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Defining Types of Learning Individuals: a Phase Portrait Approach

Vladimir L. Gavrikov [a]* and Rem G. Khlebopros [b]
[a] V.P. Astafiev Krasnoyarsk State Pedagogical University, 89 A. Lebedeva st., Krasnoyarsk, 660049 Russia
[b] International Research Center of Extremal States of Organism at Krasnoyarsk Scientific Center of SB RAS, 50 Akademgorodok, Krasnoyarsk, 660036 Russia [1]

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It has been shown in the article how the approach of dynamic systems theory may be applied to define types of learning individuals. The approach uses an analysis of phase portraits. The so-called phase portraits are graphical representations of a system dynamics in two-dimensional space of a value and its time derivative. Variations in quantity and stability of steady state points (where the derivative is zero) can easily produce different phase portraits that may be interpreted and analyzed in terms of dynamics of learning of an individual. With the help of the analysis six basic types of individuals have been defined and described: «all and now», degradation, non-learning, self-learning, threshold, culture norm. Possible implications of the analysis for research of learning are discussed.

Keywords: learning, individual differences, modeling, phase portrait analysis.

Introduction

The fact of deep and significant mental, psychological, behavioral differences of individuals seems to be widely accepted. The task of specific empirical researches in every particular case is to give details on the fact and to put in good order the variability observed. To do the work successful, the researchers need some theoretical basis that would help to categorize measurements and observations. We are undertaking an attempt to formulate in the paper such a basis in the form of a priori typology that may serve as a methodological help at planning of experiments and observations. The typology is aimed to describe the variability of individuals in regard to the process of learning.

The developed typology relates to two tendencies in the modern behavioral sciences. The first tendency refers back to at least 1950th and consists in permanent attempts to introduce the use of mathematical methods into the field of psychology. The main directions of psychology quantification comprise signal detection theory, decision theory, psychophysics, neural modeling, information processing approach, mathematical learning theory (Townsend, 2008).

The approaches based on statistics and probability theories are good developed (Bousquet et al., 2004; Poggio, Smale, 2003) while the

* Corresponding author E-mail address: gavrikov@kspu.ru

presentation of learning as a temporal process is rather weak. In fact, in the modern behavioral sciences, dynamic modeling is a seldom research methodology. Since the time of Thorndike and beginning of objective observation of behavior a numerical analysis of the research results has become a regular practice. Still most popular and detailed manuals in psychology and ethology tend rather to describe results of experiments and ideas than to discuss equations on temporal change of measured characteristics. Meanwhile, dynamic modeling has been successfully working for decades in other natural sciences (Strogatz, 2000), particularly in ecological studies (Isaev, Khlebopros, 1973; Isaev et al., 1984). In our opinion, taking into account a huge amount of facts and ideas accumulated in studies of human and non-human behavior, the behavioral science is able to use some theoretical approaches of dynamic modeling.

The second tendency is a growing interest to individual variations in the learning process. As a rule, the so-called «learning styles» are in focus of researchers, with the psychological tests being the method to identify the styles (Furnham, 2008; Chamorro-Premuzic, Furnham, 2008; Isman, Gundogan, 2009). The outputs of such testing are categories described rather in static and qualitative terms than in dynamic ones.

Method

In our current study, we are implementing techniques of phase portrait analysis into the scope of the theory of learning. Phase portrait is a regular instrument of the qualitative dynamic system theory. A simple phase portrait shows a trajectory (in fact, a lot of trajectories) of a dynamic system in the two-dimensional space (phase plane) of a value and its time derivative. Besides the trajectories a phase portrait depicts stable steady states and unstable steady states in which points the derivative turns to zero (Fig. 1.).

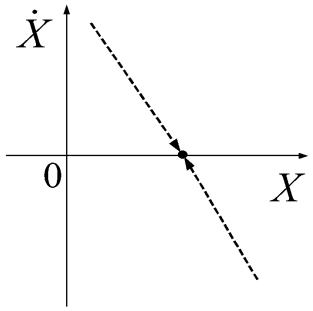

Fig. 1. An example phase portrait. X stands for a property (state variable) of a dynamic system, and $\dot{X}$ is its time derivative. A trajectory shown in the figure crosses the OX axis in a point that is called a point of steady state because $\dot{X}=0$ for the point. Therefore the example system will have no change in the point. If the system is in any other point of its trajectory it will tend to move to the point of steady state because in this particular case the point is stable

The value may describe any relevant property of the system.

In our case, the «system» is an individual or, more exact, the individual's intellectual sphere that can be applied the term «learning» to. Let X stand for a measure that is relevant to learning. It may be knowledge, skill, experience, competence etc. but also it may be a personal quality, such as speed of perception, exactness and other qualities that can be learned or trained.

It is naturally to suppose that X i) can be measured and ii) changes over time. What concerns the first supposition, measuring of knowledge levels, skills etc. is a common educational practice. Also, during the XXth century psychology was continuously trying to elaborate tests, indices etc. to quantify various individual properties and qualities. Regarding the second one, it is commonly known that knowledge, skill can grow; qualities can be trained, but also all they can degrade with time. It means that time derivative of X, denoted as $\dot{X}$, is a relevant variable to consider. The time derivative has the common sense of measure of temporal change. The higher its absolute value (magnitude) the faster the change. Positive

values of the time derivative mean increase, while the negative sign corresponds to decrease of the variable.

Suppose, then, that there are two states of an individual's intellectual sphere that can be more or less surely recognized. Let «state 0» stand for ignorance, lack of knowledge, inability, lack of skill, incompetence, lack of certain quality etc. Contrary to this, the «state 1» will stand for competence, ability, grasp of some knowledge, working knowledge of something, skill in handling etc.

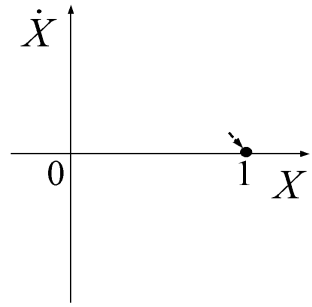

Fig. 2. A phase portrait of type I «All and now». An individual from the very beginning is in the steady «state 1» that is stable

Results and discussion

The suppositions made above are sufficient for constructing various phase portraits of the learning process of an individual and interpretation of them. But before this a preliminary note is wishful to be done. Over centuries the development of biological theories was heavily influenced by the opposition of preformism and *tabula rasa* concepts. Yet today it is hard to expect that the historical argument has been completely closed. Therefore, our typology of individual learning cannot help bearing some signs of the opposition. Sometimes we assume that a learning outcome is preformed (inborn), sometimes it is considered to develop from the scratch.

A basic typology of individuals with respect of the way they learn is given below.

Type I. «All and now» (Fig. 2).

The type implies that some individuals possess certain knowledge from the very beginning, from the moment of birth and this knowledge does not degrade.

An example that gives a good demonstration of the case is provided by a study of hunting behavior in ants. Reznikova (2008) studied learning of a complicated hunting pattern in ants. Researchers reared a population of ants from eggs, so that they had no contact to «wild» insects. Reznikova found that there are three sorts of individuals in the population of ants:

i) those that possess the hunting pattern from the very beginning in spite of that they could not learn it from more experienced individuals. It has been shown that the share of such ants among others is about 5 %;
ii) those that, from the birth, possess some fragments of the pattern and can easily complete up the full pattern through the learning from the experienced;
iii) those that do not have even fragments of the pattern.

It is obvious that those 5 % of the individual ants belong to the type I «All and now».

The type I may be quite disputable from the point of view of psychological sciences dealing exclusively with human because it implies that a human newborn child can know something. What concerns other animals, instinctive behavior of them is accepted as norm while it is widely believed that all specifically human things people learn from their social environment.

Meanwhile, if to put aside oversimplified viewpoints (e.g., that a newborn knows how to write the letter «A») there can exist some phenomena that require understanding and explanations. For example, studies of creolized languages suggest a phenomenon of inborn

grammar. It means that a baby human may not know a language tradition (the vocabulary itself) but the sense of grammar relationships may be given him from the birth (Pinker, 2000).

In any case, there is one more consideration to include the type I into the developed typology: we should make the picture complete. In other words, if the approach allows a possibility it should be enumerated and at least mentioned.

Type II. Degradation (Fig. 3).

The type suggests that an individual possesses some knowledge, skill, quality etc. from the very beginning (birth) but they degrade over time. It is described so that the trajectory for the knowledge goes from the unstable steady «state 1» down into the range where $\dot{X}<0$.

The grounds why the type should be included in the typology may be various, but the type II is at least conceivable, and the picture would be incomplete without it.

Type III. Non-learning (Fig. 4).

The description of the type may sound like a case of pathology but it is not. There are scopes of life that an individual just unable to master. If though the individual is forced to learn one of those subjects and scopes then i) the learning process will require an immense amount of effort and ii) the learning outcomes will spontaneously degrade with time. The spontaneity of degradation is characteristic of the type, with speed of degradation may vary, for example, may be rather slow.

Supposedly, the type III embraces a wide range of situations. The experience accumulated in the animal training practices suggests that it is practically impossible to teach an animal to do things that are not in their natural behavioral repertory. In human educational practice, a term «residual knowledge» is known that is usually assessed through retention tests. Many things that people learn in the secondary school will probably be erased from memory by the time of adult age or earlier even if highest marks were received for the subjects.

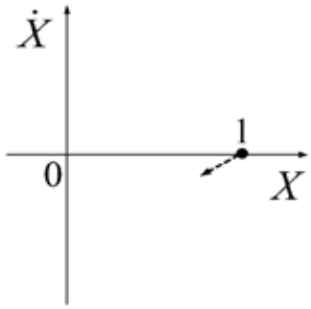

Fig. 3. A phase portrait of type II, Degradation. The steady «state 1» is unstable

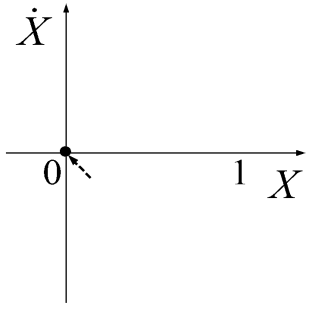

Fig. 4. A phase portrait of type III, Non-learning. The steady «state 0» is stable

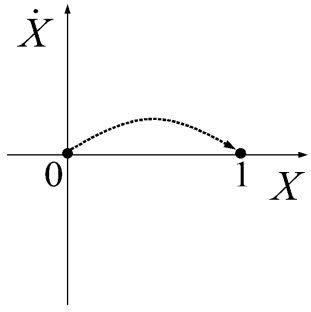

Fig. 5. A phase portrait of type IV, Self-learning. The steady «state 0» is unstable, the steady «state 1» is stable

Type IV. Self-learning (Fig. 5).

A spontaneous transition from the «state 0» to «state 1» is characteristic of the type. Initially, the individual does not possess something

that can be regarded as learning outcome but provided the sources of information, conditions etc. are available the individual acquires all the knowledge or skills. The dynamics is determined by that the point 0 is the unstable steady state and the point 1 is stable steady state. All the process goes according to the principle of positive feedback: new portion of knowledge stimulates further learning. Supposedly, the sources of development in the case of the type may be some inborn fragments that are being completed from outer environment, as it was suggested by the study of ants by Reznikova (2008).

A question regarding type IV remains unanswered: what happens if the individual does not find sources of knowledge in the environment? Would the individual remain in the non-learned state all of the life? Would still his/her potential to learn the particular subject influence his life? In the work «On aggression» Lorenz (1998) discussed his theory of autonomy of instincts. An instinct «tries» to find an opportunity to manifest itself in behavior independently of occasional absence of external stimuli. In this sense, the uncompleted fragments of knowledge will force the individual to find the lacking elements of the knowledge.

Another consideration comes from Thorndike's law of readiness (Thorndike, 1932). According to it, when someone is ready to perform some act, not to do so is annoying. From this point of view, an individual of type IV is ready to learn something, and the individual would strive for obtaining the knowledge in order to avoid the inevitable frustration as Thorndike's law suggests.

Type V. Threshold (Fig. 6).

An unstable steady state in between the «state 0» and «state 1» is characteristic of the type, with the both of them being stable. It looks like the learning process of an individual depends on a value X_{thr} of the knowledge, skill etc. level. In terms of learning of a definite scope of activity, an individual tries to master some scope of life activity, but if the individual gives up the learning before the level X_{thr} the achieved outcomes would degrade. If the individual goes in the learning beyond the threshold of X_{thr} the learning proceeds then spontaneously, and the individual reaches the stable steady «state 1».

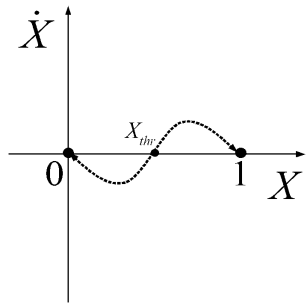

Fig. 6. A phase portrait of type V, Threshold. An unstable point X_{thr} lies in between the stable steady states «0» and «1»

It is easy to see that type V provides a generalization for some other types. A shift of the point X_{thr} closer to the «state 0» or «state 1» can yield the types IV, Self-learning or the types III, Non-learning or II, Degradation correspondingly.

Type VI. Culture norm (Fig.7).

In comparison to type V, the intermediate point may play quite a different role if it is a stable steady state. Type VI may be interpreted as another sort of threshold, a culture norm. An individual begins the learning process from the steady «state 0» and relatively easy reaches an intermediate steady state. If many individuals in a population reach the steady state it may be called a group norm or a culture norm, which describes an average learning ability for the population. The attempts to outreach the norm remain unsuccessful because the steady «state 1» is unstable.

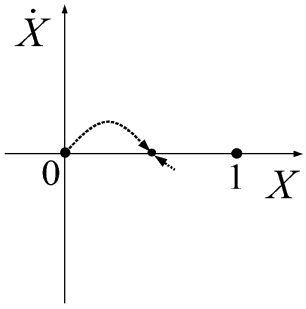

Fig. 7. A phase portrait of type VI, Culture norm. The intermediate steady state is stable

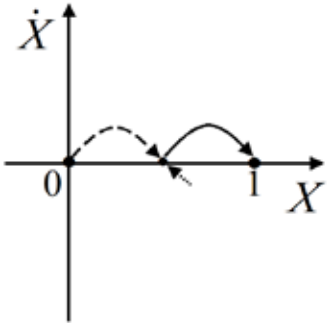

Fig 8. A phase portraits of type VI, Culture norm. A transition to the trajectory leading to the «state 1»

In type VI, there is however another possible scenario. A group of individuals can possibly switch to quite different trajectory of learning development that leads to the maximal learning progress (the «state 1»). To give an emotional description of the process one can denote it so as if the world turns over. In fact, the trajectory that helps to overcome the cultural norm is turned over as compared to the «normal» course of things.

In the philosophy of education, the phenomena are sometimes described as the transition from self-actualization to meaning comprehension. While a self-actualizing person acts according to the motto «to be not worse that others in the field», the meaning comprehension implies the grasp of universal sense of the activity and the peculiarity of the personal way within the field. The personal development goes intensively and deep into the practice and the competence breaks through the upper limit of the average (Gusinski, Turchaninova 2003).

In psychology, the similar effects of mastering of complicated activities are often described with the help of term «insight». The famous zoopsychologist Robert Yerkes (Yerkes, 1916) conducted experiments with monkeys and apes trying to study their ideational behavior and specifically their abilities to solve various problems. One of the experimental animals, an orangutan, first had little success but after it, presumably, grasped the sense of the task the number of his errors fell down to zero.

Conclusion

In the research practice, it is often useful to have an instrument allowing one to plan the research and to bring the results in order. It is also useful to cast a broad glance at the variability of the object studied because a particular empirical research is always limited by its sampling material and measurements. The application of the theory of dynamic systems presented in the study may be seen as such an instrument or at least a first step to develop such an instrument.

Initial suppositions of the study were that there are the states «0» and «1» that can be well recognized, and also that the progress or regress over time of an individual between the states can be quantitatively assessed. As a result, six simplest learning types of individuals have been defined: «all and now», degradation, non-learning, self-learning, threshold, and culture norm. It is obvious that introduction of more steady states may result in more sophisticated phase portraits corresponding to more complicated types of learning individuals.

To conclude, we should make a couple of remarks that seem to be important. The developed typology has a sense only regarding a definite scope of knowledge or a personal quality. It is quite possible that an individual belonging in one

learning scope to a type may belong to another type with regard to another scope requiring learning. Also, some questions were out of the presented analysis. Most important seem to be a possible age dynamics of individuals regarding the learning types. The learning type of an individual may change with his/her age. The importance of the age issue comes from that the modern economy forces people to learn longer and longer, so fostering of learning needs the knowledge of the age dynamics. Such evidence however can only be obtained within a definite empirical study.

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