative analysis of human movements at very high speed and accuracy, leading to numerous important insights (Bernstein 1930, 1935); the formulation of one of the central problems of motor control—the problem of motor redundancy—which is sometimes addressed as the Bernstein problem (Bernstein 1935, 1967; Turvey 1990); the introduction of the multilevel scheme of hierarchical control of movements (Bernstein 1947); and the development of a new field addressed by Bernstein as the *physiology of activity* (Bernstein 1966).

One of the amazing features of Bernstein's heritage is his seemingly never-ending chain of publications, including books, previously unknown to the research

Latash is with the Department of Kinesiology, The Pennsylvania State University, University Park, PA, USA. Talis is with the Laboratory of Neurobiology of Motor Control, The Institute for Information Transmission Problems (Kharkevich Institute), Moscow, Russia. Latash (mll11@psu.edu) is corresponding author.

community. In particular, his book *On Dexterity and Its Development*, written in the late 1940s, was published only in 1991 in Russian and in 1996 in English (Bernstein 1991, 1996). His book *Contemporary Studies on the Physiology of the Neural Process* waited for nearly 70 years to be published in Russian (Bernstein 2003) and has not been translated into English. His main book, *On the Construction of Movements* (1947), has only recently become available to the English-speaking audience (Latash 2020). In this publication, we are presenting to the research community a new manuscript, which has been discovered recently in Bernstein's files.

This manuscript represents a diary, with a collection of thoughts united primarily by the concept of time. The diary was written in a notebook marked "Officer's Field Notebook" (Figure 1), kept by Bernstein's younger friend, Victor Lebedisnky (1927–2008), an expert in pathological psychology who introduced an original classification of developmental psychological disorders. The diary describes Bernstein's views on physics of time, time in perception and action, problems with measurement of time, time travel, and even linguistics of time. It also touches on a number of related issues, including the precision of measurement of space, determinism and causality, the concept of God, dreams in animals, and definition of life. The manuscript also offers a glimpse into Bernstein's sense of humor, his attitude toward gibberish in science, and his attitude toward the events in the Soviet Union.

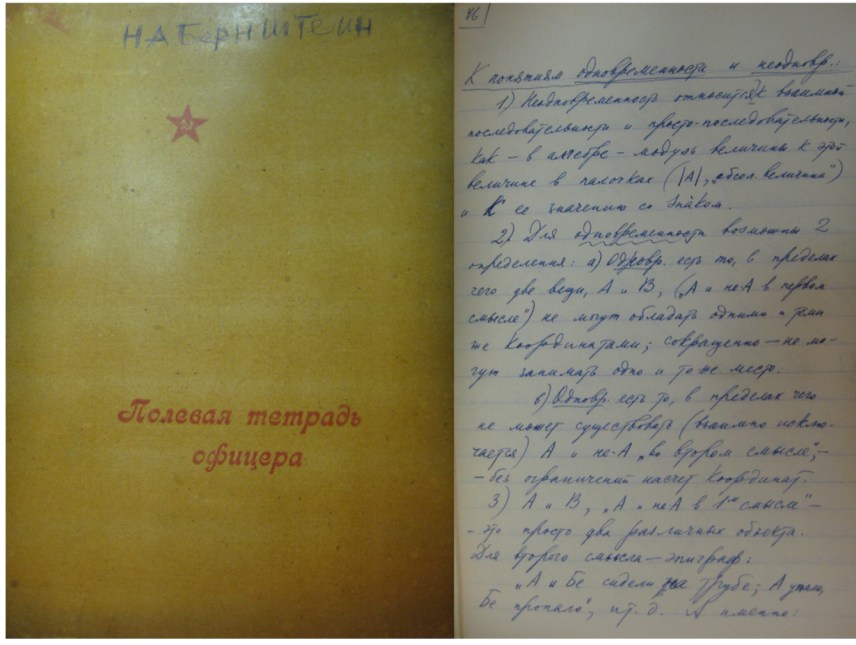

Figure 1 — Left, the cover of the "Officer's Field Notebook," with Bernstein's name written by another person in the top left corner. Right, a page from the diary, showing Bernstein's handwriting.

We have limited these introductory comments to describing the situation in the Soviet Union in general and Bernstein's professional life in particular at the time the diary was written. Then, we focus on a few specific statements made by Bernstein, which were selected based on our subjective feelings and preferences. Bernstein's text is mostly self-sufficient and self-explanatory.

Nikolai Bernstein in 1949

Until 1948, the biography of Nikolai Bernstein could be seen as smooth and successful, even privileged. He directed several research groups in different institutions in Moscow and was not affected by the Stalin purges of the 1930s. His main book, *On the Construction of Movements* (1947/2020), was published soon after World War II, and soon thereafter (in early 1948), it was awarded the Stalin Prize—the highest distinction of the country. Of course, Bernstein could not be unaware of the situation in the country, including the arrest and execution of people he knew (including Alexei Gastev, the former Director of the Institute of Labor where Bernstein worked in the 1920s). However, he remained a loyal citizen and, on a number of occasions, expressed his loyalty to the country and the dominating ideology.

The situation started to change in 1948. Two events signified the end to the post-War "thaw" (liberalization). The first was the session of the Academy of Agricultural Sciences (ВАСХНИЛ) in 1948, which declared genetics a false, "bourgeois" science and led to the persecution of a number of prominent scientists in the field of genetics. The second was the beginning of the anti-Semitic campaign under the name "war with cosmopolitism," which started in the middle of 1948 and continued until Stalin's death in 1953. Bernstein's Jewish heritage was known (although his parents converted to Christianity in the 19th century), and he became the target of a number of presentations, letters to authorities, and publications by colleagues. The planned publication of his book *On Dexterity and Its Development* was stopped. In the spring of 1949, Bernstein lost two of his positions, in the "Central Scientific Institute of Physical Culture" and "Moscow Scientific Institute of Prosthetics."

By the second half of 1949, it was clear to Bernstein that he had been labeled a "cosmopolitan" and had to prepare for persecution. This situation culminated the following year, during the infamous "Session of the Two Academies" (The Academy of Sciences and the Academy of Medical Sciences) in 1950, which declared the theory of I.P. Pavlov the ultimate truth and attacked all those who were labeled "anti-Pavlovian." During the session, Nikolai Bernstein was mentioned only a couple of times, in particular in the speech by E.A. Asratyan: "When random anti-Pavlovian gibberish is presented by Stern, Efimov, Bernstein, and similar personalities illiterate in both letter and spirit of Pavlov's theory, this is not even annoying but rather ridiculous (cited after Schnol, 2010, p. 103 and "Scientific Session", 1950, p. 107)." Soon after this session, Bernstein was fired from all his positions and remained forcefully retired until his death in 1966.

In August–September of 1949, when the diary was written, Bernstein was fully aware of the looming danger. There is little in the diary showing his feelings, with the exception of one statement discussed later. He remained, first and

foremost, a stoic scientist who did not allow issues of politics, expediency, and personal safety to affect his lines of reasoning.

The speed of Bernstein's thinking and writing is amazing: The whole text was written within about 1 month. The text is very dense and sometimes breaks into brief statements that look like a plan for further exposition, which sometimes does not come. Nevertheless, the general line of thinking remains clear and does not require explanation. In contrast, in other parts, Bernstein turned rather verbose, using detailed illustrations, quotations from classical Russian literature, and so forth. We selected the following few points from Bernstein's text, which seem to us particularly bright illustrations of this thinking.

What is Life?

In the diary, Bernstein addressed the crucial question of biology: What is life? On the way to an answer, he offered a couple of classifications. First, Bernstein separated reactions from actions, which he addressed as spontaneous, but still related to an external influence. The context, in particular, the relation of both action and reaction to an external influence, suggests that Bernstein implied what we would now call feedback and feed-forward adjustments to an external event. Indeed, both reaction and action are further classified into those restoring the homeostasis (acting against the external influence) and those acting synergistically with the external action, that is, amplifying its effect.

This led him to the following definition of life: "*Living objects* and groups are those that can be characterized with aspiration (or display of aspiration) towards their conservation and prolongation." In other words, if, in the presence of a perturbing influence, feedback and feed-forward actions by a system in different directions show a preference for certain directions that help maintain homeostasis and evolutionary success, you are dealing with a living system. Bernstein himself admits that this definition is weak because of its obvious teleological underpinnings. However, it resonates with other definitions offered at about the same time (e.g., Schrödinger 1944) and several recent developments.

In particular, the uncontrolled manifold hypothesis (Schöner 1995; Scholz and Schöner 1999) assumes that living systems consisting of abundant spaces of elements can stabilize salient performance variables to which the elements contribute in a task- or intention-specific way. This is reflected in a specific structure of motor variance in the space of variables produced by the elements. Bernstein assumed that a defining feature of living objects is their ability to structure space in terms of probabilities of actions in different directions, depending on actual and expected external influences, that is, in a situation-specific way. The two assumptions seem to be close to each other, although they are formulated in different spaces. Indeed, they become very similar if one assumes that "task" or "intention" within the former definition is defined by the overarching goal of evolutionary success.

Bernstein was not the only one in the 1940s thinking about how to define life. At about the same time, the great physicist Erwin Schrödinger wrote a famous book entitled *What is Life?* (1944). He emphasized the distinguishing ability of living systems to reduce their entropy at the expense of the environment. This assumption looks to us to be related to the one suggested by Bernstein. Indeed, "conservation

and prolongation" as the guiding principle of acting in the everchanging world may be viewed as being directed against an increase in the entropy of a living system expected from external influences.

On God and Kant

One of our favorite statements in the Bernstein diary is "Here is a problem of theology: Can God change the past? Rulers can." This quotation is literally bursting with meanings. First, it reflects the asymmetry of the past and future, which was one of the central topics considered by Bernstein. Second, it invokes God, which was not very typical of Bernstein's writings. Third, its last statement is full of sad sarcasm that requires an explanation for those who are not well familiar with the history of the Soviet Union.

During the Stalin purges of the 1930s, history was continuously changed, at least in official publications. Old newspapers were unavailable because they had glorified former leaders of the communist party who had since been executed. Old photographs and even paintings were modified, with some faces covered with black ink and others replaced with more acceptable ones. Some photographs were fake; for example, the famous photograph of Lenin and Stalin sitting side by side on the bench was constructed from two unrelated photos. George Orwell, in his famous novel *Nineteen Eighty-Four*, described the Records Department of the Ministry of Truth, which was occupied with implementing changes to ("rectifying") documents reflecting the past. All these adjustments to the past were implemented upon the direct orders from the "Rulers" of the Soviet Union (Stalin and his narrow circle) and from the Big Brother of *Nineteen Eighty-Four*, who were, by these actions, more powerful than God.

Furthermore, Bernstein referred to Immanuel Kant with another sarcastic statement:

> A miracle, much more surprising than the starry heavens above us and the moral law within us, is that the omnipotent God cannot turn non-existent a tiny motion of a cilia by the most insignificant worm that took place a second ago.

Indeed, Kant was fascinated by the heavens and moral law. Bernstein contrasted those concepts with the tiny motion by a worm that cannot be reversed or made nonexistent, even by God. In other words, we know the past, but cannot change it; we do not know the future, but can affect it: Isn't time a weird coordinate?!

Clinic for Sick Thoughts

Bernstein took research seriously. He was intolerant of undefined concepts, imprecise statements, and juggling meaningless words in scientific discussions. He referred to such statements with the Russian word "галиматья" (from French "galimatias"), which we translate as "gibberish" (could be "balderdash"). According to the recollections of his younger colleague, B.I. Khodorov (personal communication to V.L. Talis, cited after the unpublished manuscript by Talis VL: "The doctor who loved steam-engines"), Bernstein could be very direct in

expressing his negative opinion about seminar talks with highly idiomatic expressions, like "My ears wither!" (I cannot listen to this anymore!).

In the manuscript, he developed an interesting and, to our knowledge, unprecedented concept of a "Clinic for sick thoughts" with the purpose of purging gibberish from scientific discourse. In our times, such a clinic would be priceless!

There are quite a few questionable statements in the following text. Some of them could have reflected insufficient knowledge by Bernstein of some of the recent advances in physics and mathematics. Others were reflections of hasty writing. In such cases, the translator did not dare to introduce corrections, new references, or criticisms into the original text. In the following translation, there are two types of footnotes: those written by Bernstein and those added by the translator. They are marked as NAB and T, respectively.

N. A. Bernstein: From the Notebook (August – September 1949)

The "W-coordinate" of time and "U-coordinate" of space

"I can see my representation" (image on the retina)

Definitions of time. The razor-sharp edge of the "present". The natural philosophy of the two signs of time.

August 20, 1949

1). On the exact definitions of (a) meaning and (b) contents of terms. The notion of mutually-conditional terms during a dispute.

2). Elements of judgements as terms. Definition of syntactic links and main verbs. Terms: "I" ("аз"[1]), being, existence, object, matter, "external" world, etc.

3). Two types of judgement: objective (object-oriented) and subjective.

4). Analysis of the subjective judgement. Interpretation of such judgements and their components by representatives of different schools.

5). Analysis of the main gnoseological sophism (mistake, antinomy?) of idealists. Image on the retina, the supreme ruler within the constrained cranium and scouts delivering reports that can be checked only by their cross-interrogation. (We see and hear not the world but see and hear only reports by the scouts").

6). Evolutionary review of perception, cognition, and speech.

7). Goals of a scientific theory: a) predicting law; and b) explanation, i.e. description and reduction to known and more general.

8). The role and objectives of a hypothesis.

9). The "principles of economy" and their critique. The principle of "equal simplicity" and its heuristic meaning.

10). Rejection of the main ontological proof of the idealists.

August 16, 1949

1. Logics, in contrast to other natural sciences, requires defining not only terms (nouns and verbs) used in speech, but also the syntax of arguments – their forms, auxiliary elements, etc. Logics is the science of spoken cognition used as a tool for understanding, and the technique of equipping and using speech for this purpose.
2. It is not an easy but needed task – to adjust the etymology. Declinations of Russian nouns and pronouns are beneficial; that is why, one has to find a way to declinate personal pronouns ("me"), adverbs (yesterday, tomorrow, here, there, etc.). One may need to rationalize and expand the formation of verbal nouns (which is easy in English and German). For generalization, a number of suffixes have to be defined exactly. We should start using or expanding the usage of other suffixes, for example, suffixes "able". Visible is not the same as being in the field of vision, existable; negligible; conceivable, mental, etc. One cannot rely on the arbitrary interpretation by the reader; it is the same as to define ellipse as an egg-shaped curve.
3. Analysis of the pendulum. Galileo's theorem. The tautochrone pendulum of Huygens and actual requirements to the pendulum. Analysis of notions: measurement of time, comparison of intervals, "speed" of time; dt in the denominator and in the numerator; determinism and time.

August 22, 1949

Topics to note: I – Time is Minkowski's cosmos, film and movie projector, and the origin of (inevitable) dt/dw.

II. Definition of existence with respect to past and future. Independence. Past, "barely past" and perception; effectors, future and their dependence. Demonstration of independent existence in classics of dialectics – via practice. It also proves dependence. Dialectical unity.

August 24, 1949

I. The original definition of existence: (a) existence in four coordinates x, y, z, t (=it); (b) independence of a (perceiving, contemplating, judging) subject.
Further, this definition is refined depending on interpretation of time: time can be viewed as either (1) one of the coordinates of the stationary, indivisible complex – the cosmos of x, y, z, t of Minkowski, or (2) as a variable, which has crucial difference between the two signs (past and future).
The second interpretation of t: definition of existing is fully applicable to the past, which is characterized by: (a) unambiguous definitiveness; and (b) complete independence of the subject. Hence, characteristics of something existing in the past only are (a) existence in the x, y, z, t system; and (b) independence.

Perceived, or even thought of as, true present is in fact undoubtedly already past ("barely past"): Some time is spent on psychophysiological processes in receptors and central mechanisms of recognition-comprehension. As a result of

those milli- and centiseconds, factually, anything perceived is already past, not present (the bullet one has heard has already failed to kill). Perception is delayed with respect to an event by substantial time allowing this event to attain all the attributes of the past, rest itself into exactly defined coordinates and become fully independent ("the word is not a sparrow . . . ", "what has been written with the pen . . . "[2], etc.).

In contrast, actions, effector processes, by the same token, relate to the future ("barely future" or "micro-future"). In terms of psychophysiology, this is the time interval between the motivation to move to the neural impulse, from that impulse – via all the psychomotor stages – to realization of the planned effect in the environment. Hence, when the motivation to move emerges, even at the moment of the generation by the cortex of an effector impulse, the effect of the action is in the fully developed future.

Therefore, definition of currently existing in relation to the future rules out independence and replaces it with dependence on the subject, potentially or in its extreme – full dependence. As far as future is concerned (both micro- and macro-), for prehistoric men, the world was nearly independent, for a contemporary collective of people – dependent significantly, and for future society – there are no limits to this dependence.

The classics of dialectics addressed human experience as the strongest argument in favor of "objective", i.e., independent existence of the external world. According to the aforesaid, the same experience establishes its increasing dependence. This is not a logical discrepancy, not a sophism, and not a result of different meanings assigned to terms (error of homonymy), but a pure example of dialectical, dynamical unity of opposites: the essence of the transition ("passage") from the future via the razor of the present to the past is in overcoming the independence, turning it dependent in both its potential and action, and lowering it into the past (where it solidifies into an independent form) in the desired shape.

II. Without predetermining acceptability of the first interpretation of time as a stationary cosmos *x*, *y*, *z*, *it*, let us mention the following:

It does not matter whether our movement along the coordinate *t* is something fully subjective or has a much broader and general physical nature, this movement necessarily presupposes and requires coordinate *w*. Indeed, coordinate *t* (or *it*) exists in cosmos as a whole with the other three spatial coordinates, and characteristics of movement along *t* require placing it into the numerator of a differential; consequently, the denominator represents another variable, which we addressed with the symbol *w* without predetermining its nature.

One can offer the following example as a very clear illustration of this point and the necessity of the function d*t*/d*w*. According to this interpretation of cosmos, all existence is similar to a film placed into a movie projector. The frames in the bottom (accepting) reel of the projector do not differ qualitatively (as far as their contents are concerned) from those that are still in the top reel. There is a principled difference between the reels, not between the frames – at least because every frame in the top reel is doomed to get to the bottom reel, while all those in the bottom reel were at some point in the top reel and did not experience during the transition any changes except a change in their location. Therefore, the film contains – in a stationary form – coordinates of both space (at least two out of three) and time *t*.

Existence is the transition of the film through the projector, and the motor expresses in its motion the variable *w* and the derivative d*t*/d*w*. We can run it faster or slower (changing d*t*/d*w*) without any effect on the film and its contents. A temporary pause of the motor (of any duration up to infinity) is analogous to the subjective aspect of sleep without dreams or to death.

III. To the analysis of: (a) unity of personality, metempsychosis, its coordinates, etc.; (b) on the synchronicity of the razor; on freedom of choice and fatalism; on determinism and the notion of causality.

August 24, 1949

1). Nobody would think of becoming a champion of a theory where the hypothenuse cubed equals the sum of cubes of the legs. The problem is to achieve the exactness of mathematics in (a) proving the statutes of idealism wrong; and (b) achieving a situation when, just like in mathematics, everyone would be able to deduce all the theorems of the true theory of knowledge. The whole cogency of the non-experience-based mathematical knowledge is in the possibility for everybody to deduce its positions in an undisputable way.

August 24, 1949

As a follow-up: (1) Two types of statistical probabilities: (a) probability, which grows in a lawful way (and can be illustrated quantitatively) and approaches unity with an increase in the number of objects: kinetic theory, radioactivity, etc.; and (b) probability that shows no such an increase and, moreover, no such regularity – for example, meteorological and medical prognoses, hereditary phenomena, etc. – to summarize, the whole field of biology. [For analysis of *future tense*].

2). Is the accuracy of division in ether infinite, step-like, or statistical?

(a) Gravity: Atom on the Sun × atom on the Pluto; lines of force action and space curvature;

(b) Waves of light through a point in ether. What is the function of its time changes and can it exist?

3). The history of the evolution of the meaning of concepts:

a). God-spirit (spiritual atoms, etc., non-material matter);

b). Laws of nature and possibilities of their violation. The meaning of the concept of "miracle".

August 25, 1949

To the analysis of measuring time intervals:

1). The only realistic method of such measurement is establishing synchrony of the initial and final instants of a time interval with readings of a *clock*, which continues to move from the beginning to the end of the measured interval.

[Note. Under the "*clock*" we understand any reliable, according to our opinion, standard, which ensures a sequence of consecutive processes of equal duration – for example, a pendulum, the daily rotation of Earth, etc.]

2). Ensuring perfect synchrony is possibly only in the present, i.e. within a psychophysiological reaction or reaction of a measuring device. Time intervals in the past that were not registered with synchronous marks at the proper time – definitely cannot be defined. [See later on defining a sequence of events in the past.]

3). Ascertaining synchrony (briefly: *noting t*) by a living subject-observer is a psychophysiological reaction of an arc type, namely: the first half-arc is perception of the noted event; the second half-arc – reaction to this event by turning a chronometer on, or perceiving and comprehending the readings of the arms of a moving clock, etc. In the latter case, the impression of watching the face of the clock with the moving arm may be continuous but its conceptualization at a given instant and transformation into numbers proceeds as an active reaction to perception of the received event.

4). To note *t*, a living subject-observer is not necessary; by replacing the observer with an automatic device, we make sure that essential factors for the instant of time of noting *t* are only: (a) perception of the event; and (b) maximally close to synchrony reaction to perception, which generates a projection of the noted *t* on the moving clock. For example, turning on the stopwatch (and turning it off at the moment when the end of the event is perceived); or dashes placed on a tape moving with a constant, precisely known speed, etc. Hence, both synchrony and interval duration are categories that do not require a subject (i.e., "objective").

If one and the same tape is used to record automatically both a) synchronous reactions of the device to events (dashes) and b) isochronous marks from a clock, measuring the interval between two dashes could be interpreted in two ways:

1). Time (*t*) is replaced by the tape motion in space, and this dependence can be expressed as a function d*x*/d*t*. The markings placed on the tape by the running clock represent a method of automatic recording of the function d*x*/d*t* to decipher the values provided by the moving tape.

2). If the clock markings have sufficiently high resolution or allow good interpolation, such that one can always find among those marking the ones that are synchronous with the dashes drawn by the device, one can consider the tape simply as a graphical recorder, which shows directly comparable dashes by the device and synchronous (overlapping) markings by the clock.

The meaning of the process of measurement of intervals has to follow the steps described earlier in points 1 and 2.

5). Commonly encountered notes of the time coordinate of a single event represent masked notes of the time interval between two events (the currently observed one and another one observed earlier, which is used as the origin of the time coordinate, for example 0 h 0 min of the first day of A.D.). A necessary condition for assigning value to such a quasi-single measurement of a time instant – continuous movement of the same clock from the initial to the final event. (Of course, the notion of "the same clock" allows replacing

specific mechanisms with mutually-synchronized ones, but it is doubtful that such a replacement would be reliable in the absence of the continuous standard clock of the daily rotation of Earth.)

The following is worth discussing: Although, in contrast to space, time based on the available data is absolute; *although its intervals cannot be moved and do not allow superposition*; although time moves in the same way for all observers and, likely, for the whole Universe –nevertheless, noting a single time coordinate (not an interval with the beginning and the end) makes no sense.

August 25, 1949

Note:

(1) *Movement* – (one or another) form of a function that links space with time.

(2) We need classification of meaningless statements (for example, concealed id. Per id., dt/dt, homonyms and synonyms, etc.) *An example of gibberish due to synonymia*: An object exists in the present; does it exist in the past? "A" claims that it does not (any more). "B" claims that it exists in the past. "C" claims that it does not exist but existed. "D" – that its existence is left in the past. Etc. They argue although they all say the same things (within the constraints of ill-defined terms.)

(3) Until now, philosophers strived only to identify "healthy" thoughts in contrast to "sick" ones. They tried to convince the sick ones (from their point of view) that they are sick and remove them from the playing field. It is timely now to establish a clinic for "sick" thoughts – meaningless ones, a gibberish clinic, and start developing "sopho-pathology", rejecting squeamishness similarly to anatomic-pathologists. We have to study mistakes to overcome them; the task is to make them impossible, like smallpox.

(4) The problem: How can one define, without using subjective data and using only objective materials, what the difference is between something that has already happened and something that has not happened (yet)?

(5) The question (a) on infinite divisibility of world continuums and (b) on the limit of accuracy of this divisibility. Small deviations of causes lead to large deviations of consequences (cf. diverging series). This brings about the problem of accuracy of possible predictions: The micro-deviations, which have to be considered for prognosis are similar to those emerging in problems like $[(\text{atom} \times \text{atom})/(\text{light year})^2]$. Future is determined in the past similarly to the existence of all future generations in Adam's semen.

(6) If one tries to move from consequences to causes in various situations such as collision of balls or sequential reflections of a beam of light in the balls, sequences of molecule collision in the gas, etc. – this is similar to movement along a quickly converging mathematical series in the direction from its beginning towards the end. But not all such series can be continued in both directions (can be done for a geometrical progression but not for the e^x series). As a result, look at what happens with an event that can be characterized by such a series and we track it in the natural order, from the

causes to the consequences. (This resembles elation of a person who has just finished recounting all the decimals of π in the opposite order.)

(7) There will necessarily happen a single event, not two events (see the related remark by the warden in "The seven who were hanged" by L. Andreev[3]), because *to happen* means turning past from the future, which is necessarily unambiguous. According to the time coordinate (i.e., "in its proper time"), all the future has to become past with its obligatory unambiguousness. But as long as it has not happened yet, i.e. as long as it is future, something may happen (or it may not happen); moreover, in many situations, this depends on us. The essence of this has to be discovered, because this is definitely not subjective, and meanwhile, it encompasses the whole problem of free will, fatalism, etc.

Note: We are very hampered by the lack of verb tense in our language that would express future in the past. "I was in the cottage and I was going to leave.", "The train was due to leave", "I shaved and then I had to go home" etc. In contrast to plusquamperfectum (which is also missing in Russian), in the required form, the current ongoing time (although it is in the past) is represented by a simple past form of the verb: I shaved, the trained stood motionless, etc., with respect to which the required time is future. In the case of plusquamperfectum the situation is opposite: it expresses something preceding the main action expressed by the past tense form: "When I arrived he had been already gone (il était allé)".

(8) Dogs definitely have dreams but are unable to describe them to anybody. Future electroencephalography will be able to ascertain this fact, record the underlying physiological processes, etc., but it will not reproduce the dreams. Is dog's dream an objective phenomenon? What category is it?

(9) (Briefly, a paragraph from "The Time Machine"[4]): The inventor of the time machine, Mr. Smith got an idea to travel exactly one week backwards. What did happen?

"$Smith_1$ was sitting in the chair contemplating the final details of this invention, which was not yet a completed machine. Suddenly, the door opened and his doppelganger – $Smith_0$ – stepped in. He speaks to the stunned $Smith_1$: "I finished the machine, visited the future and decided to travel one week backwards. Exactly one week ago, I, $Smith_0$, was sitting in the chair where you sit now and was thinking about the invention. Suddenly, my doppelganger – $Smith_{-1}$ – told me exactly the same what I am telling you now and informed me that he had just completed building the machine, exactly one week after he had been visited by his doppelganger, $Smith_{-2}$ – etc.

$Smith_1$ listened to this story, did not think much about the fatalism embedded into all the events, showed his doppelganger $Smith_0$ back to the time machine (and this was a good thing to do – otherwise, everything would be even more entangled) and started to put final touches on his invention. A week later, he finished the machine, travelled on it into the future and (volens-nolens) sat in it once again, travelled exactly one week backwards and visited his doppelganger, $Smith_2$, sitting in the chair and watching $Smith_1$ in amazement. $Smith_1$ told the sitting $Smith_2$ the whole "white bull story" and warned him that he, $Smith_2$, in a week would explain the same story to the confused $Smith_3$, etc."

This is how the double enfilade of reflecting each other doppelgangers came about, infinite in the direction of both positive and negative subscripts, i.e. having

no essentially zero subscript that would be different from all other subscripts. Which one of those Smiths and when got the idea to travel one week backwards? And how many Smiths were there?

August 27, 1949

Notes:

(1) The variety of meanings of the term "non-existing": There are no megatheriums, bird's milk, violations of the law of conservation of energy, square triangles, euoi.

(2) Two different meanings of the word "*definable*": (a) objective meaning (this but not that, corresponding to itself, displaying unambiguous existence, etc.), and (b) subjective (actually subjected to being defined or thought of as an object undergoing being defined). To define or to subject to being defined means (a) to create a reflection of an object in cognition; and (b) measure it, i.e., compare this reflection with some qualitative or quantitative standard. Let us use for the objective meaning a synonym "definitive", then we arrive to the following lines of thought.

A. There is a definitive specimen of an object, which (objectively) exists. Taking its reflection and comparing to a standard, we get a definition for the object via defining its reflection: e.g., this is a female crow, etc.

Definition as a process is performed with the reflection, definition as a result relates to the object and, in our opinion, is salient for it.

B. An ideal elastic ball moving with some velocity undergoes a sequence of bounces from randomly located in the vicinity immovable balls. If we mentally replace the moving ball with a light beam and consider the surfaces of the immovable balls as mirrors, these convex surfaces would represent strongly diminishing mirrors, where the optical reflections of nearby balls are small, and reflections of higher orders (of balls in other balls) very quickly progressively reduce as a geometrical series. Possible directions of the beam, which would, after being reflected by N balls, land at a point on ball $(N+1)$, are constrained by a very narrow solid angle, which reduces quickly and infinitely with an increase in N. The same is true for trajectory of the center of the moving ball.

After a sequence of N bounces, the polygonal line of the trajectory of its center is a well-defined line along its whole extension. In other words, movement of the ball from the initial push to the last considered moment of time is well-defined and causally conditioned over its whole definition.

If, in this "mental experiment", we want to apply the same known to us law of causality to the predestination of the trajectory of the center of the ball, first of all we have to define the initial direction of the movement, the coordinates and radii of the balls, etc., i.e., (a) to obtain their reflections – but this can be done only with a certain degree of precision, i.e. a value of measurement (reflected) error –, and (b) measure them, which is also associated with an inevitable error of measurement. The notions of precision and error are not applicable to the object itself, – in our case, to the definitive trajectory; they, however, are inevitably linked to reflections and measurements of an object, i.e., to its definition.

After all the mentioned characteristics are defined, we have to apply to them the known law of interaction of bouncing balls. According to the previous text, the angular error in estimating the initial parameters inevitably increases in a geometrical progression with N, and since the solid angle cannot be over 4π, after a sufficiently large N, inevitably, complete indeterminism of further fate of the ball comes about in conditions of its fully stable and unperturbed definitiveness. We have to mention that, independently of the magnitudes of the parameters of this problem, the magnitude of 4π is achieved for very small N; for example, for the mean distance between the centers of the balls being five times larger than their diameter – one square minute of the initial angle turns into 9π (4π is about 148451000 square minutes) after seven collisions.[5]

The importance of the mentioned difference between definitiveness and certainty is in the elimination of important misconceptions: Confusion of the two notions leads to a conclusion that an undefined magnitude or phenomenon are not definitive, and this leads to unjustified limitations assigned or doubts with respect to the law of causality.

Definitiveness relates to the object, certainty – to its reflection.

(3) The word "*reflection*" means "we are in the process of understanding or have understood the object". To state and insist that we understand only reflections is analogous to saying that "we understand only our understandings of objects." This is the same as thinking that to see means to observe from inside the brain images emerging on the retina – as if there were a small person sitting in the brain with eyes watching the images emerging on the retina from the back (these are secondary optical images).

These aberrations are very closely related to difficulties experienced by psychophysiologists formulated as the problem "when and where did humans learn not to notice and correct the upside down images on their retinas?"

(4) Magnitudes encountered in geometry are results of measurement, i.e., they have sense only if a measurement standard (which can be arbitrary) is identified: length, area, time interval, etc. However, there is a number of geometrical and kinematic categories, which possess full definitiveness, i.e., reality independent of any standards and measurement processes. Computation of these categories is crucial for being able to separate them clearly from their measured reflections and, hence, to avoid making mistakes. (Objectively) definitive categories include:

1. *Segment*, i.e., two points in space at the current time instant or in abstract time.
2. *Angle*, i.e. three points or two straight lines with a single common point (with the same stipulation regarding time).
3. *Trajectory*, i.e. a definitive set of points in space (x, y, z, t) occupied by a moving material point. The points along the trajectory itself, viewed as an object, are defined, i.e. they are equal to themselves, objective in a sense of independence from the observer. [6] Reflection of the same trajectory for its exploration and measurement depends on the choice of system and origin of coordinates, standard (unit) of length, etc., i.e., it can be infinitely variable. This analysis solves the problem of what can be viewed as "objective" trajectory of the falling

stone observed from the ground or from the moving train, and whether such a trajectory exists. The problem looks complicated because of the confusion between the object and its reflection, definitiveness and certainty.

(5) To avoid another error of homonymity, in future we have to use the term "*definition*" only for the result of definition ("hypothenuse is a side of a right triangle across from the right angle", etc.), and address the process as "*process of definition*".

August 29, 1949

Notes:

(1) (It would probably be appropriate to use algebra here): Conditional and Conjunctive forms.

A]. If – then:

a). If there [will be] P, there will be Q – expresses causality "if there is hail tomorrow, the crops would be ruined", or conditionality "if his wife allows, he will go for a visit."

b). If (there is) P, then (there is) Q – the present tense denotes that time is not considered, generalized – an expression of general lawfulness.

– if a bird lags behind the flock it dies (causality)

– if one cuts the rope, the stone drops (conditionality)

c). If there [will be] P, do Q or
If there [will be] P, I will do Q: Order or intent with conditional constraint.

– if you pass the exam tomorrow, come to visit me;

– if I pass the exam (if my lottery ticket wins), I will go to a resort.

d). If there was P, then – fictional form, which places past subjectively in a formal relation to future [see below, note 2].

B]. If something happened – then in two equivalent forms:

If P happened/had happened, then Q would happen/have happened.
Q would happen/have happened if P happened/would have happened

a) with the meaning of future tense – two meanings (syntactic homonym)
a1 – synonymous with if–then:
If the weather cleared up, my son would go for a walk;
= If the weather clears up, the son will go for a walk.
a2 – If P happened, Q would happen too, but . . .
If you forgave him (tomorrow), he would reform, but . . .
It would actually be the other way around because you will not forgive him.
If tomorrow a fairy visited me, I would ask her for a miracle, but – there are no fairies and miracles.

b) In the past tense meaning – only with the negating "but"
If I had gone (in proper time) to the College of Medicine, I would have

been a medical doctor now (the form of the sentence implies that this is not true[7]).

Note 2:

Fictive (subjective) future form in the absence of knowledge about the past: If I do not know what happened, I can think and speak about the past as if about the future in the sense of ambiguity inherent to the future (using forms "if P happened, then Q would have happened", "either P or Q happened" etc.). But the illusion can transform from the feeling of ambiguity ("Eugene . . . .runs toward the expecting fate with an unknown tidings as with a sealed letter" . . .[8]) into the feeling of dependence (Levin's prayer, after the lightning strike, for the lightning not causing demise of his family.[9]).

Here is a problem of theology: Can God change the past? Rulers can.

Note 3:

For a whole range of notions, the suffix "ение" has two meanings: (a) process of action; and (b) its result. It makes sense to keep for this suffix "ение" only the meaning of result of action. For the process, it would make sense to use always the expression "process of something" or the suffix "ание":

Решение – решание
Определение – определяние
Отображение – отображание
Ощущение – ощущание
Представление – представляние
Рассуждение – рассуждание
Умозаключение – умозаключание[10], etc.
Exception: Воспоминание – вспоминание

August 31, 1949

To analyze: (1) Reflection refers to an object as a variable to its limit.
(2) Object and fact.
(3) Laplace's thinker and its extrapolation.

Response to Kant: A miracle, much more surprising than the starry heavens above us and the moral law within us, is that the omnipotent God cannot turn non-existent a tiny motion of a cilia by the most insignificant worm that took place a second ago.[11]

August 31, 1949

Notes: To the notions of reason and reasonability:

(1) *Reason* – An idea about a future fact that is the driving force for my actions.

(2) *Life* – generalization of observations allows drawing the conclusion that numerous kinds of objects (items) are characterized by actions directed to keep and prolong their (pertaining to the objects and their versions) existence. Namely:

If one: classifies all the encountered influences on those objects into (a) those directed towards their safety and existence, and (b) those directed against their safety and existence, and use the "+" sign for the former and "–" sign for the latter;

classifies all the possible actions originating from these objects – both as results of influences on them (reactions) and spontaneous ones (actions) – into those directed against those influences (–) and collaborating with those influences (+); and

then, generalizing the observations shows that, out of the four possible combinations of influences and actions:

1. (+ +) = +
2. (– –) = +
3. (+ –) = –
4. (– +) = –

The two top combinations dominate strongly (preserving influences with collaborating actions and destructive influences with counteracting actions), both resulting in the "+" sign. Objects and their versions characterized with such strong predominance are designated as alive (living, endowed with the feature of life); but objects and their versions that show equal probabilities of all four combinations are classified by us as parts of the inanimate nature.

Briefly, this objective generalization of observations can be expressed with the following imprecise definition: *Living objects* and groups are those that can be characterized with aspiration (or display of aspiration) towards their conservation and prolongation. Hence, the subjective and teleological term "aspiration" is not essential here and is used only for brevity of the definition of life and living objects.

3). Along similar lines, allowing ourselves a bit of inexactness for the sake of brevity, one can designate actions and reactions of living objects directed at their preservation and prolongation as (essentially) *useful*, and those directed against – as useless or *hurtful*. Hence, the notion of usefulness, as applied to the living world, has nothing to do with a goal, its subjective definition and teleology.

Statistically, variability of such selective and complex organizations is much more probable than lack of variation, even because, for any value "*A*", there are many more values "non-*A*" and, as a result, the probability of observing a "non-*A*" is much higher than the probability of exact repetitions of "*A*". Generalization of observations shows that, in reality (in spite of the efficacy of tendencies to repeat), variability in the living world is omnipresent at all times.

If, according to the offered definition, we understand *usefulness* of actions by living objects as their directedness toward preservation and prolongation (with respect to the individual and the species), then the Darwin theory shows that every non-indifferent variation of an individual affecting its genotype, i.e. transmitted to the offspring, is necessarily useful in the selection process independently of the origin (causes) of this variation or its usefulness for this particular individual: A variation hurtful for the individual decreases its chances and leads to smaller numbers of and diminished chances for its offspring; and vice versa.

The mentioned obligatory directional tendency of the selection scheme (survival) is a direct consequence of the definition of life, and does not require anything else.

4). Independently of how the problem of absolute determinism of facts will be solved, – the example of omnipotent mind by Laplace is wrong in principle. Prediction of facts by a thinking individual, i.e., with the help of an apparatus of cognition, is possible only with the help of reflections of objects and facts, their measurement (comparison to a standard, estimation) and processing. Reflections are

necessarily approximate reproductions of existing objects – variables approaching objects and facts as their asymptotes, and therefore, they are subjected to the aforementioned statement on divergence of approximations; it is applicable to a broad multitude of cases. That is why, predicting extrapolation is so rarely possible – nearly exclusively in the fields of (a) planetary mechanics; and (b) laws of large numbers.

With respect to the previously discussed example of reflections from the balls, it is necessary to add that for both reflections of the beam and elastic ball collisions, there is full reversibility of the processes, which is the brightest illustration of the difference between sequences of facts and their reflections. If one analyzes "backward" reflections of the beam, there is divergence from the following to the preceding, i.e. something directly opposite to what happens for the "forward action."

September 1, 1949

Note: 1). Selecting proper terms.

Past	Existed	(Being?)_____?	
Present	Existing	Existence	To exist
Future	Forthcoming	Upcoming	Await

2). Judgements of objects should be classified into (a) predicative; and (b) attributive.

Attributive judgements establish a certain feature or property of an object: The earth is spherical, Caesar was brave, those in the Caucasian region live long, etc. *Predicative* judgements express that something has happened (is happening, will happen) with the subject, i.e. a fact of its change: Caesar was murdered; a patient (subject) had a seizure (predicate)[12], the plane has landed; the clock chimed five o'clock; and you (subject) will die by your horse[13].

The essence of the difference between the two aspects is in the following:

No matter what is viewed as moving and what is considered motionless, undoubtfully, there is relative motion in time:

A). I – as a rational person – move with respect to facts, events, changes – to put it briefly, to everything measurable in time – from the past, via the present, into the future. Let us denote this direction with the word "*forward*" (+).

B). Everything enumerated in point A, i.e. essentially changes or events, formally – data, move with respect to myself from the future via the present into the past. The word present implies a point of their motion by me. This direction can be denoted as "backward" (–).

C). Every object, which can be viewed irrespective to changes happening with or within this object, which can be assigned its own history, which can serve as a subject of predicative judgements, – by the very fact of its triple property participates in the same movement as the subject in A, i.e., forward. In predicative judgements, such an object crosses in our judgements with other objects moving with respect to it backwards.

We (subjects) move forward and look only backwards. This may be the reason we always see only objects that move away from us. This is very inconvenient.

3). For terminology: *Object* (material) – is a subject of judgement, as it is defined in logics, which possesses (independent, "objective") existence.

Fact – existing ("objective") change – action, event, etc. in any time (past, present, future) *Object* – material object and fact together, i.e., either an element or a group of elements within the existing world.

September 3, 1949

To the notions of simultaneity and non-simultaneity:

1). Non-simultaneity refers to mutual sequence and simple sequence, as – in the algebra – modulus of a value refers to this value surrounded by vertical sticks (|A|, "absolute magnitude") and to its magnitude with the sign.

2). For *simultaneity*, there can be two definitions: a). Simultaneity is something delimiting an interval where two objects, A and B ("A and non-A in the first meaning") cannot occupy the same coordinates; briefly – cannot occupy the same space.

b). Simultaneity is something that does not allow to exist A and non-A "in the second meaning" (they are mutually exclusive) – without constraints on coordinates.

3). A and B, "A and non-A in the first meaning" – these are simply two different objects. For the second meaning, the epigraph is: "A and B sat on the chimney; A fell, B disappeared, . . . etc.[14]" Namely, "non-A" in the second meaning is a change in A, its attributes and properties (including the attribute of existence; "A fell, etc."), which does not preclude A from remaining itself. To satisfy this requirement, A has to belong to one of categories ("object" or subject in a sense of earlier reference, B), which demand being singular or possessing individuality. The former is the existence of core properties that make object A itself (under all modifications) and ensuring its identity. Individuality is something that separates A from everything that is non-A in the first meaning. All these definitions, so far, lack clarity.

Clarification of the previous text should form the basis for understanding movement of time.

September 6, 1949

Notes:

1). To earlier page: Verbal nouns should have three forms: a) process in the present, b) processes in the completed past, and c) result. For example:

Understanding – process in the present
[completed] Understanding (cf. "taking") process in the past
Notion – the ultimate product
Solving – (a problem by myself)
[completed] Solving – (of a problem by myself)
Solution (of the given problem), etc.[15]

2). *Definitions* of terms:

a). *To seem*: to seem – based on the impressions (percepts), to presume – based on the material of judgements equally express a conclusion from the same material admitting its limited confidence (subjective estimate of probability $0.5 < r < 1.0$, because the seeming or presumed are perceived by us as more probable than their negation).

b). *To understand*: synonymous with "capturing the meaning" where "capturing" means "receiving into the contents of cognition".

c). *Meaning*: Has two values, which should definitely be united, but I have not been able to do this yet:

c1). An idea, conditionally or symbolically linked to an impression, a thought, or a groups of those: Meaning of a word, speech, attack in chess, mimics, etc.

c2). An intrinsic link between ideas (meaning of a problem, etc.) or between actions by a living being, which possess systematicity, goal-directedness, etc.

September 14, 1949

1). И вот уже трещат морозы,
И серебрятся средь полей
(Читатель ждет уж рифмы «розы»:
На вот, возьми ее скорей!)
(«Евгений Онегин»)[16]

2). Елена закрыла лицо. «Вы хотели заставить меня сказать, что я вас люблю» – прошептала она – «вот . . . я сказала.»
(«Накануне», глава XVIII)[17]

September 14, 1949

"Now": The distance from us to the Andromeda nebula (900,000 light years) is such that if the Earth, from the very beginning of its existence, two billion years ago, moved with its speed (30 km/s) not around the Sun but in a straight line towards Andromeda, it would have covered by now only 2/9 of the whole route; it would have had seven billion years of moving with the same speed. If we draw a model of the whole Solar system, including the Pluto, with the diameter of 1 cm (using the scale of 10^{-15}), the Alpha of Centaur would be about 50 m away, our neighboring stars – about 100 m from each other, the diameter of the Milky Way – about 900 km, and the Andromeda nebula – about 9000 km away (about the distance from Moscow to Khabarovsk). The most remote of the discovered galaxies – two or three millions of kilometers from the Sun – which itself would be a sphere with the diameter of 1.5 microns.

And we can claim definitively that, no matter where in the vicinity of Andromeda were a thinking intellect able to perceive the external world and no matter how it were designed, – it would definitely be able to know what happened one hour, one year, and one century ago from the current instant, and would definitely not be able to know what will happen within one hour. This tiny hour has not happened yet, neither for us, nor for the inhabitant of Andromeda, although in 60 minutes it will become reality both here and there.

October 20, 1949

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Notes

1. The old-Russian name of the first letter of the Cyrillic alphabet meaning "I" (T).

2. Quotations for well-known Russian proverbs: "The word is not a sparrow, after it has flown away, you cannot return it back" and "What has been written with a pen cannot be cut-off with an axe (T).

3. «Рассказ о семи повешенных», Леонид Андреев.

4. After "The Time Machine" by H.G. Wells.

5. One square second turns into 20π after $N = 10$; $4\pi = 41236.4$ sq. degrees = 148451000 sq. minutes = 534423600000 sq. seconds (NAB).

6. The fourth category should include categories of number (only countable number of objects, not their relations) (NAB).

7. In contrast to English, Russian sentences in (a2) and (b) have the same grammatical forms (conditional mood); however, the words "in proper time" and "now" indicate that the situation does not belong to the realm of possible—(T).

8. From "The Bronze Horseman", A.S. Pushkin (T).

9. From "Anna Karenina", L.N. Tolstoy (T).

10. Solution—the process of solving; definition—the process of defining; reflection—the process of reflecting; perception—the process of perceiving; imagination—the process of imagining; argument—the process of arguing; conclusion—the process of concluding. Exception: recollection—the process of recollecting (T).

11. See in H.G. Wells "The story of Mr. Fortheringay" (The man who could work miracles); but there an interval of time was canceled altogether (NAB).

12. Of course, one should distinguish logical objects from grammatical ones (NAB).

13. "Song of Wise Oleg» A.S. Pushkin (T).

14. A joke common among children. You ask the puzzle: "A and B sat on the chimney. A fell down, B disappeared, what is left on the chimney?" The answer is "and" (T).

15. Most English verbs have two counterparts in Russian—an imperfective verb can refer to a process (I am writing) while a perfective verb can only refer to a singly completed action (I have written/I will have written), and thus it cannot refer to present. A completed action can lead to a result (something written). Consequently, according to Bernstein, ideally, there should be three corresponding verbal nouns denoting a process, its completion, and its result (T).

16. Hoar-frost that crackles with a will is already silvering all the plain ... (the reader thinks the rhyme is *lilies*: here, seize it quick for this quatrain!) ("Eugene Onegin" by A.S. Pushkin, translated by C. Johnston, 1979) (T)

17. Helen closed her face. "You wanted to force me say that I love you—she whispered—here . . . I have said it." ("On the eve" by I.S. Turgenev) (T).

References

Bernstein, N.A. (1947/2020). On the Construction of Movements. Medgiz: Moscow (in Russian). English translation in: M.L. Latash (Ed.) (2020). *Bernstein's construction of movements* (pp. 1–220). Abingdon, UK: Routledge.

Bernstein, N.A. (1930). A new method of mirror cyclographie and its application towards the study of labor movements during work on a workbench. *Hygiene, Safety and Pathology of Labor, 5,* pp. 3–9, and 6, pp. 3–11. (in Russian).

Bernstein, N.A. (1935). The problem of interrelation between coordination and localization. Archives of Biological Science 38: 1–35 (in Russian). English translation can be found in: Bongaardt, R. (2001). How Bernstein conquered movement. In M.L. Latash & V.M. Zatsiorsky (Eds.), *Classics in movement science* (pp. 59–84). Urbana, IL: Human Kinetics.

Bernstein, N.A. (1966). *Essays on the physiology of movements and physiology of activity*. Moscow: Meditsina (in Russian).

Bernstein, N.A. (1967). *The co-ordination and regulation of movements*. Oxford: Pergamon Press.

Bernstein, N.A. (1991). On dexterity and its development. (in Russian).

Bernstein, N.A. (1996). On dexterity and its development. In M.L. Latash & M.T. Turvey (Eds.) *Dexterity and its development* (pp. 1–244). Mahwah, NJ: Erlbaum.

Bernstein, N.A. (2003). *Contemporary studies on the physiology of the neural process*. Moscow, Russia: Smysl. (in Russian).

Latash, M.L. (Ed.) (2020). *Bernstein's construction of movements.* Abingdon, UK: Routledge.

Schnol S.E. (2010). *Geniuses, villains, and conformists in Russian science*. Moscow, Russia: LIBROCOM Publ. (in Russian).

Scholz, J.P. & Schöner, G. (1999). The uncontrolled manifold concept: Identifying control variables for a functional task. *Experimental Brain Research, 126*(3), 289–306. PubMed ID: 10382616 doi:10.1007/s002210050738

Schöner, G. (1995). Recent developments and problems in human movement science and their conceptual implications. *Ecological Psychology, 8,* 291–314.

Schrödinger, E. (1944, 2012). *What is Life? Canto Classics*. Cambridge, UK: Cambridge University Press.

Scientific Session Dedicated to Problems of Physiological Theory of Academician I.P. Pavlov (stenographic report). (1950). Moscow, Russia: Academy of Science Publisher (in Russian).

Turvey, M.T. (1990). Coordination. *American Psychologist, 45*(8), 938–953. doi:10.1037/0003-066X.45.8.938