Actes du Congrès international de recherche en sciences humaines et sociales, Paris 24-28 juillet 2012
(G. Tchibozo, dir.) – Strasbourg (France) : Analytrics, 2012, p. 121–129

Proceedings of the International Congress of Humanities and Social Sciences Research, Paris 24-28 July 2012
(G. Tchibozo, ed.), Strasbourg (France): Analytrics, 2012, pp. 121–129

SCHEME TRANSFER IN SCIENCE: PHYSICAL PSYCHOLOGY

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Abstract

Any science at all can be made into a formal scheme applicable in entirely different domains, a kind of general paradigm. This is especially so with natural sciences, which extensively employ mathematics in their special models. However, such scheme transfer should obey certain rules, to avoid reductionism; the formalism has to be adapted to the new application area, properly reinterpreted in the terms of the target science. In this report, I illustrate the general principles of interdisciplinary scheme transfer on the sample case of applying the scheme of Newtonian mechanics to the psychological theory of motivation dynamics. The perspectives of the extensive use of physical models in psychology are discussed, to overcome the traditionally psychophysical approach and develop a new direction of research that could be called physical psychology.

Introduction

A conscious being is always participating in a hierarchy of activities; each activity is basically a transformation of an object $\boldsymbol{O}$ into some product $\boldsymbol{P}$ by the subject of the activity $\boldsymbol{S}$ as expressed by the scheme $\boldsymbol{O} \rightarrow \boldsymbol{S} \rightarrow \boldsymbol{P}$ (Ivanov 2009). In general, the object, the subject and the product of activity are hierarchical, and this hierarchy grows as a result of activity reproduction in a social context. In particular, each activity eventually becomes represented in the subject as an inner formation, so that another activity can be unfolded following the same pattern. Such scheme transfer is a universal mechanism of creativity, including the arts, science and philosophy.

In scientific research, the formal models of some object area (a range of activities) are explicitly constructed as a part of the scientific product. These models are different from the scheme of the scientific activity itself, since they represent the logic of the object area rather than the inner logic of a particular science. However, the existence of an explicit scheme favours its transfer to different sciences. I will discuss the arising problems on the example of physics and psychology, which are commonly considered as the typical representatives of “natural” and “humanitarian” science respectively. Both physics and psychology have many branches, but the general ideas can equally be illustrated with any special choice.

Hierarchical Mutuality

One can either employ physical models in psychology, or, conversely, introduce some psychology in physics. Both possibilities are vividly discussed in the literature. One of the typical mistakes is to literally understand such scheme transfers; hence arbitrarily contrived physical processes to implement conscious behaviour, or the tales of the mystical influence of consciousness onto physical systems. This "naive" approach may occasionally lead to useful predictions, when it happens to follow true formal analogies. Still, it is generally misleading, eclectically mixing two quite different sides of reality.

Nature is a hierarchy, and each level of this hierarchy should be studied with methods appropriate at this level; 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. Any psychological event can always be considered from the physical side as a sequence of physical events, while there are physical events that do not assume any psychological content, and the same physical events can accompany many psychological events.

The hierarchy of nature is not rigid; it manifests itself as different hierarchical structures, and 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" them. In particular, one may seek for some combination of physics and psychology, which cannot be unique.

The levels of hierarchy are *qualitatively* different, and one level cannot 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 must be considered as a collective effect arising from thousands of communication acts between many people rather than from some neural or physical processes in one's brain (Vygotsky 1986; Leontiev 1978; Luria 1973). However, consciousness would be impossible without appropriate material premises; one of which is the admirable versatility of the human brain.

Mental phenomena cannot violate physical laws; this, in particular, makes it possible to predict some gross thought regularities common to all kinds of conscious being. The structure of the physical world influence mental processes (Dyson 1979), and this is yet another possible direction of boundary studies between physics and psychology.

Consciousness can manifest itself on different levels, and there are numerous examples of the collective subject, each of them assuming a specific physical system as its substrate. This physical system considered as such obeys the same laws of physics as any other similar system and can be studied by physical methods. For example, one can treat the human body as a mass subject to the Earth's gravity, as a thermodynamic machine, as a source and receiver of electromagnetic waves, as an arena of nuclear reactions *etc*. Such a study can be practically important in engineering, medicine, or, say, in the plastic arts. Theoretically, the presence of the human reason can modify the physical behaviour of the human body, and it is quite legal to scientifically study this influence. Within physics, this means yet another constraint with the properties of a semi-empirical nature. The parameters of this constraint might serve as a numerical measure of certain psychological effects (Korenev 1977, 1981).

On the other hand, any physical measurement is culturally determined, and the form of the physical theory essentially depends on the traditional modes of activity. One could study the cultural aspects in the history of physics, and the psychology of physical research in particular.

Observer Paradigms

The organisation of any science reflects the organisation of the standard activities in its object area. Quite often, these activities take the form of *measurement*, when the products of activity are correlated with some standard outcomes (a scale), while the object and the subject are similarly characterised by a limited collection of parameters. As soon as the scheme of measurement in one science is similar to that used in another, the transfer of the formalism involved is possible (Vygotsky 1983; Ivliyev 1988).

Thus, in a psychological experiment, if somebody is presented a series of standard stimuli and required to choose one of the standard answers, this is a well known scheme of the scattering experiment in physics, and the corresponding mathematics is applicable. On the contrary, when the evolution of a selected parameter is monitored in a controlled situation, the scheme of the traditional mechanics can well be adopted. Also, some techniques in social psychology resemble thermodynamic measurements. As the state of the subject is essentially modified in psychological process, the description of reflexive phenomena in physics (such as nonlinearity, collective effects *etc*) can become the source of ideas for psychology, and borrow ideas from psychology as well.

In this context, the test subject in psychology is compared to a physical system, while the input and output are in the hands of the *observer*. Physical science deals with some *formal model* of observer, rather than a real human being, and it is this model that shapes the physical theory. Such a formal observer is just a representation of a 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 it is only the rules of observation that change from one physical science to another depending on their specific methods. Hence, the debate on which physics is more appropriate for describing consciousness (quantum or classical mechanics, relativistic or nonrelativistic theory, *etc*) is meaningless; no kind of physics describes psychological phenomena, while all kinds of physics can equally be made paradigms for psychological study.

In the classical mechanics, the formal observer is introduced through the idea of a *reference frame*. Such an observer is effectively infinite and coincides with the whole of the Universe. In the relativistic generalization of classical mechanics the reference frame is not a static prerequisite, but rather the process of establishing the connection between different spatial points, so that the relativistic observer is essentially local. Quantum mechanics generalizes the classical ideas in another direction, and its observer is extremely big, even much bigger than the classical (infinite) observer. Each point of its space (a 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 intrinsic *symmetries*.

In the same way, the abstraction of an observer might be discovered behind any other branch of physics. In all cases, the abstract observer of a physical theory does not imply any direct interfering of a human being with a physical system; all one needs to do is to *prepare* the physical system to behave in a definite manner, while the physical processes themselves are independent of the observer.

Psychology little differs from physics in this respect. Psychological experiments differ by the degree of observer involvement, and the same formal techniques are available, save that one is to avoid any destructive methods. However, psychological motion develops on a level different from that of physical motion, and the possible changes in the physical state of the subject are of accessory importance.

Physical Psychology

Psychology, if it wants to be a science, has to develop its own abstractions, and one cannot demand it to give a comprehensive explanation of any detail of a single behavioural act. On the contrary, psychological analysis is aimed at classifying individual acts, bringing then under some predefined categories, which are familiar enough to enable people's control over their own behaviour, just like people control physical processes.

In complement to inventing theories from scratch, psychologists can take a ready-made formal scheme from physics (or another science) and apply it to psychological phenomena. Of course, no physics can *explain* 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 computer analogies. All what is legal to ask is how these biological, chemical or physical processes are involved in a conscious action, as soon as one knows that they are indeed involved.

The common way to introduce physical methods in psychology is to restrict the experimental situations to mere physical (or rather physiological) impact, observing the standard behavioural reactions. This level of psychological study is known as *psychophysics* (Zabrodin & Lebedev 1977). It does not reveal the specifically subjective aspects of conscious activity, concentrating primarily on the material premises of human psychology.

Lifting the restrictions on the nature of stimuli and reactions, we come to psychological experiment proper, with psychological conditions for the object, conscious test subject and true behavioural acts as the outcome. The experimental setup and its formal representation in theory still can reproduce certain physical models. This scheme transfer does not change the psychological orientation of research. Since it is psychological phenomena that are to be described, the parameters and variables must be psychologically reinterpreted, losing any relation to their physical counterparts. The results formally obtained in this model are psychological, rather than physical. That is why, in contrast to psychophysics, such an approach could be called *physical psychology*.

On the lowest level, physics may serve to psychology merely as a source of useful metaphors (Nalimov 1981). However, there is a whole range of theories intermediate between such metaphorical usage and predictive theories based on the equations of dynamics. One such model, combining quantum-mechanics and information theory with the ideas of the hierarchical approach has lead to a new theory of aesthetic perception, opening broad perspectives for both theoretical aesthetics and practical applications in the arts (Avdeev & Ivanov 1993; Ivanov 1994, 1995).

Physical psychology can be considered as a special discipline combining the elements of physics, mathematics and psychology without being reduced to either of them.

Newtonian Mechanics and Motivation

Classical mechanics plays a special role in physics. It brought physicists a huge experience of constructing mechanical models for thousands of special cases. There are numerous reformulations of classical mechanics, clarifying its relations to other physical sciences. This is why new physical theories are first applied to classical models, which is the best way to demonstrate the essence of a new approach.

In psychology, a similar role belongs to the theory of motivation (Leontiev 1978). Each particular activity is governed by some motive and unfolded in a sequence of actions directed to 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 transforms into another. Sometimes, the former goals become motives, and a motive may become merely an intermediate goal.

The basic objects of Newtonian mechanics are *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. Let the position of a material point be given a vector $\boldsymbol{x}$. The position of the material point changes with time t; this movement is described with the vector of $\boldsymbol{v} = d\boldsymbol{x}/dt$. The first derivative of $\boldsymbol{v}$ is called *acceleration* and denoted with the letter $\boldsymbol{a}$. Yet another important quantity is the 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:

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

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 $\boldsymbol{x}(t)$.

Let us assume that, in certain situations, a motive can be represented by a point in some *motivation space*. In this model, the goals will belong to the same space, to enable transformation of goals into motives, and motives into goals. Any 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; the activity can thus be obtained as a solution of an equation of motion, similar to that of classical mechanics.

Within this analogy, the mass m of the material point corresponds 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 (represented by some forces). Velocity $\boldsymbol{v}$ naturally describes the rate and direction of activity; this is an example of a characteristic that has no direct psychological analog, though it is quite compatible with the psychological view. 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, highly inert individuals are more persistent in their activity; also, the higher the rate of activity is, the less noticeable is the influence of other activities.

When masses do not depend on time, the law of motion can be rewritten as

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

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

In Newtonian dynamics, acceleration plays a special role. Any change in the state of motion assumes non-zero acceleration, and it is acceleration that is felt by a classical observer as a mechanical event. For an observer moving without acceleration, the dynamics of any mechanical system is described with the same equations of motion, as for observer in peace; such motion is called inertial. In the mechanical model of activity, acceleration can be associated with people's subjective experiences.

Now, the overall picture of human activity is pictured as follows: a person's interaction with the world results in some distribution of forces in the motivation space of the person; these forces excite definite affects in the person, changing the state of motion.

The immediate consequence of this model is that the same force will excite weaker emotions in a person with higher inertia; 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 as well.

In the Russian physiological school, the temperament is characterised by strength, mobility, and balance. Thus, the sanguine temperament corresponds to strong, mobile, and well-balanced nervous processes; the choleric temperament is poorly balanced, while the phlegmatic temperament lacks mobility; all the weak temperaments are called melancholic. In our sample model, this correlates well with the principal law of dynamics: $\boldsymbol{F} = m\boldsymbol{a}$. The strength of temperament describes the person's sensitivity to external circumstances. In the "mechanical" language, this means that the environment acts with less force on a person with greater strength of temperament; that is, the absolute value of the force F is inversely related to the temperament strength. The relation of mass m 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 (pure inertial motion).

With these assumptions, the sanguine temperament must be characterized with small F, which, for 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 holds for the choleric temperament, which assumes low inertia and hence even a small force can break the balance in a choleric person. As for the melancholic temperament, it assumes high sensitivity to the processes in the environment, that is, with high values of *F*. The effect of high *F* on the person's activity can be different, depending on the person's inertia, which corresponds to the empirical distinction of the three types of melancholic temperament. Inert individuals remain balanced in spite of their strong interactions with the world. Medium inner mass results in much more pronounced affective reactions. The weakest type of melancholic (a classical melancholic) is characterized with low inertia; this is an extremely vulnerable person, feeling the flood of emotions at a slightest turn of the situation.

The mechanical treatment of temperaments differs from the traditional approach in that strength and balance are no longer assumed to be individual constants, being true dynamic variables, which may significantly change in the course of activity. One possible solution of this problem is to treat temperament as the averaged feature of activity, relating its parameters to the time-averaged values of force and acceleration. For many periodic and quasi-periodic modes of motion, the absolute value of force (acceleration) varies in a narrow range, only changing its orientation. In the simplest case of circular motion, the force and acceleration are constant, which complies with the traditional treatment of temperament.

This "mechanical" model of activity can provide more analogies between physics and psychology. For more complex result, I would mention the possible application of this model to the description of neuroses. Normally, there are no inaccessible regions in the motivation space; for any given point there exists some trajectory (activity) containing this point. However, a person's interaction with the world can sometimes result in a singular potential, breaking the simple topology of the motivation space. The well known Coulomb potential of a charged point is an example from physics; in this field potential energy assumes an infinite value at the position of the electrical charge. In such cases, activity can come very close to the point of singularity, but it will only move around it, never achieving this point. The existence of such forbidden areas 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. The immediate implication is that a neurosis cannot be overcome by the own activity of the person; the treatment of neuroses requires a change in the person's environment, which will remove the singularity from the motivation space.

As expected, the person is not always aware of the motive of activity. Indeed, the goal (the point in the motivation space) is 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 especially evident in the case of circular motion, with the motive in the center of the circle, and the goals always equally distanced from the motive. To make the motive conscious, a special activity of *motivation* is needed, additionally deflecting the trajectory of activity towards its motive; such dissipative forces can also be treated within the mechanical model. In general, some activities will include motivational actions, and some will not, depending on whether the motive point lies on the trajectory of activity or not.

Conclusion

Simple mechanical conceptions can be introduced into psychology of activity to describe phenomena quite different from the original physics. The same physical model is also applicable to other areas of psychology. Thus, one could reinterpret the mechanical equations of motion to describe communication between people, interaction of social roles in a small group, and so on. Alternatively, other physical theories can be used to describe dynamics of motivation in the situations of uncertainty and socially induced choice. For instance, while the paradigm of classical mechanics characterizes an individual action 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, and the action will become a process in this internal space, resulting in a probabilistic outcome on the level of outer activity. Better representation of consciousness requires more sophisticated physical models, involving controlled nonlinearity and collective motion.

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