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Functional systems theory and the activity-specific approach in psychological taxonomies

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This brief opinion contribution reflects on the application of Anokhin's functional systems theory in the development of models of temperament in Russian differential psychophysiology. It points to the benefits of using an activity-specific approach in temperament theory. This approach suggests separating traits related to physical, communicative and mental aspects of behaviour.

This article is part of the theme issue 'Diverse perspectives on diversity: multi-disciplinary approaches to taxonomies of individual differences'.

1. The problem of 'partiality': how to divide individual differences

Russian psychophysiology of individual differences (differential psychophysiology) originated with work of Pavlov around 1906. After receiving the Nobel Prize in 1904 for his studies on conditional reflexes, he launched a massive theoretical and experimental investigation into types and properties of nervous systems. With generous financial support from the Soviet Government, his research facility eventually became the Institute of Physiology of the Russian Academy of Sciences, conducting a range of observations and experiments of unprecedented scientific rigor [1]. Pavlov called this programme a 'continuing experiment', which ran for 30 years with weekly 'Pavlovian Wednesdays' discussions until his death in 1936. The main focus of this research was similar to the topic of this theme issue: the taxonomy of individual differences.

Pavlov considered temperaments as types of nervous systems and suggested that we need to learn those properties of nervous systems that make animals so consistently different, and then to reason about types as compositions of the expressions of these properties. Experiments in his Institute initially involved animals (dogs, mice, rabbits, rats, monkeys, goats, sheep and guinea pigs), but then extended to children and adult humans from late 1920s–1930 until World War II. What is interesting is that Pavlov realized that properties of nervous systems are not independent dimensions. His final model has three dimensions: strength, balance and mobility of nervous processes; however, these dimensions are not orthogonal, and this accommodates four Hippocrates' types. The Strength dimension has two extremes: Strong and Weak nervous systems. An increase along the dimension of Strength ('energetic' trait) leads to emergence of a second dimension (Mobility). Pavlov observed that only the 'strong' (high endurance) type of nervous systems differentiates by Mobility (that results in two types, Mobile and Rigid), and then only the Mobile types differentiate further according to the Balance of the nervous processes (resulting in two types: Mobile-Balanced and Mobile-Unbalanced). 'Weak' nervous systems did not show any differentiation into rigid and flexible types (being mostly rigid), and rigid types did not show any differentiation with respect to 'balanced' and 'unbalanced' types. Pavlov was fascinated by Hippocrates' concept of temperament and made parallels between the Weak type and melancholic temperament; among the Strong types he attributed phlegmatic temperament to the Rigid type, sanguine to the

Mobile-Balanced type and choleric temperament to the Mobile-Unbalanced type. Pavlov's associates and graduate students confirmed this structure of the dimensions of temperament in their studies on children and adults (see [2] for references). This model was later adapted in Polish differential psychology by Jan Strelau's group [3].

After World War II, Boris Teplov restored this line of research in the Laboratory of High Nervous Activity under the Russian Academy of Education and focused on individual differences in specific modalities—visual and auditory [4,5]. After Teplov's death, Vladimir Nebylitzyn, who became Head of this laboratory, added a significant number of novel and modern methods to this programme. Nebylitzyn, still working within Pavlovian tradition of differential psychophysiology, conducted studies of individual differences using verbal-motor tasks, photo-chemical reflex by applying bright stimuli in visual modality, measurement of the decay of sensitivity to auditory stimuli, anticipatory reaction to these stimuli within neurophysiological systems, measurement of the rate of extinction of conditioned reflexes with and without reinforcement, and with variations in conditional stimuli. Nebylitzyn described the phenomenon of enhanced sensory sensitivity in individuals with so-called weak nervous systems. Moreover, individuals with strong nervous systems (strong endurance) maintained their photochemical reflex, as measure by specific devices during multiple repeated stimulation, whereas the reflexes of individuals with weak nervous systems extinguished much sooner. He also found that individual differences in delta and theta-rhythms of the EEG could predict the speed of extinction of learned reactions, and that the differences in depression of the alpha-rhythm in the EEG before, during and after stimuli (variability in anticipatory and reactive processes) could be identified as a trait/property of 'dynamism' [4–7]. These results from Nebylitzyn's laboratory were confirming the neurophysiological correlate for a trait of Tempo, and they were the first experimental evidence of high reactivity (sensitivity) of people with low endurance, later confirmed in studies of other researchers [8–10]. Nebylitzyn, however, mentioned to me once that even Pavlov hypothesized earlier that individual differences in the dynamics of the Na+-K pump might entangle people's sensitivity with their endurance.

I worked in Teplov's and then Nebylitzyn's laboratory practically from the beginning of its existence, and my own EEG studies [11–14] also showed consistent individual differences in EEG patterns that could be linked to differences in endurance (I called it ergonicity), plasticity in behavioural responses, tempo of activities and emotionality. These studies brought up a question: how can we divide temperament traits, and other individual differences in groups? We called this question a *problem of partiality*. We were given a green light (and money) to measure individual differences in physiological experiments using any design we wanted, and this might sound like heaven to Western psychologists but in reality, when we had too many results, it was not an easy task to decide what is important, what is not the next step in research. At least two dimensions of temperament were not debated: energetic and emotionality dimensions. Nebylitzyn (and so our laboratory) shared the opinion that the cortico-limbic complex regulates emotionality aspects of behaviour, whereas the cortico-ARAS complex regulates construction of actions, regardless of emotionality. Similar to the position of Kant [15], Heymans [16] and Eysenck [8], he expressed this view justifying the division of temperament traits into two groups, Emotionality and Activity, at the Congress of Psychologists in Tbilisi, 1968. Troubles started, however, when we wanted to find further differentiation between traits. The number of dimensions was increasing with every year, and at that time some researchers were coming with lists of 20 or 30 properties of nervous systems, each being a candidate for a temperament trait. Pavlov suggested three major dimensions, or properties of nervous systems, as described above. Teplov and Nebylitzyn, using these dimensions, examined different modalities (visual, auditory, tactile) and found that three classic Pavlovian properties of nervous systems can differ in the same individual, depending on modality. They, therefore, considered dividing temperament and individual differences in terms of both—modalities and dynamical properties. Moreover, new properties were added, such as 'lability' and 'dynamism' in descriptions of the individual rate of behavioural response to stimuli.

There was an idea to go the 'neuroanatomic way' (popular nowadays in the West), mapping individual differences to functions of specific neuroanatomic structures. This idea, however, was quickly devalued by Luria's position on integrative functioning of the brain. Despite continuing credits for identifying specific functions of the frontal lobes and other brain regions, Luria was against the idea of 'localization' of regulatory functions by specific areas of the brain, except for three blocks (discussed below). Neurophysiology in Russia was developing very fast after World War II, since there was, unfortunately, a big base of cases with various brain injuries. Several Research Institutes had been opened under the Russian Academy of Science (then—USSR) and Russian Academy of Medical Sciences specifically studying the neurophysiology of behaviour. Luria's anti-localization position was widely supported by many neurophysiologists, coming with more and more evidence of entangled regulatory brain systems. As Luria's PhD student and as an anthropologist by training, I, of course, supported his position too, but a question remained: how to partition biologically based traits, and how to find evidence for such partiality, if everything is so interconnected in the human brain?

Around that time, in the 1960s, factor analysis became popular in Western differential psychology. Teplov at age 60 started learning it with much enthusiasm and passed this enthusiasm to Nebylitzyn and to me. We were obsessed with this method, factorizing our results after every small new pack of data, and, similar to modern personality theorists, we also attempted to derive our classifications using factor analysis. Eventually, we learned that it is only good for verifying psychometric properties of our tests but is useless in developing classifications of systems, whose components are so closely interconnected. Our 'factors' were coming in two to three big bunches, and their facets were changing their structures like ladies change their clothes. This disappointment in statistical methods was a sober reminder of the complexity of the neurophysiological systems that we were dealing with. So, our attention moved back to the core of neurophysiology, to how behaviour is being constructed by our biological systems.

2. Functional systems architecture: Anokhin, Bernstein and Luria's models

When I was working in Nebylitzin's laboratory and then as Head of this laboratory (i.e. the Nebylitzyn Laboratory of

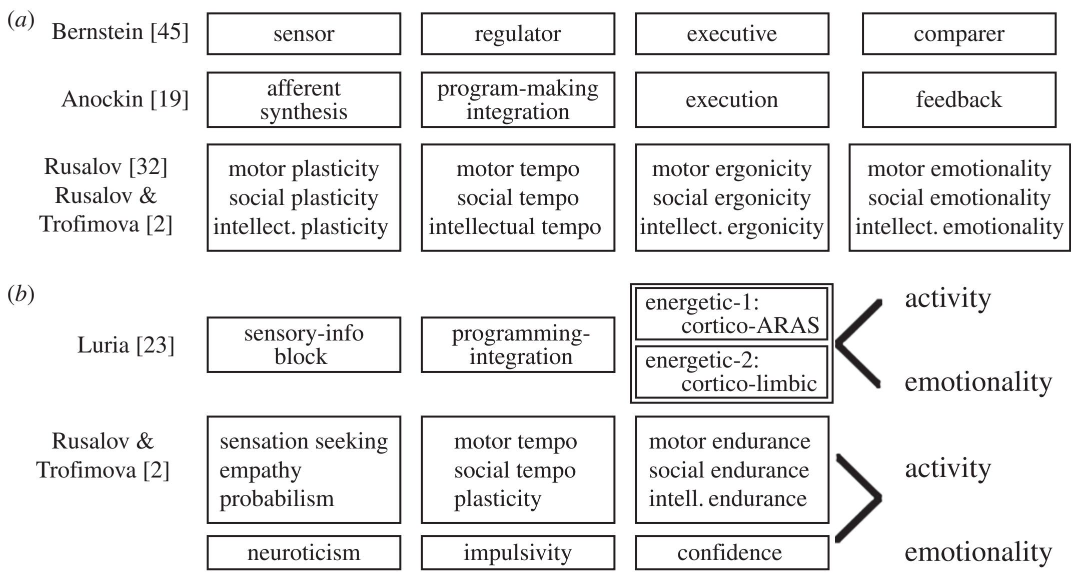

Figure 1. Two activity-specific models of temperament that differentiate between traits related to physical, communicative and mental aspects of activities. (*a*) Rusalov's model follows Anokhin's and Bernstein's 4-block model. (*b*) Trofimova's model follows Luria's 3-block model.

Differential Psychophysiology under the Institute of Psychology, Russian Academy of Sciences) my associates and I applied several experimental techniques (during 1960–1990s). We recorded absolute thresholds in visual, auditory and tactile modalities, strengths of excitation and mobility in auditory and visual modalities, EEGs and measured evoked potentials, problem solving in deterministic and probabilistic conditions and the speed of solving problems using a variety of intellectual tests [11–14,17]. We also measured 'ergonicity' (the ability of a person to sustain prolonged or intense activity). Intellectual ergonicity was measured as the time spent and number of capitulations while attempting to solve unsolvable problems [11,14,17]. Intercorrelations between these measures showed that the most individually consistent traits that could be associated with specific psychophysiological measures and EEG patterns were: ergonicity, plasticity, tempo and emotionality.

At that time (in the mid-1970s) Anokhin's [18,19] theory of functional systems and Bernstein's [20,21,45] theory of construction of behaviour converged and gained more and more interest both in Russia and in the West [21,22]. Listening to Anokhin's lectures convinced me that, instead of reflexology, a structure of temperament could be mapped around functional blocks described by Anokhin and Bernstein. The main idea was: if we describe individual differences *in behaviour*, it is very relevant to describe them along a structure of behavioural acts. At that time cybernetics was very fashionable and these models described the *construction of behaviour* in several blocks: (i) afferent synthesis, (ii) decision making/programming of an action, (iii) execution of an action, and (iv) feedback comparison between the result and the programme (which Anokhin called 'acceptor of results'). Moreover, Luria, my PhD supervisor, had his own model of three neuropsychological blocks regulating human behaviour [23]. He based this model on his famous work with a large number of brain-injured victims of World War II. When we were comparing his model (information-sensory block, programming block and energetic block divided into ARAS-based and limbic structures) with my research and Anokhin–Bernstein models, we saw a convergence of these models but interpreted it slightly differently (figure 1).

Being under the influence of the theory of functional systems, I suggested matching the four traits described in our research on the structure of temperament to the structure of functional systems as described in Anokhin and Bernstein's work. I called the energetic blocks in these models 'ergonicity'. The Afferent Synthesis block in Anokhin's model (or Acceptor of Information in Bernstein's model) in my view reflected a spectrum of alternatives for a programme of future actions (I called it plasticity), speed of execution was called tempo, the 'acceptor of results' in Anokhin's model (of feedback block in Berstein's model) corresponded to the emotionality trait in my model. High sensitivity to mistakes, to negative feedback from the results of actions was considered, therefore, in my model as a source of neuroses and consistent negative affects [13,14,41].

3. Activity-specific approach in temperament research

In my studies, I measured the frequency and duration of tapping by hands and feet, speed of writing, speed of reading, speed of solving arithmetic problems and eventually found that individual differences are consistent in three types of these activities—physical-motor; verbal (writing, reading) and problem solving (intellectual). I observed that individuals that had high ergonicity for communications did not necessarily have the same endurance for solving mental problems (especially when we used unsolvable problems in our experiments). Fortunately, the idea of distinguishing between three aspects of activity was already in the air. The Director of our Institute of Psychology, Lomov suggested partitioning behaviour (and individual differences) into two groups: 'activity' and 'communication', as two types of interactions: object–object and object–subject. I, therefore, was able simply to 'follow the idea of the leader': I proposed that four temperament traits identified in my research in mid-1970s [13] should be differentiated into two types—physical and social, resulting in an 8-component model of temperament [24]. Credit for the idea that temperament traits differ for physical and socio-verbal aspects of activity actually belongs to Nebylitsyn who first suggested this idea to me and even in his writing. In my first book [13] I also concluded that individual differences in verbal tasks are probably regulated by different neurophysiological systems than those regulating motor-physical tasks, even though in both tasks motor centres are involved. Soon after my first 8-scale Structure of Temperament Questionnaire (STQ) was published and was adopted in the West [25–31], I started working on an upgrade of this model to include 4 more scales describing intellectual aspects of behaviour. This research resulted in the Extended STQ [2,32–36]. Irina Trofimova and I call this the 'activity-specific approach' in temperament research, as it separates between aspects of behaviour related to specific types of activities—physical, social-verbal and mental.

We found practical and theoretical benefits of assessing the STQ-s 12 components as separate traits, and the STQ was widely used in Russia after 1990 in organizational psychology (helping to facilitate staff selection and placement), personality psychology, clinical psychology and educational psychology [2,33]. Use of the English versions of the STQ-77 showed that what is usually measured by Extraversion scales of other tests is just a social-verbal type of ergonicity which does not correlate with physical ergonicity (endurance) or intellectual ergonicity (sustained attention), and therefore these three types of ergonicity represent different temperament traits [24,34–41]. Separation between 12 traits as described in activity-specific models also helped to find a differential pattern of temperament profiles matching the symptoms of depression and general anxiety [38–40].

Nebylitzyn and I were always curious how temperament traits are associated with neurochemical systems. We even prepared the paperwork necessary for funding such a research programme under the Institute of Psychology, Academy of Sciences of the USSR, in which our laboratory was located. We could have had our own research on the role of neurotransmitters in temperament if not for the tragic death of Nebylitzyn in 1972. I was very pleased to see that one of our PhD graduates, Irina Trofimova, decided to come back to the idea of building bridges between temperament research and neurochemistry. She offered a revision of my 12-scale STQ model (lower part of figure 1) in correspondence with Luria's 3-component model of regulatory brain systems. She linked the functionality of neurotransmitter systems to the traits described in her model, the Functional Ensemble of Temperament [37,38–40,43,44], and I am glad to see that she integrated insights from the same models that inspired me: the architecture of functional systems theory by Anokhin [19]; the construction of action cycles by Bernstein [21,47]; Luria's [23] model of three regulatory blocks in the human brain and my activity-specific approach [2].

In summary, I believe that the 'partiality' problem (i.e. the way we can partition temperament into traits) can only be solved using a 'functional' approach. This approach analyses the structure of human actions and uses the same structure for classifying temperament (biologically based) traits. Statistical methods cannot derive this functional structure for us, even though factor analysis makes such promises when it delivers a grouping of our variables. Unfortunately, work on identification of functional structures of behaviour involves experiments in multiple sciences, and, fortunately, modern differential psychologists do not need to start from scratch in walking this road. I hope they can borrow the insights coming from the century-long experimental tradition of neurophysiological studies of individual differences conducted in Russia.

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