Anticipation in the Framework of Dominance Studies

Introduction

The problem of anticipation can be seen as one of the leading motives in the legacy of the neurophysiologist and philosopher A.A. Ukhtomsky. It is also one which in particular reflects the underlying unity of his wideranging and little explored works, contributing to a large number of fields sometimes far beyond the traditional boundaries of neurophysiology – both in the spheres of humanities and natural sciences. In both cases, the nature of temporality and determinism in human and biological life, the possibility of purpose, value and action in the natural world were the problems most fundamentally informing Ukhtomsky's investigations in all their diversity. Simultaneously, these are the questions which his research shares with modern anticipatory studies.

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The neurophysiological traditions associated with leading physiologists of the past such as A.A. Ukhtomsky, N.A. Bernstein, P.K. Anokhin, and numerous other ones working in related directions can be seen to still cast relevant light on basic problems in life and mind sciences. As noted at the time by several Western researchers investigating this in detail [..], the basic units of analysis employed in the systemic schools of Soviet neurophysiology could be clearly distinguished from those of their Wesetern counterparts. First of all, this pertains to the understanding of systems in terms of their irreducible and emergent properites, which in living and cognitive systems are inherently bound to their formative history both in individual and phylogenetic development.

It's in this respect important to note that respective trends in biology have regained interest only since the 1990-s, as the field of evolutionary-developmental biology emerged to synthesize the areas of population genetics, embryology, and ecology, which for a major part of the 20th century had developed in relative isolation. This regardless of their essential role for constructing a unified approach to evolution and development, and biology as a systemic discipline in general. As noted by Gilbert, however:

"Although most of developmental biology lost interest in the environmental regulation of development, this environmentalist tradition lived on in Russia, eventually becoming a major part of the Soviet agenda for developmental biology. To A.N. Severtsov, one of the founders of the Russian school of evolutionary morphology, a complete theory of evolution had to causally explain the morphological changes seen in paleontology through the mechanisms of genetics, ecology, and embryology. He believed that genetics alone was insufficient, because it did not address the "how" of evolution. Only ecology and embryology, together, could provide a mechanism for evolutionary change. In his landmark volume Factors in Evolution (1949), Severtsov's student I.I. Schmalhausen attempted to integrate evolutionary morphology, population genetics, experimental embryology, and ecology into a coherent framework to provide a causal theory for evolution." [Gilbert and Bolker 2003: 4]

Analyzing the "Russian evo-devo" and synthesis in evolutionary biology, Levit notes that the very idea of science as a national endeavor must at first seem absurd to most current researchers in biology, reading recent textbooks introducing their discipline and the now intensively developing field of evo-devo. However, considering the historical formation of this field in Russia, he concludes that "the very character of the Russian developmental biology and its intellectual environment predisposed a strong bias towards environmentalist interpretations and thus anticipated what we now call ‘‘ecological developmental biology’’” (Levit 2007: 131). The unique territory of Russia made it possible to investigate extremely diverse ecosystems, at the same time, there was a strong philosophical influence from the German romantic thinkers, predisposing researchers towards broad theoretical generalizations. The periods of partial political and social isolation from the international community following 1917 contributed to the divergence of scientific traditions, further enhanced by the relatively conservative orgnization of Russian scientific schools – devoted more or less loyally to developing the methodology and ideas of their founding fathers. “As a consequence, distinguishable biases within the Russian scientific schools appeared, which however does not mean that these traditions can be opposed to the other national schools” (Levit 2007: 131-132), as indeed, these developed within their own historical context and specific features (e.g., disposition to a higher degree of specialization and division in Western biology).

These considerations are no less relevant for the fields of neurocience and cognitive research, distinguished in the Soviet Union by their particular ties with developmental and evolutionary problems, and indeed hardly possible to consider without this essential dimension. In the most extensive treatment available on the history and methodology of Soviet sciences, L. Graham notes that from all disciplines, the methodological frameworks of Soviet neurophysiology and psychology came to form the most clearly distinct approaches in comparison with Western research in the same areas […]. On the one hand, this has its roots in Russian philosophy, which particularly in the figure of V. Solovyov had a profound influence on the leading thinkers and scientists of the time – among them A.A. Ukhtomsky and D.N. Uznadze, both of whom came to see the problems of freedom and activity as extending to the whole sphere of biological life, seen as a self-creative and non-deterministic phenomenon. Naturally, other philosophical and social factors had a profound influence. As indicated on the other hand, the above-mentioned biological schools of Russian evolutionists had sought to establish the unity of the living organism in its individual and historical (phylogenetic) development. This would be a theoretical perspective with far-reaching consequences also for understanding the role of ontogenetic physiological factors in evolution, as factors operating in the present time and realized in the active behavior and neurophysiological functions of the organism. The evolutionary developmental (epigenetic) perspective in fact allowed the leading figures of Russian neurophysiology such as L.A. Orbeli and A.A. Ukhtomsky to therefore simultaneously pioneer the field of evolutionary physiology, and develop interpretations on the possible relations of ontogenetic activity and the evolution of functions which current research is only beginning to consider. Thus, they write:

> “What has been formed in preceding generations through adaptation to a given environment is reproduced with exceptional rapidity by the new organism of the same type in the same environment. One and the same physiological reaction, beforehand taking decades and centuries to develop, now develops in years, months, and hours. *The difference is only in the speed of reaction development.*
> The life of the real animal (individual) is an extremely fast adaptation to the conditions of life along the traces of ancient and preceding elaborations of its species, and in addition to that, the elaboration of novelty” [Ukhtomsky 2000: 265, original emphasis].

> “The study of conditioned reflexes reveals us the pathways of the functional evolution of the nervous system. The available corrective mechanisms with which we are born were formed in the course of thousands of years according to the same fundamental rules which characterize the formation of new conditioned corrective relations in the course of weeks, sometimes days or hours of our individual lives” [Orbeli 1923].

This indicates that learning and memory formation (as studied in conditioned reflexes) share some of the same basic mechanisms that are employed during embryogenetic development (formation of inborn nervous connections), a fact which is well substantiated by current studies, but highlighted by Orbeli and

Ukhtomsky in the possible common origins. Although both researchers, and similarly N.A. Bernstein, P.K. Anokhin, and other leaders of Soviet neurophysiology drew heavily on the principle of recapitulation to explain such parallel formation and differentiation of functions, the particular interpretations followed by them should be clearly distinguished from those originally advanced by E. Haeckel – which unfortunately due to their misformulations contributed to the demise of the whole idea as a scientifically valid one. Yet at the same time, the same evolutionary developmental principles in their modern formulation were succesfully shown by Soviet researchers to be fundamental in a vast range of comparative evolutionary, ontogenetic, and clinical neuroscientific investigations […].[1]

The controversy of recapitulation deserves attention, as the nature of time in biology in the unity of its historical (phylogenetic), developmental (ontogenetic), and functional (microgenetic) sense forms the very substance of problems related to anticipation in the interpretations of Soviet schools, almost invariably considering time as a historical-genetic and explanatory principle as opposed to an abstract indifferent variable not participating in or defining the nature of functions which it describes (e.g., as in time-reversible physical processes[2]). In the late 1800s, Haeckel characterized the developmental sequence of embryogenesis as a kind of rerun of the species' evolutionary history, based on the ideas that 1) evolutionary changes generally result from adding new ontogenetic changes to the terminal phases of anchestor's development (principle of terminal addition), and 2) there is a scala naturae type of hierarchy of development, where species could be ordered along a single developmental sequence. In contrast to the discredited scala naturae concept, terminal additions in fact can occur in phylogeny, yet the developmental sequence of brains does not recreate adult ancestral stages of the species' evolutionary history (Butler 2005: 60). On the other hand, the same problem had received a different interpretation by the Baltic German evolutionist K. von Baer, a major figure in the history of Russian biological science:

"In the early 1800s, Karl von Baer realized that developmental sequences do not recreate stages from "lower" to "higher" groups of animals. He did note, however, that resemblances occur among embryos within a group, and that the resemblances decrease as development proceeds. von Baer concluded that those features that are common to a group appear earlier in development than the more specialized features of individual taxa within the group. Thus, in the development of the brain of a seagull, for example, we would expect features common to chordates to develop first, followed by features common to all vertebrates, and so on in sequence through features common to jawed vertebrates, sarcopterygians, tetrapods, amniotes, birds, and finally seagulls. von Baer thus believed that over evolution, there is conservation of a number of developmental stages. This concept is referred to as "von Baerian recapitulation," and a growing body of data supports it (Butler 2005: 60-61).

Modern studies showing similar patterns in human brain postnatal development and evolution [Hill et al 2010] highlight the importance of this principle beyond embryogenesis, with significant implications for understanding the longterm development of neurocognitive maturation and functioning into adulthood. It was shown by Hill et al [..] that human postnatal cortical expansion is strikingly nonuniform across different brain regions (ares of lateral temporal, parietal, and frontal cortex expand nearly twice as much as other regions in the insular and medial occipital cortex between term birth and young adulthood), which compared with the macaque monkey cerebral cortex allowed to infer that the patterns of human brain evolutionary expansion are remarkably similar its postnatal development. These results are more

[1] Gilbert'i tsitaat.... seletus Lysenko/Haeckel'i analoogiast.
[2] In this sense it's observed that "no formula of physics actually implies that time passes" (Boxenbaum 1986: 1053).

understandable considering that evolutionary phenotypic changes are a direct result of changes in the ontogenetic sequences, among which shifts in the timing and duration of certain maturation processes relative to others (heterochronia) is a central mechanism [Butler 2005].

These modern studies provide further important considerations due to von Baer's central position in Russian evolutionary thought, and more generally, for understanding the points of departure for later Russian and Soviet neurophysiology beyond the well known classical works of its founding fathers I.M. Sechenov (…), I.P. Pavlov (..), V.M. Bekhterev (…), and others, including Ukhtomsky's teacher N.E. Wedensky (…). Thus, the position of Russian and later Soviet neurophysiology within general evolutionary physiology and biology can be thought to define some of its essential features, of particular importance when analyzing the role of temporal factors and anticipation in the context of general theoretical biology as this was pervasive in the systemic traditions of Soviet neuroscience.

From the contemprary perspective, it's important to note here the clear parallels of these traditions with current research in the behavioral and developmental branches of Western neuroscience. Here, the notions of behavior, form and function as essentially temporal and tied to the whole organism in its own developmental time have emerged to complement the traditional molecular and genetic explanations of biological activity in terms of preformed "developmental programs", encoded in genetic bluprints or preconfigured neuronal circuits, as had been relatively commonly assumed until recently. On the contrary, currently "we are witnessing a resurgence of interest in a diversity of mechanisms – especially developmental mechanisms – that contribute to the form and function of the organism. Most importantly, the behavior of whole organisms has emerged as a central product and *causal influence* of developmental change" (Blumberg et al 2010: 1, our emphasis). This view attempts to place all factors guiding development – from genes to behavior to social systems – in proper balance within a framework of epigenetics and developmental systems. In this respect, it is hoped that "perhaps we are beginning to see glimpses of a new kind of synthesis which will unify time scales from the neurophysiological to the developmental to the evolutionary" (Blumberg et al 2010: 3).

"It now appears that researchers working at both molecular and population levels of analysis are returning to the whole organism in general and development in particular […]. We are coming to appreciate that – in contrast to the comparative anatomy of behavior espoused by Lorenz (1937, 1981) – behavior is not an entity such as a bone or internal organ that has a continuous existence. Rather, *each behavioral performance is unique and ephemeral*, although it may be recognizably similar to other performances by the same individual in the past or other individuals of the same species. *Behavior is elaborated in time* despite the common research practice of treating individual behavioral acts as instantaneous for purposes of analysis. From these perspectives, the causation of behavior, which encompasses the "proximate" physiological mechanisms that generate behavior, also should be seen as a question of historical origins, albeit on a much briefer time scale and therefore within the same continuum of phenomena as development" (Blumberg 2010: 2, our emphasis).

The parallels between these emerging research programs and the earlier work in Soviet traditions is striking, all the more as no reference whatsoever between them seems to have been established within neuroscience proper (as opposed to evolutionary developmental biology, where these connections are actively investigated [..]). On the other hand, what is perhaps the most fundamental and distinctive feature of the considered Soviet authors' works is not only their historical approach, enabling to pioneer evolutionary-developmental perspectives in neuroscience, but first of all the specifically anticipatory dimension that was highlighted by them as an essential and leading factor in the historically formed behavior and cognition of living organisms. It is this dimension that perhaps reflects the most complex and still challenging aspects of the early Soviet schools' legacy, and a dimension which so far finds close theoretical parallels only in the field of anticipatory systems research pioneered in the West since the 1980-s […], and until now, also independently form the respective Soviet traditions. An analysis of these important parallels will have to remain a task for the future. Instead, we will turn to a consideration of the problems of biological time and anticipation as they were formulated by one of the founders of systemic neuroscience in Russia and Soviet Union – A.A. Ukhtomsky.

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The modern context for analyzing Ukhtomsky's contribution is highly diverse and interesting, as indicated above. On the one hand, interest in developmental behavioral neuroscience is on the rise and has never been more active [Blumberg]; within cognitive neuroscience the problems of multiscale temporal dynamics and time-based information coding schemes are emerging as definive of novel developments in the field [Cohen 2011, Papo 1-2, Spivey], simultaneously requiring a "new cognitive metaphysics", in addition to methodological and technological advances to reframe the basic approaches [Van Orden 1-2]. On the other hand, as noted by the same authors – until most recently the question "what are the temporal dimensions of cognition?" has hardly ever been asked by cognitive neuroscientists, "possibly because it appears as either trivial or meaningless" [Papo], and systematic frameworks to investigate or even pose it seem to have been lacking.

> "The problems cognitive neuroscientists try to solve are poorly defined on both the cognitive and neuroscience sides /…/. In the analogy to Plato's cave, our current approach to understanding the biological foundations of cognition is like looking at shadows cast on a region of the wall of the cave without observing how they change dynamically over time /…/. Time is a factor that is often *though not always* ignored in human cognitive neuroscience, and yet several considerations suggest that neural systems may use time as a factor for information coding, processing, and transmission [Cohen 2011: 1-3, emphasis in original].

On this background, it can be suggested that perhaps one of the most comprehensive and systemic attempts at defining the problems of life and mind sciences in a unified language on both sides has been proposed by the neurophysiological school of Ukhtomsky. As will be seen, this was achieved precisely through redefining the role and nature of temporal parameters as organizing factors in neurophysiological and mental functions.

The concept and studies of dominance founded by Ukhtomsky reflect not only one of the most comprehensive neurophysiological generalizations of the past century, but formulated some of the most fundamental principles of physiological investigations in general [Batuev et al 1990], and the integrative and systemic approaches of neuroscience emerging in the Soviet Union in particular. "The whole scientific work of Ukhtomsky least of all belongs to history: in its scientific-conceptual insight it surpassed its own time to the extent that he's our contemporary, whereas the real assessment of some of his ideas and positions even now remains a task for the future" [Batuev et al 1990].

Recent work has highlighted important parallels between the dominance concept and synergetics, which it anticipated in many respects […], as well as the prefiguring of Soviet cybernetics by Ukhtomsky's research […]. Indeed, the dominance concept draw on the latest developments in many contemporary areas ranging from theoretical biology to physics – on the natural science side of the theory. On the other hand, in line with the historical principles of neurophysiology advanced particularly by his teacher N.E. Wedensky (18..-1922), an attempt was made by Ukhtomsky to reconcile these contemporary scientific developments with humanitarian disciplines and to formulate an over-arching, yet concrete, living and experiential understanding of the physiological embodiment of the human mind, its place in nature and society.

On the physiological side, this required a thorough reconsideration of the basic concepts and methods of classical physiology, and the traditions characterizing natural scientific thinking more generally. As Ukhtomsky notes:

"During thousands of years scientific thought has been particularly fascinated by the solid body with its constant properties. This could be most easily subjected to scientific investigation and prediction. The mechanistic natural science considered as its natural task to see everywhere, including in physiology, only solid bodies and the results of their interactions in the organism.

Where it was by no means possible to reduce phenomena to the static bonds of solid bodies and talking about processes and events was still inevitable, particular interest was developed for cases where two or several opposed processes form a more or less stable equilibrium, constantly reestablishing itself. Although we're no more dealing here with a solid body with once and for all stable properties, it's still a combination returning to the initial state sufficiently quickly to be reckoned as an extremely close approximation to a solid body with stable properties /…/. In both cases – in reducing events to the laws of solid bodies and in reducing them to equilibrium laws – what was tempting was specially the possibility to understand phenomena outside of and independly of time [Ukhtomsky 1936/2000: 126].

Ukhtomsky notes that from the early 19th century, classical physiology began to increasingly draw on evolutionary theory and its subfields in the explanaiton of functions, and respectively came to assume the role of termporal factors on the macroscopic scale of processes occurring in living nature – e.g., the formation, modification, and disappearance of species and ecosystems as recorded by paleontological evidence was reflective of changes occurring on an irreversible and unique timescale. At the same time, the view that physiological functions could actually proceed under the immediate dependence of currently given temporal conditions and variations in the microintervals of time would still remain largely neglected. Thus the tasks of the new physiology as envisaged by Ukhtomsky comprised two essential factors: to expand the field of experimental and comparative physiological investigations to the whole of animal and plant kingdoms to study the genesis of functions, and to introduce the historical method with particular reference to microintervals of time as fundamental and irreversible constituents of temporal macroscopic processes. [Ukhtomsky 1937/2000]

"As the events of life always proceed with irreversible succession, equilibrium and reversibility play a secondary and subservient role, and the biologist is still forced to reckon with time as an independent factor not subjet to any exceptions. Therefore it is not so much schemes of equilibrium and reversibility that have a real meaning for the physiologist, as the *relative speeds and intervals of processes* realized in the organism. /…/ Where we speak about the *periods and rates* of interrelated reactions, their duration enables to distinguish *measurable intervals, the relative congruence or divergence of which in the cooperating tissues and organs predetermines the events which occur in them*" (Ukhtomsky 1937/2000: 129, original emphases).

This marked a profound departure from the classical traditions of physiology, and as indicated above, may may not have lost its relevance in the current context of neuroscience and cognitive research. With regard to one of the central physiological concepts underlying dominance theory, Ukhtomsky described this methodological difference characterizing as follows:

"For Western sciences the time of excitation onset (chronaxie) plays mainly the role of a constant characerizing one or another tissue. In lability[3] we see a coefficient that not only changes in the course of reaction, but a coefficient which through its modifications defines in principle the nature of ongoing reactions in the tissue. Western scientists look for conditions in which "temporal parameters" such as chronaxie would change as little as possible. The school of Wedensky directs all its attention at the

[3] Defined as functional mobility/inertia, and technically measured as the maximum number of electrical discharges a system is able to produce per unit of time (1s) under maximum stimulation frequency and with precise correspondance to it.

laws of normal lability changes, holding the view that shifts in lability represent the defining factor in the course of ongoing reactions" (Ukhtomsky 1978:143; italics in original).

This measure attempts to establish the changing temporal interrelations within which the classical parameters of excitation threshold, rate, and onset could be understood as particular instances and values, and be conceptually related to the progressive metabolic and energetic changes which the physiological system undergoes on the whole during its activity (Fig. 1.). It was shown by Ukhtomsky that funtioning does not necessarily lead to decreasing work capacity and functional state of the tissue; on the opposite, in many instances the reverse could be proven to occur: in the course of activity, the tissue gradually assimilates higher frequency rhythms associated with the mobilization of its energetic and metabolic reserves and resources, and increases its lability during exchange with its environment, to the point that the process of work and activity were understood by Ukhtomsky as self-optimizing and autocatalytic phenomena, potentially increasing the non-equilibrium properties of the biological system in the course of its operation. This was seen as particularly characteristic of the physiological state referred to as a dominant state, described by Ukhtomsky in one of his last papers as "a disruptor of equilibrium, as well as a restorer of work capacity in the very energetic meaning of the word" (1978: 209). One of the leading, although implicit questions underlying this problematic was expressed in the same paper – possibly reflecting the influence of one of the founders of (Soviet) theoretical biology Ervin Bauer[4] (- 1937) [1935]: "If a condition was physiologically and physico-chemically possible where a state of higher potential would also become a more stable state /…/, it would be incomparably easier to understand the quick return to this stable equilibrium [after excitation interval], even though it has a higher potential" [Ukhtomsky 1941/1978: 225].

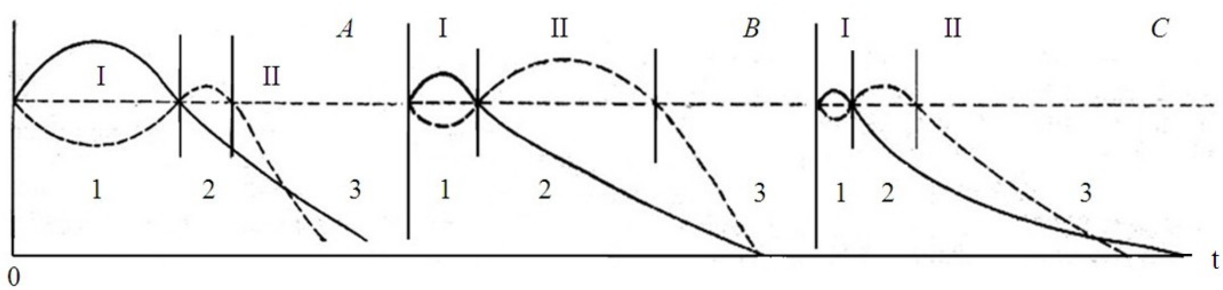

Fig. 2. Schema showing the changing relationships of polarization, lability, and excitability in nervous tissue under prolonged stimulation. Abscissa – duration of stimulation, ordinate – changes of polarization and lability (continuous line) and changes of excitability (dashed line). I – phase of lability and polarization increase; II – phase of polarization and lability decrease. 1 – phase of primary excitability decrease; 2 – phase of excitability increase; 3 – phase of secondary excitability decrease. A, B, C – the influence of agents either amplifying or dampening one or another phase of the reaction. Changes in the rate of elementary cellular reactions, i.e. lability, are parallel to shifts in the polarization level of the cell (increase with hyperpolarization, decrease with depolarization). [Golikov 1968]

"In the central nervous system we have an occasion which violates the principle of least action. It's entirely probable that an individual action potential, once already initiated either in a single neuron, an isolated nerve trunk, or a separate myofibril, will

[4] As testified by Ukhtomsky's close younger colleague I.A. Arshavsky [1990], Ukhtomsky was aware of Bauer's work, although did not refer to it in this paper, nor in his lectures devoted to the problems of biological equilibrium. At the same time, Bauer's work in this area was groundbreaking and remains of great contemporary interest [1993], in addition to voicing similar problems and sharing important ideas with Ukhtomsky's own research (cf. the problem expressed in Ukhtomsky's quote above). Arshavsky, perhaps under the circumstances of his time, expressed surprise over this omission on Ukhtomsky's part. We know today that Bauer had been arrested and executed in 1938, and his works disappeared from Soviet libraries.

normally proceed according to the scheme of least action.[5] At the following moment after an impulse, however, the forced process of potential restoration sets in with the absorption of energy from the environment, and the total working effect can accumulate for as long as necessary, until there is no exhaustion /…/. What concerns the organism on the whole, of course the higher the excitation is, the higher also the expenditure and decrease of potential – however, in normal circumstances the higher also the forced process of restoration, accompanied by the absorption of energy from the environment. How distinct from "least activity"! And first of all, is the organism strictly speaking a closed system in the course of its work? And if it's true that the "organism strives towards equilibrium with its environment", then how profound and voluminous would this environment be in which the organism finds its equilibrium and state of rest?" [1927/1978: 79].

[5] Various parts of the same excitatory unit are characterized by differential lability here. In neurons and nerves, the most labile segments such as the axon and nerve fiber are characterized by a reduced metabolism and simplified biological properties, to the extent that they appoximate to a physico-chemical or almost physical system in Ukhtomsky's description. Other excitatory systems, first of all the cytoplasmic soma of nerve cells restore their resting state significantly slower, involving complex biochemical processes and significant energetic exchange with the environment. These structures are simultaneously less labile. [Ukhtomsky 1941/1978: 213].