Physics and Psychology in the Hierarchical World: Towards Physical Psychology

Pavel B. Ivanov

Troitsk Institute for Innovation and Fusion Research (TRINITI)[†]

Written: 12 December 1995

Abstract

Some aspects of the applicability of physical concepts and formal methods in psychological research are discussed on the basis of ideas present in the scientific and philosophical literature of the former Soviet Union. The possibility of combining physics and psychology into a new interdisciplinary science is inferred from a general hierarchical approach. This combination is not unique, and the difference is discussed between the traditional psychophysics and the new science suggested by the author, physical psychology. This science investigates the possible applications of physical models in psychology reinterpreting the formal schemes of physical theories in psychological terms. As an example, an original mechanical model of human activity and motivation is described, and the directions of its development and generalization are indicated.

1. Introduction

Recent controversy on the adequacy of quantum and classical mechanics [Psyche 1995] for explaining consciousness has shown that the interrelations between physics and psychology still attract attention of scientists and philosophers, and there are questions requiring more consideration. The problem of consciousness naturally arises in any science concerning human (or human-like) behavior, such as psychology, linguistics, or artificial intelligence. Still, any one of these sciences has much of its own to investigate, without special reference to conscious action. One might expect that the same holds for physics as well.

Most generally, there are three groups of questions:

1. What can psychology give to physics?
2. What can physics give to psychology?
3. Is there any way to combine these sciences?

For brevity, I mean all the variety of sciences related to human behavior and consciousness under “psychology”, from neurophysiology to philosophical treatment. Similarly, all the variety of physical sciences together with metaphysical generalizations is assumed under “physics”. Of course, the same questions may be asked about any particular branch in psychology or physics; this requires a specific projection of the general discussion.

In the literature, the first of the three groups of questions is represented exclusively by the problem of introducing observer into quantum mechanics. I discuss this problem in Section 2. Still there are other aspects of applicability of psychological concepts in physics, and I present some considerations on that in Section 3, which is mainly devoted to the role physics may play in psychological research. Section 4 describes a new interdisciplinary area of science, which I name *physical psychology*; the subject of this science is specified, and some of its methods are discussed. As an example, a mechanical model of temperament is outlined in Section 6, which is preceded with a brief summary of

---

[†] The author is no longer affiliate to TRINITI

Newtonian mechanics required to understand the model (Section 5). Concluding remarks indicate possible applications and the ways of generalization of the mechanical model, including the description of consciousness in physical psychology.

There are different schools in both psychology and physics, and I cannot equally speak about all of them. In the early 1980s, there was a wide discussion of similar questions in the scientific circles of the former Soviet Union [Tsekhmistro 1981; Kravchuk 1983; Sudakov 1983]. These ideas are less known to the English-reading audience and may therefore provide new possibilities for extending the range of related topics. That is why, in this article, I have chosen to base my argument on the Russian scientific tradition. It is assumed that the reader is acquainted with American and European literature on the subject and may compare my approach with it. Accordingly, most references in this article are to the works of Russian-speaking researchers, though I tried to find the English translations where possible.

In a few words, my position might be stated like this:

> 1. Nature is a hierarchy of objects, and each level of this hierarchy should be studied with methods appropriate at this level, so that the hierarchy of sciences reflects the natural hierarchy of the world. Thus, physics studies *physical objects* that are different from *psychological objects*; still, the both kinds of objects exist in Nature independently of whether somebody is studying them or not. The development of any science is the process of simultaneous formation of its subject and its methods.
>
> 2. The hierarchy of Nature is not rigid, it manifests itself as different hierarchical structures, so that the levels distinguished in one structure may be fused together in another, and vice versa. Every two levels of the hierarchy imply an intermediate level, combining the features of the both. In science, it means that for every two sciences one may construct another science, lying "between" these two. In particular, one may seek for some combination of physics and psychology, which, evidently, is not unique since there can exist sciences intermediate for this combination and the "pure" physics or psychology.
>
> 3. The levels of hierarchy are *qualitatively* different, and no one of them can be reduced to another, or deduced from the other levels. In particular, psychological phenomena cannot be reduced to physiology, chemistry or physics, or deduced from them. Human psychology is drastically dependent on social factors, and consciousness should be considered as a collective effect arising from thousands acts of communication between many people, rather than from some neural or physical processes in one's brain. However, consciousness would be impossible without appropriate premises, one of which is the admirable versatility of the human brain.

These brief formulations are, to some extent, unfolded in the following discourse, though I do not try to argue for them specifically, since this would lead me far from the subject of this article.

2. The Observer in Physics

The beginning of the twentieth century was marked by the appearance of two famous physical theories which seem to picture the Universe quite differently compared to the earlier conceptions. Both relativity and quantum mechanics are strange enough to excite popular admiration. Still, while people have gradually grown accustomed to the contracting measures and curved space-time, they cannot generally comprehend the transition from quantum waves to the solid definiteness of the perceptible world. Such transition is then attributed to some conscious intervention, and the observer is claimed to be an indispensable part of quantum science.

But are quantum and classical theories so different as it seems? Actually, there are many formulations of the both, sometimes presenting rather smooth mutual transitions between them [Mensky 1983]. And is there any real need in the observer?

From the practical side, the task of a physicist is to predict the results of certain manipulations with material bodies using some pre-defined procedures called *physical methods*. The registration of some result follows a formal scheme which is called *measurement*. When an experimenter reports his results to the physical community, the main efforts are spent to make the experimental procedure as close to a common standard as possible, and to reduce the influence of any side factors, including experimenter's mind and personality. Thus the very idea of measurement assumes the extinction of the observer, and this holds equally for classical and quantum measurements. Physical theory refines the schemes of measurement abstracting from the last traces of individuality; the whole of physics becomes then fully observerless.

The same idea can be put another way. Physical science deals with some formal model of observer, rather than with a real human being, and it is this model that is reflected in the form of the physical theory. Such formal observer is just a representation of some standard procedure, and the observer's activity is reduced to the implementation of a sequence of operations, which could be much better performed by some automatic device. In this sense, the observer is present in any part of physics, and not only in quantum mechanics. It is only the rules of observation that change from one physical science to another depending on their specific methods.

How the observer is represented in classical mechanics? There are many formulations of classical mechanics, and each formulation has its own way of postulating the formal behavior of the observer; still, one may say that all these observers are physically equivalent since they lead to the same dynamics. For example, the traditional Newtonian mechanics models the observer introducing the conception of *reference frame*. To observe the classical behavior of a physical system, the observer should be present in any point of the three-dimensional space in the same moment of time, to become aware of any event immediately. Such observer is effectively infinite and coincides with the whole of the Universe. This may be possible if the movements considered are much slower then the movements involved in the process of measurement (adiabatic limit).

The relativistic generalization of classical mechanics is obtained when the movements described are as fast as, or even more fast than the processes implied by the measurement scheme. To maintain the conception of the reference frame, physicists have to associate it with the own movement of the observer, thus mixing space and time in the four-dimensional space-time. In other words, the reference frame is not a static prerequisite, but rather the process of establishing the connection between different spatial points. Relativistic observer is essentially local and cannot be aware of any events occurring in very far spatial points.

Quantum mechanics generalizes the classical conceptions in the opposite direction, so to say. While relativism speaks of a very small observer, the observer of quantum theory is extremely big, even much bigger than the classical (infinite) observer. Each point of its space (reference frame) becomes a whole three-dimensional space, and each point of this *internal* space is supposed to be somehow structured too, when it comes to accounting for spin and other *group* features. For example, the infinity of atomic physics is practically about several microns, or even fractions of a micron, which can be considered a point in many macroscopic movements. Theory idealizes this scale difference, taking the *practical* infinity for the true infinity; this is the source of formal contradictions arising when one tries to comprehend the transition from quantum processes to macroscopic measurements, from one level of hierarchy to another.

Usually, physicists clearly understand the limited applicability of theoretical abstractions and easily switch from one theory to another depending on the circumstances. Thus, the region between atomic and macroscopic lengths is better described by quasi-classical approach, and the same nucleus may be considered either as a solid body, or as a Fermi gas, or as a quantum liquid. Only the most deep theoreticians can forget the reality and raise a controversy about nothing. Unfortunately, many popular relations of physical theories lack indications to the limits of their applicability, so that the readers might be deluded by some peremptory claims.

In a quite analogous way, the abstraction of observer might be defined for any other branch of physics: thermodynamics, electromagnetism, hydrodynamics, and so on. Similarly, there must be natural transitions between physical sciences. For example, adiabatic processes in thermodynamics manifest quite classical behavior, so that phenomenological parameters like temperature, volume, or pressure, may be used as generalized coordinates.

3. Physical Methods in Psychology

Since physics provides a variety of abstractions to describe some idealized actions of a human observer, it may be asked whether such formal descriptions might be useful to study human behavior in general, rather than only physical experimenting. For instance, quantum or classical mechanics might reflect some features common to a wide range of human activities, or even some universal traits. After all, science begins where unique events may be generalized and thus made the abstract schemes applicable to many particular cases. Psychology, if it wants to be a science, has to develop its own abstractions, and one cannot demand that it give a comprehensive explanation of any detail of an isolated human act. Rather, psychological analysis should classify individual acts, bring then under some pre-defined categories, which are familiar enough to enable people's control over their behavior, just like people control physical processes.

I should stress that physics in no way can *explain* the origin of psychological phenomena and consciousness—this is the task of psychology proper. Likewise, psychology cannot be derived from any chemical or biological laws, from the physiology of the brain or some computational considerations. All one may ask is how these biological, chemical or physical processes are involved in a conscious action, as soon as one knows that they are actually involved in it.

There are different ways of approaching psychology from the physical side. One way is to treat a human being as a physical object, albeit very unusual one. Then we can physically act on that object and observe its physical reactions, trying to catch the apparent regularities in some formulas. For instance, exposing a person to some flashing lights, various sounds, electric shocks, sequences of words or even congruous texts, music or movies, may result in person's reactions, like pressing a button, saying something, going to a nearby supermarket and buying a new hat, and so on. Physical measurement does not worry about the specific personal sense of these reactions; all that is relevant is distinguishing a number of *physically different* outcomes which can be somehow labeled with a numerical parameter. Such procedures can be highly formalized, and they differ from physical experiments proper only in their object. This is a psychological study in the least degree, and it may be also considered a kind of physical research, namely *psychological physics*, or *psychophysics*. The most popular psychophysical methods include various timing procedures, the measurements of transmission characteristics (for example, the dependence of evaluated sound pitch on the sound frequency), and numerous threshold measurements (quite analogous, say, to ionization potential measurements in atomic physics) [Zabrodin and Lebedev 1977].

Here, the key point is the usage of *physical* criteria for distinguishing different reactions. Thus, if one is interested in physiological consequences of some manipulations with a human being, this should be called psychophysiological rather than psychophysical investigation. Likewise, one might consider the influence of stress onto speech production—this is a psycholinguistic study. Psychological research would center on specifically psychological phenomena, such as the change in the motivation structure, or the level of self-respect. It does not matter how formal the means of this study are, as long as the focus on the psychological side of the problem is preserved. In fact, psychological concepts are not a bit less abstract than the most abstruse constructions in theoretical physics. The term "*the will*" may seem somewhat more clear than "*autoionization*", but this is mostly due to more evident manifestation of will in our everyday life, while autoionization is not so easily observed, though it is much more common in Nature.

There is an important distinction between the higher and lower levels of hierarchy. Any psychological event can always be considered from the physical side as a sequence of physical events, while there may be physical events that do not assume any psychological content, and some physical events may accompany many psychological events. However, since human knowledge about the physical world is governed by people's practical needs, science only deals with events related to some human activity, and it would be quite admissible to reveal some relation to psychology in any *known* physical event.

Now, it is evident that psychophysics is not the only way to combine physics and psychology. Since any movement in the mind is realized as a sequence of physical events, mental phenomena must not violate physical laws, and one may predict some gross features of thinking for a number of hypothetical creatures living in the worlds with different values of some fundamental physical constants. Thus, another application of physics to psychology is to consider the influence of a definite structure of the physical world to mental processes [Dyson 1979].

One more possibility is to build a "compound" theory, where the influence of mind on physical movements is introduced explicitly as some phenomenological *constraint*, and in turn, physical laws are regarded as the constraints for the possible changes of mind [Korenev 1977, 1981]. Unfortunately, this approach did not attract many scientists, because the construction of such theory requires a tremendous technical work.

Now, let us imagine that one carries out a purely psychological research, and the results strongly resemble the behavior of some physical system. The researcher might trace this analogy as far as it is possible, and apply a well developed physical theory to the regularities observed at the psychological level. This seems even more admissible since physics itself has been extensively practicing such formal borrowing of theories since pre-historic times. I have already mentioned the mechanical treatment of adiabatic thermodynamic processes. Virtually, one can find no physical theory that has not ever been influenced by some other science, either physical or not.

This application of physical theories and mathematics in psychology may be rather superfluous, when physics is taken only as a source of useful metaphors [Nalimov 1981]. There may also exist less metaphorical theories, trying to predict the processes in some simple situations solving the equations of dynamics [Ivliyev 1988].

Modern physics is rather broad-flung, and it includes many models far from the traditional description of dynamics. Fractals and neural networks became very popular nowadays in the physics of condensed media and surfaces; also, there are theories examining computational or informational properties of physical systems [Bernstein and Levine 1975; Caianiello 1992]. Sometime, these theories may lead to a new revolution in physics, and they can also be applied to psychological problems to obtain an explanation of existing mental structures. One such model, combining quantum-mechanical and informational conceptions with a general hierarchical approach has been reported recently [Avdeev and Ivanov 1993; Ivanov 1994]. An explanation of the discrete nature of musical pitch perception has been given, so that the properties of all existing musical scales could be described with a few *a priori* computable values. Similar scaling was discovered in visual perception as well [Ivanov 1995].

When the formal constructions of physics are applied to a psychological problem, they do not change the psychological orientation of research in general. Since it is psychological phenomena that are to be described, the parameters and variables of the theory must be psychologically interpreted, and they lose any relation to their physical counterparts. Accordingly, the results formally obtained in this model are psychological, rather than physical. That is why one can speak of such theory as a branch in psychology, which could be called *physical psychology*.

4. Foundations of Physical Psychology

Physical psychology investigates possibilities for psychological interpretation of physical theories, building new models on their basis to more exactly describe psychological phenomena.

This formal transfer could only be possible if there were an actual similarity of methods of the both areas of science. Luckily, such similarity does exist. In the most general form, it ascends to the universal logic of scientific research, which reflects the unity of the Universe. Naturally, specific methodological parallels may be found too. One of them is the general scheme of scientific experiment, assuming the registration of some object's response to a standard external influence [Vygotsky 1983]. The object is thus considered to be a *system*, that is, it transforms some input into some output trough a sequence of internal states. Most clearly, this approach manifests itself in the matrix formalism of quantum scattering theory, and in the stimulus-reaction scheme of classical behaviorism. The alternative class of scientific methods may be called structural approach, and the main goal of a structural study is the explication of the internal integrity of the object, connecting its distinct parts into the whole, opposed to its environment. One may take the atomic paradigm in physics or gestalt psychology for the examples. Recent research often combines structural and systematic methods, which leads to the consideration of the object's development, and the stages of this development become represented in it as different levels of its inherent hierarchy [Leontiev 1978; Vekker 1981; Eliseyev 1983; Ivanov 1994, 1995].

Physical psychology does not aim to obtaining any new psychological data, leaving this to psychology proper. The models of physical psychology should conform to existing psychological data and give reasonable results where it is possible to measure some of their parameters. However, physical psychology could help to understand the meaning of the existing experimental procedures in psychology, and even suggest new quantities that psychologists might measure. Still, the methods of physical psychology should not replace the specifically psychological methods, especially where there are no physical models available.

Also, physical psychology is not a branch of physics, since its subject differs from the subjects of physical sciences. Physical psychology borrows ready models from physics, but it applies them to the systems of quite another type, in which the processes do not directly correspond to physical processes in a system of material bodies. One might say that physical psychology is the physics of the ideal, in contrast to the ordinary, “material” physics. But, since the ideal and the material are just the two sides of one reality, one should expect that some features of physical models in psychology would somehow manifest themselves in physical research proper, and there would be a way back, from psychology to physics.

For physical psychology, a person is not only a material body having a definite movement in the physical space-time. The main interest concentrates on internal, subjective processes that cannot be characterized with reaction delays, sensory organ attenuation curves, spatial distribution of excitation in the brain and interactions of its parts, the mechanics of muscles etc. That is why the subject of physical psychology does not coincide with the subject of psychophysics, which describes just these external manifestations of psychic processes. In a way, this difference is similar to the difference of the physiology of higher neural processes and neurophysiology: the former studies the physiological mechanisms underlying psychological phenomena, while the latter describes these phenomena in terms of neurodynamics [Luria 1973].

Since theoretical physics widely exploits mathematics of any kind, it might be expected that the same mathematics would be applicable to ideal, psychological processes. This application, however, is different from that of mathematical psychology. The latter studies the possibility of correlating psychological entities with mathematical objects as such, the ways of mathematization. Naturally, one or another mathematical representation is a necessary stage in the development of a physical model, but mathematics is only a background for physical theory, the principal concepts of which lie beyond any mathematics. In physical psychology mathematics is only introduced through a physical model, and does not require direct mathematical analysis of psychological data. For example, there are situations in physics, when the same model is described with different mathematics (like the Heisenberg and Shrödinger representations in non-relativistic quantum mechanics); when this model is transferred to psychology, all its mathematical forms are transferred with it, and may be used without any special reservations as soon as the analogs of the corresponding quantities are discovered. On the other side, the mathematical methods of psychology cannot always be related to any physical model.

Thus, physical psychology has a definite subject different from the subjects of psychophysics and mathematical psychology; it combines the elements of physics, mathematics and psychology never coinciding with either of them.

5. The Scheme of Newtonian Mechanics

Classical mechanics plays a particular role in physics. Hundreds of years brought physicist a tremendous experience of constructing mechanical models for thousands of special cases. There are many quite different formulations of classical mechanics, establishing its links with other physical sciences. This is why new physical theories are often first applied to classical models, which is the best way to demonstrate the essence of a new approach.

Speaking of physical psychology as a new science, it would be natural to apply to classical mechanics to get a general conception of how physical models might work in psychology. The simplest mechanical theory is the commonly known Newtonian mechanics which is the first step in everybody's studying physics. In the following section, I present a psychological model built on the basis of Newtonian mechanics. Omitting the computational details, I focus on the conceptual shift from physics to psychology, and on the ways of interpreting formal mechanical results.

To fix the terms, I should briefly describe the formalism of classical mechanics in the Newtonian formulation. The basic objects of this theory are called the *material points*. Each material point is characterized by its *mass*, which is usually denoted with the letter m. For each material point, one can specify its *position* in some *configuration space*, which can be either the ordinary three-dimensional space or some abstract space of one or more dimensions. One can fix a *reference frame* in the configuration space, and the position of some material point is then defined with a set of numbers, which are called its *coordinates* in this frame. Usually, these coordinates are considered as the components of a vector, that is, the mathematical object characterized by both its absolute value (or length) and its orientation in the configuration space. I will denote the position of a material point with the letter $\boldsymbol{x}$, where the boldface indicates that this is a vector, and the length of this vector will be denoted with the same letter x in normal face. The movement of a material point is just changing its position in the configuration space with time t; this movement is characterized with a definite *velocity*, described with a vector $\boldsymbol{v}$, the first derivative of $\boldsymbol{x}$ in time: $\boldsymbol{v} = d\boldsymbol{x}/dt$. The first derivative of $\boldsymbol{v}$ is called *acceleration* and denoted with the letter $\boldsymbol{a}$. One more important quantity is material point's *momentum* $\boldsymbol{p}$ defined as the product of its mass and its velocity: $\boldsymbol{p} = m\boldsymbol{v}$. The principal law of Newtonian dynamics is then formulated as follows: the first derivative of $\boldsymbol{p}$ in time is a vector function $\boldsymbol{F}$ of time, material point's position, and its velocity:

$$d\boldsymbol{p}/dt = \boldsymbol{F}(t, \boldsymbol{x}, \boldsymbol{v}) .$$

The function $\boldsymbol{F}$ depends on the nature of the physical system concerned and is called *force*. The solution of this *equation of motion* gives the position of the material point at any moment of time, and all the other characteristics can be calculated knowing $\boldsymbol{x}(t)$.

A mechanical system may consist of many material points. In this case, the force acting on any one of them depends also on the positions and velocities of other material points, and the law of system's dynamics (commonly known as the second law of Newton) becomes a system of equations, one for each material point in the system. However, such system can be treated as containing only one material point moving in the space of higher dimension. For example, two points in the ordinary space are characterized by six coordinates, which can be interpreted as a point in a six-dimensional space.

Usually, in Newtonian mechanics, masses do not depend on time, and Newton's second law can be rewritten as follows:

$$d\boldsymbol{p}/dt = d(m\boldsymbol{v})/dt = m\, d\boldsymbol{v}/dt = m\boldsymbol{a} = \boldsymbol{F},$$

that is, the force acting on a material point equals its acceleration multiplied by its mass.

In some cases, $\boldsymbol{F}$ does not depend on t explicitly, and there exists such function $U(\boldsymbol{x})$ such that

$$\boldsymbol{E} = m\boldsymbol{v}^2/2 + U(\boldsymbol{x})$$

does not depend on time. The value E is called the *total energy* of the system, and it is the sum of *kinetic energy* $m\boldsymbol{v}^2/2$ and *potential energy* $U(\boldsymbol{x})$. Since potential energy depends only on the position in the configuration space, it can be considered as some potential field existing in this space as an independent entity. The equation $E = \text{const}$ is called either the conservativeness of the system, or the law of energy conservation. For conservative systems, $\boldsymbol{x}(t)$ can also be retrieved from this equation.

One of the most popular mechanical systems is *harmonic oscillator*. In the simplest case, it is defined by the equation of motion

$$m\boldsymbol{a} = -\omega^2 (\boldsymbol{x}-\boldsymbol{x}_0),$$

that is, the force is proportional to the displacement from some *equilibrium point* $\boldsymbol{x}_0$, and directed always back to this point. This equation describes a wide range of oscillations around the point $\boldsymbol{x}_0$. The one-dimensional solution is

$$\boldsymbol{x} = \boldsymbol{x}_0 + \boldsymbol{A} \cos(\omega t + \varphi),$$

that is, the material point repeatedly ($\omega/2\pi$ times per the unit of time) moves away from the equilibrium point, and then returns to it, moving on in the opposite direction. The constant $\boldsymbol{A}$ is called the amplitude, and the constant phi is called the phase of the oscillation. Potential energy in this system is given by the equation

$$U = m\omega^2(\boldsymbol{x}-\boldsymbol{x}_0)^2/2,$$

which has the same form as the expression for kinetic energy, with the only replacement $\boldsymbol{v} \to \omega(\boldsymbol{x}-\boldsymbol{x}_0)$. The minimum of the potential energy corresponds to the equilibrium point.

Also, there are more complex solutions, when each component of vector $\boldsymbol{x}$ oscillates with its own amplitude and phase. For example, the two-dimensional oscillations include the movement along an ellipse, and the circular movement around the equilibrium point. In this latter case, the velocity and acceleration of the material point are constant in the absolute value, and it is only their orientation that changes. This means that not only the total energy is conserved, but both the kinetic energy and the potential energy are constant too.

6. Motivation and temperament

According to the general theory of A. N. Leontiev [Leontiev 1978; Ivanov 1995], human activity is governed with some motive and is realized in a sequence of actions directed to their specific goals. People are unaware of their motives, and it is their goals that are conscious. In the course of action, the motivation may change, so that one activity flows into another. Sometimes, the former goals become motives, and a motive may become just an intermediate goal.

Let us imagine, that, in some situations, a motive can be represented by a point in some *motivation space*. The goals belong to the same space, to enable the free transformation of goals into motives, and motives into goals. Now, human activity is represented by a trajectory $\boldsymbol{x}(t)$ in the motivation space, that is, by a sequence of points representing the current goals. The motive of this activity is naturally represented by some attracting center in the motivation space, so that the activity can be thought of as a solution of the equation of motion, just like Newton's second law in classical mechanics.

Within this analogy, the mass m of the material point may correspond to the internal inertia of mind, which is an important personal characteristic. The greater is the mass, the less readily the person yields to external influences (which can be represented by some forces in the mechanical model). The velocity $\boldsymbol{v}$ naturally describes the rapidity and the direction of an action; this is the example of characteristic, that has no direct psychological analog, though it is quite compatible with the psychological conceptions. As for momentum $\boldsymbol{p} = m\boldsymbol{v}$, the corresponding psychological characteristic might be called the *persistence* of the activity, that is, its ability to preserve the same course in spite of any deflecting forces. Quite naturally, persons with high inertness are more persistent in their activity, and the higher is the rate of activity, the less noticeable is the effect of other activities on it.

In Newtonian mechanics, the special place belongs to acceleration. Any change in the state of motion assumes a non-zero acceleration, and it is acceleration that is felt by a classical observer as a mechanical event. When the observer is moving without acceleration, the movement of any material point is described with the same equations of motion, as for the motionless observer. This means that all the reference frames moving without acceleration are mechanically equivalent; they are called inertial frames. It is natural to put forward the hypothesis that the analog of acceleration in the psychology of activity is the subjective feeling of all the forces acting on the person; this feeling may be associated with the person's emotions.

Now, the general picture of human activity looks as follows: a person’s interaction with the world (including the person’s body, and the brain) results in some distribution of forces in the motivation space of the person; this forces excite definite emotions in the person, which change the state of motion, that is, the rapidity of changing actions and goals, and the direction of this change.

The immediate inference of the model is that the same force will excite less emotions in a person with high inertia, since acceleration equals force divided by mass. This is the well known low emotionality of the people with phlegmatic temperament. Following this line, one could ask whether the other classical temperaments (sanguine, choleric, and melancholic) might have a mechanical explanation too. It is well known, that the conception of the four temperaments takes its origin in the Ancient Greek philosophy, and it has been physiologically interpreted in Pavlov’s theory of reflexes. The temperaments are distinguished according to the values of three parameters: strength, mobility, and balance. Thus, the sanguine temperament assumes strong, mobile, and well-balanced nervous processes, while choleric temperament is poorly balanced and the phlegmatic temperament lacks mobility; all the weak temperaments are called melancholic. The mechanical interpretation of these parameters of temperament can be given on the basis of the principal law of dynamics: force equals mass times acceleration, $\boldsymbol{F} = m\boldsymbol{a}$. One can notice that the strength of temperament characterizes the degree of a person's sensitivity to external circumstances. In the mechanical language one may say that the environment acts with less force on a person with the greater strength of temperament, that is, the absolute value of the force is inversely related to the temperament strength. The relation of mass to inertia (the inverse of mobility) has already been indicated. Quite naturally, balance is characterized by the value of acceleration: the completely balanced state of the system assumes zero acceleration.

With these assumptions, the sanguine temperament must be characterized with small F, which, at medium m, results in low accelerations a. Since the phlegmatic temperament is characterized with a significantly higher mass, even much greater forces cause rather low accelerations, and a phlegmatic person keeps balance in a wider range of situations. The opposite is valid for choleric temperament, which assumes rather low inertia: even a small force can break the balance in a choleric person. As for the melancholic temperament, it is mostly characterized with a rather great sensitivity to the processes in the environment, that is, with high values of F. The effect of that on the person's activity may be different, depending on the person's inertia. Actually, there are three kinds of melancholic temperament corresponding to the three other temperaments. Very inert persons remain balanced in spite of all their strong interactions with the world. Medium inertia, like that of sanguine person, results in much higher emotional reactions. The most weak type of melancholic is characterized with low inertia; this is an extremely vulnerable person, feeling the flood of emotions at any turn of the situation.

The mechanical treatment of temperament differs from the traditional approach in that the two of the parameters of temperament, strength and balance, are usually assumed to be individual constants, while force and acceleration in the mechanical model are true dynamic variables, which may change very much in the course of activity. One solution of this problem could be that temperament reflects the averaged features of activity, and its parameters should be related to the time-averaged values of force and acceleration. For many periodic and quasi-periodic movements, these variables vary in a small range in the absolute value, assuming any possible orientation. The simplest case is the circular motion described in the previous section. The absolute values of force and acceleration are exactly constant for this movement, and they can be directly interpreted as the parameters of temperament.

The mechanical model of activity can be developed in detail, finding more analogies between physics and psychology. My purpose is only to demonstrate how physical theories can be reinterpreted to become the theories of some psychological phenomena. As an example of a more complex result, I would like to mention the possible application of this model to the description of neuroses. Normally, no place in the motivation space is inaccessible for human activity: for any given point there should always exist some trajectory containing this point. Still, the person’s interaction with the world may sometimes result in a singular potential, breaking the simple topology of the motivation space. The well known physical example is Coulomb potential of a charged point, assuming the infinite value at the position of the charge. In such cases, activity may come very close to the point of singularity, but it will just move around, never achieving this point. The existence of such forbidden area in the motivation space corresponds to the clinical picture of neurosis. The mechanical model permits the description of different kinds of neuroses, depending on the singularity type. As one can see, neurosis cannot be overcome by the own activity of a person, and the treatment of neuroses requires the change in the person's environment removing the singularity from the motivation space.

7. Conclusions

I have demonstrated how relatively simple mechanical conceptions might be introduced into psychology of activity. Naturally, there are many other applications of the same model. Thus, one can reinterpret mechanical equations of motion so that they would describe the development of communication between a number of people, the interaction of social roles in a small group, and so forth.

Also, one can borrow some other theory from physics, and apply it to the same problem. For instance, quantum mechanics would be useful to expand the description of an individual action, which in the above model is represented by the momentary goal and persistence of activity. In the quantum model, the point in the classical configuration space will be replaced with some internal space, as it was described in Section 2. Then, the action may be considered as a process in this internal space, resulting in a probabilistic outcome at the level of activity.

Surely, the most interesting problem of physical psychology is the description of consciousness. However, the origin of consciousness cannot be discussed within physical psychology. One can only speak about representing consciousness in any physical-psychological model using the concepts and laws appropriate for this model. Thus, in the theory of activity described above, consciousness is referred to the level of action, and the person is not aware of the motive of activity. This can be easily understood if one regards the goal (the point in the motivation space) as a focus of awareness; the activity is then interpreted as the gradual shift of this focus from one goal to another. Since the points of minimum potential energy (representing the possible motives) do not, in general, lie on the trajectory of activity, the motives remain unconscious. This is the most obvious in the case of circular motion, with the motive in the center of the circle, and the goals always equally distanced from the motive. Actually, there may be some processes of *motivation*, which make the discovery of the motive of activity a special goal. Some activities will include motivational actions, and some will not, depending on whether the motive point lies on the trajectory of activity or not.

Other physical models may give a more detailed description of consciousness. Thus, physics has discovered many cases of *collective motion*, when the different parts of the system move in accord for a comprehensible time. Collective phenomena, such as solitons in liquids and solids, plasma pinches, autoionization states in atoms, and many others, appear due to some kind of non-linearity, that is, the interaction of a physical system with itself mediated by its environment. As G. R. Mulhauser [Mulhauser 1995] has indicated, each body in the cosmos is in many ways bound to its environments, and consideration of an isolated system can be possible only in abstraction. The more so for the human brain, which is eventually just the device to perform universal reflection, virtually interacting with the whole world. There is experimental evidence that consciousness is essentially a collective effect arising from the variety of interpersonal communications [Vygotsky 1986; Leontiev 1978]. This collective nature is reflected in the organization of the human brain and the interplay of the neural processes accompanying human activity [Luria 1973]. That is why the physical theories of non-linear phenomena may add more light to the problem of consciousness.

References

Avdeev, L V and Ivanov, P B (1993) “A mathematical model of scale perception.” *Journal of Moscow Physical Society*, **3**, 331–353

Bernstein, R B and Levine, R D (1975) “Role of energy in reactive molecular scattering: An information-theoretic approach.” *Advances in Atomic and Molecular Physics*, **11**, 215–297

Caianiello, E R (1992) “Quantum and other physics as systems theory.” *La Rivista della Nuovo Cimento*, **15**, no. 4

Dyson, F J (1979) “Time without end: Physics and biology in an open universe.” *Reviews of Modern Physics*, **51**, 447–460

Eliseyev, E N (1983) *Structure of development in complex systems* Leningrad: Nauka (In Russian)

Ivanov, P B (1994) “A hierarchical theory of aesthetic perception: Musical scales.” *Leonardo*, **27**, no. 5, 417–421

Ivanov, P B (1995) “A hierarchical theory of aesthetic perception: Scales in the visual arts.” *Leonardo Music Journal*, **5**, 49–55

Ivliyev, Yu A (1988) “New mathematical methods in psychology, their development and application (a problem study).” *Psikhologicheskiy Zhurnal* (Psychological Journal), **9**, 103–113 (In Russian)

Korenev, G V (1977) *Introduction to the mechanics of man* Moscow: Nauka (In Russian)

Korenev, G V (1981) “A mathematical model of a psychomotoric act.” *Psikhologicheskiy Zhurnal* (Psychological Journal), **2**, 124–139 (In Russian)

Kravchuk, N V (1983) *Methodological notes on the possibility of the application of quantum theory to the modeling of some aspects of psychics* Preprint ITF-83-69R Kiev: Institute of Theoretical Physics (In Russian)

Leontiev, A N (1978) *Activity, consciousness and personality* Englewood Cliffs, NJ: Prentice Hall, Inc. (Originally published in 1975)

Luria, A R (1973) *Foundations of neuropsychology* Moscow: Moscow State University (In Russian)

Mensky, M B (1983) *The path group: Measurements, fields, and particles* Moscow: Nauka (In Russian)

Mulhauser, G R (1995) “On the end of quantum mechanical romance.” Online: *http://psyche.cs.monash.edu.au/volume2-1/psyche-95-2-19-decoherence-1-mulhauser.html*

Nalimov, V V (1981) “On the possibility of metaphorical use of mathematical conceptions in psychology.” *Psikhologicheskiy Zhurnal* (Psychological Journal), **2**, 39–47 (In Russian)

Psyche (1995) (Vol. 2) Symposium on Roger Penrose’s *Shadows of the Mind* Online: *http://psyche.cs.monash.edu.au/psyche-index-v2_1.html#som*

Psyche (1995) (Vol. 2) Symposium on Quantum Theory and Consciousness. Online: *http://psyche.cs.monash.edu.au/psyche-index-v2_1.html#qm*

Sudakov, K V (1983) “Systemic quantization of the behavior.” *Uspekhi Fizicheskikh Nauk* (Advances in Physical Sciences), **14**, 3–26 (In Russian)

Tsekhmistro, I Z (1981) *Search for a quantum conception of the physical origin of consciousness* Kharkov: Kharkov State University

Vekker, L M (1981) *Psychic processes* (Vol. 3) Leningrad: Leningrad State University (In Russian)

Vygotsky, L (1983) “History of the development of the higher psychic functions.” In: *Collected works in 6 volumes* (Vol. 3, pp. 5–328) Moscow: Pedagogika (Written in 1931; partially published in 1960) (In Russian)

Vygotsky, L (1986) *Thought and language* (Alex Kozulin, ed.) Cambridge, MA: MIT Press. (Original work published in 1934)

Zabrodin, Yu M and Lebedev, A N (1977) *Psychophysiology and psychophysics* Moscow: Nauka (In Russian)