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Methodology of Physiological Processes Polyparametric Cognitive Modeling

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The kernel of the methodology of polyparametric cognitive modeling of physiological processes is:

- The allocation of fractal process and their parameterization;
- Description of the object's functional state by uniform set of represent- tative parameters in the corresponding dimension;
- Construction of fractal's geometric intellectual model;
- General principles of symmetry implementation to determine and to assess the linkages of model's elements, as well as patterns recognition methods to analyze multivariate data.

Elements of system's models (and subsystems) are the amplitude and temporal parameters of oscillatory processes. Similarity of these elements has been observed at all levels of living things (cellular, organ, systemic- organismic), i.e., oscillatory process parameters are the elements of electro- physiological sub-systems of the overall (whole) system - *the entire organism*.

The ratio of electrophysiological processes parameters is considered to be based on well-known ideas about the interaction of wave processes (Wiener N., 1983). Fractal geometry of the system model allows defining relationships that satisfy the requirements of the systems approach. Informational links between power generating structures of particular organs and the whole organism are calculated based on the geometry of the model, using general principles of symmetry and the opportunity to represent the results in the form of codes. This knowledge about the organization of electrophysiological processes is new, because informational phenomena of modern physiological experiment cannot be observed.

It should be emphasized the objective element of polyparametric model (this physical quantity of physiological processes parameters) and a high degree of the model formalization, which facilitates the use of analytical classification methods. Geometric images are easy to interpret at substantial level, which can significantly reduce the mathematical difficulties in the classification.

For the diagnosis of physiological functions, four types of symptoms are used:

- Absolute values of process parameters;
- Their relative deviations (depending on the modal values - Mo of each parameter);
- Ratio of parameters within the physiological system;
- Ratios of different physiological systems parameters (Dmitrieva N.V., 1998, 2000). The degree of fluctuations is assessed not with conventional points that always causes difficulties, but with direct measurement of the system parameters ratious. This opportunity to quantitatively define the ratio of processes parameters in their entity defines the optimal condition of the multivariate data analysis method, as it significantly reduces mathematical difficulties and preserves physiological interpretation of the results.

As an example (fig.1), presents a model of electrophysiological pro- cesses in the heart (on the basic of electrocardiogram parameters, ECG). In a two-dimensional coordinate system the absolute values of ECG parameters lay: the minimum and maximum, with no diagnostical meaning (value) for the clinic, and the values corresponding to the fashion Mo parameters. Set of electrophysiological parameters values are looped (right triangle), whose legs are the vectors of amplitude and temporal ECG parameters. Each leg has its own dimension.

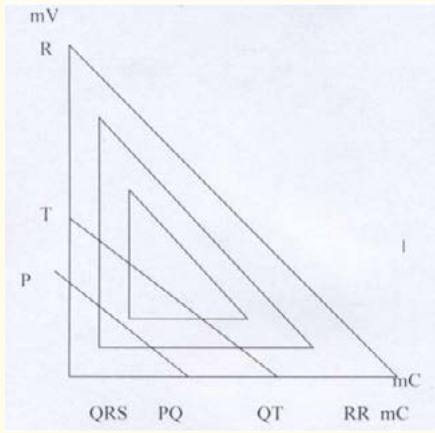

Figure 1: Model of the healthy person's ECG subsystems.

R, *T*, P-amplitudes of ECG waves. *QRS*, *PQ*, *QT* - ECG intervals (timing electrocardiogram parameters). For further information on the construction of the model - see the text.

Generalized contour, limited by the maximum and minimum values of ECG parameters (external and internal contours of triangles) that have no pathognomonic interpretations (significant for clinical diagnostics), is the intelligent converter, engaged in continuous analysis of the parameter's absoute values «behavior» and forming in accordance with it the appropriate classification actions (for example, translation of ECG parameters of a patient into the system of nosological diagnoses).

Smart converter is hybrid: *a dynamic part* (absolute values of parameters) and intellectual (active) part provide additional features (correlation parameters), imposed on the dynamic characteristics. This is a visual representation of information and quantification of intra-connections in the subsystem. Formation of the transmitter model is based on structural-algorithmic mechanism of functioning of the intellectual-image system.

For a healthy per-son (without clinical signs of functional impairments), the absolute values are within the area bounded by the exterior and interior of the triangle, i.e. fluctuate significantly, while their ratio, determined on the basis of harmonic proportion, remains close to the invariant value (for relatively healthy person).

Due to significant deviations of the parameters ratios from the invariant value, there it is possible a common system pulling down with further consequences of functional cardiac disorders.

Another example of polyparametric cognitive modeling is the model of systems analysis and diagnosis of the functional state of the whole human organism (fig. 2A, B, C).

As elements of the system model, a unified set of representative para- meters (absolute values X_1-X_{20}) of physiological parameters represented as vectors in polar coordinates was used. Each vector has its own scale, defined via modal level (middle circle).

Generalized circuit, limited by the maximum and minimum values of parameters (inner and outer circle), having no pathognomonic values (clinically important parameter's deflections), is the intelligent converter, engaged in continuous analysis of parameter's absolute values «*behavior*» and forming in accordance with it the appropriate classification actions.

The proposed model is visual representation and a quantification of informational intra- and inter-system links (coefficients) of an organism's physiological functions. Formation of the transmitter model is based on a structural- algorithmic mechanism of the intellectual-image system functioning. Conceptual is the definition of functional state of newly acquired individual image concerning the standard - model of the ideal level of system's functional state, without using complex and uncertain level notion of «average human» and his. Geometric images are easy to be interpreted at substantial level.

The polyparametric protocol (fig.2B) of satisfactory functional state rep- resents:

first column - the absolute values of physiological parameters;

second column - the correlation coefficients of these parameters (rule of calculations on fig.2C).

The model was being implemented as a hardware-software complex and tested in comparison with traditional clinical methods of diagnosis and physiological function of the human condition (Dmitrieva N.V., Glazachev O.S., 2000 -2010).

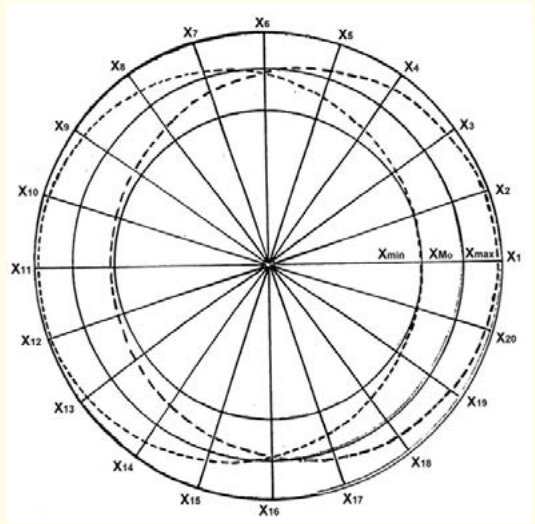

Figure 2A: Polyparametric image model of an "ideal human functional state", measured on the basis of electrophysiological processes parameters.

On the Fig.2A bullet point marked functional state with a predominance of sympathetic regulation type, dashed line - with a predominance of parasympathetic tone.

Symbolic indication of vectors (parameters) is given in (Dmitrieva N.V. et al., 2010) and is represented in the form of numeric electrophysiological parameter's values of:

electrocardiogram, reovasogram, electromyogram, body core and body shell temperature, and arterial blood systolic and diastolic pressure;

on the right of the vertical axis of the image are the temporal parameters; on the left - the amplitude parameters.

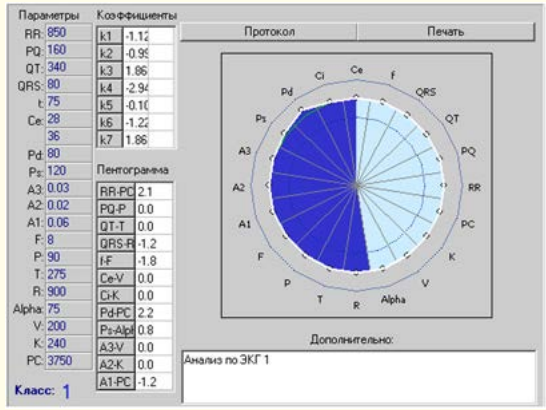

Figure 2B: Model of «ideal human functional state»: polyparametric model of the system of electrophysiological processes with the designation of additional interconnection parameters ratios.

In the left column are physiological parameters absolute values, the next column - informational ratios as.

Bright image segments - temporal physiological parameters, shaded - amplitude parameters (a screenshot of the interface of polyparametric diagnostical program is presented).

All this allows us to consider polyparametric intellectual descriptive models as a cognitive tool in biomedical research.

From the point of view of the existing classification of intellectual systems, these models simultaneously belong to multiple classes:

- The class of dealing with multidimensional data;
- To systems allowing extracting meaningful and useful patterns;
- To the prediction systems, etc.

Polyparametric cognitive modeling, being in the mainstream of cognitive graphics, has a number of important features. A main important feature is that the system model allows identifying the possibility to detect the relations between the parameters of physiological function.

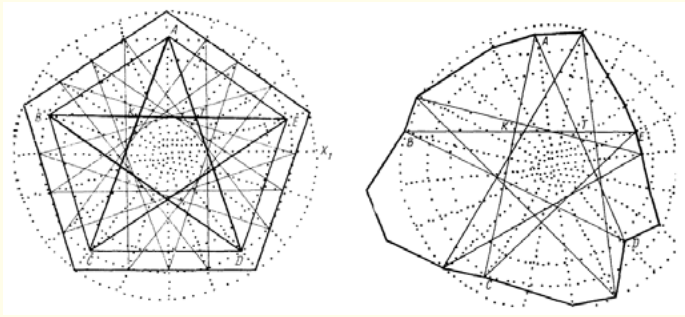

Figure 2C: The image model for the calculation of the coefficients of intersystem interactions of physiological parameters.

From the left - satisfactory functional status, from the Right - a state of functional stress (In the proposed method, additional technology fits into the model of the pentagon, the tops of which reach points of parameters, and the rotation of the pentagon consistently determines the coefficients of (K_{1-20}) physical parameters above mentioned physiological processes by the formula ($X_{n\ Xn\ +8}$) / ($X_n\ X_{n+8\ -y}$), where $X_n\ X_{n+8}$ - side of pentagon - star - between two physical parameters - n-and n+8, which corresponds to the length of the line connecting the first top and the third (right to left starting at 15 hours) top star, y - a segment of the line, bounded by the intersection points to the other party pentagon.

Coefficients found correlated with the reference value of the coefficient ratio of the parameters, similar calculations on the basis of a regular pentagon and a pentagram inscribed in the middle circle model satisfactory functional status (reference value - W = 1.30901 is invariant under projective transformations).

Classification of functional state is based on a variance re-imposed on the coefficients standard: at up to ± 10% - satisfactory functional status, up to ± 35% - stress, and up to ± 50% - overstressed functional state; larger deviation (50% and more) - the failure of adaptive processes, then visualized pattern of multidimensional parameter's space interactively is interpreted in clinical physiological terms.

Supporting of diagnostic conclusions is carried out on the basis of ratio coefficients and their interpretations. At the end the character and specific, individual feachures of adaptation syndrome are described.

Then, as it was noted, the use of physical parameters with the exact dimension defines an objective description of physiological processes. Together with the geometry of the model this defines the reality of metrics and informational links of its elements.

Therefore, based on polyparametric cognitive models, it became possible to identify informational regularities of the functional organization of physiological systems - the cardiovascular, respiratory, regulatory autonomic nervous systems of a human being, and to show that a functional procedure is in continuous relationship with the essential spatial and temporal para- meters of these systems.

These ratios quantify harmonic proportions with invariant factor for heal- thy people (Dmitrieva N.V., 2008). It became possible to modeling multiple functional states of human body, which became the basis for the development of human health polyparametric diagnostic methods and testing them in clinical conditions and in applied settings (Dmitrieva N.V., Glazachev O.S. et al, 2010). Such analysis combines visual assessment of multidimensional data, their quantitative evaluation and assessment of system elements links and relations.

Polyparametric cognitive modeling of electrophysiological processes based on the geometry of images makes it possible to generate new knowledge and to identify regularities within the relationship of functions in hierarchical physiological aspect.

Application of polyparametric methods has a visibility of illustrative graphics and the ability to quantify informational physiological functions as coefficients, which serve as new diagnostic features, as well as additional classification features, the ability to characterize qualitatively and quantitatively the living system as a whole, and its components (subsystems).

Conceptual is the definition of functional state of newly acquired individual image of evaluated person with respect to the developed standard - model of the standard (ideal) level of functional state of a human being, without using the «average man» notion. The basis of the model was statistical data in whole range of their fluctuations. The absolute values of physiological parameters vary within a wide range (20-50%), but the deviation of their ratio coefficients from invariant (for healthy people in a satisfactory condition) does not exceed 5-8%. This opens up a new way towards the metric of adaptive norm as a very rigorous value.

The principal novelty is the application of general principles of symmetry to analyze functional state and invariants of parameter's ratios as a quantitative measure of the object's conservation, which also serve as new diagnostic features of human functional state associated with the balance of physiological systems interaction. The interaction's imbalance of autonomic nervous system is reflected in the shift of the image and violation (dtsbalancing) of its contour (Dmitrieva N.V., 1995, 2008). A visual representation and infor-

mational intra- and inter-system connections quantifyable expression in the human body allowed comparing their dynamics with a traditional clinical diagnosis of a functional state in dynamics (Dmitrieva N.V., Glazachev O.S. et al, 2010).

These features are the key indicators of the body's adaptability and current stage of an individual adaptational syndrome development.

The essence of the examined concept of adaptive norm is to determine the health state as a level of adaptation processes by diagnosing individual adaptation syndrome.

As an example (fig. 3A, 3B) we present the data on the regression of adaptation syndrome of students, when there is a restoration of autonomic status after exams, which manifests itself in the regulation balance of sym- pathetic and parasympathetic regulatory mechanisms.

Our results point to the possibility of polymetric method for tracking the dynamics of the functional state of the organism development.

The obtained results of systems analysis of polyparametric models of electrophysiological processes give rise to imaging the functional order in organization of these processes as a continuous harmonic ratio set of essential space-time parameters with respect to the invariant value for healthy people. In the state of stress and overwork of the body, in the first place there are different violations of invariant parameters relations of physiological functions (Dmitrieva N.V., 2008).

In significant deviations of the parameters relationships ratio from the in- variant values, there is possible a pulling down of the common system with the corresponding consequences of functional disorders of organs, systems and whole organism, leading to human homeostasis disturbance and to varied pathologies development.

One of the advantages of such model presentation is the ease of the metrology problem solution, which, first of all, is important to establish physiological limits of these processes, and which puts electrophysiology in the category of exact scientific disciplines.

The real world is much more complex than can be represented by simple models. For the purpose of distinguishing the concepts of real world objects geometry and abstract geometric constructions, V.I.Loshchilov proposed the term «*Biogeometry*».

The experience of polyparametric modeling and it's exploitation on the diagnosis of functional conditions has prompted us to use polyparametric method for determining the norm of electrophysiological processes of adaptation syndrome development on the basis of informational-systems appro- ach to the analysis of the ratio of physiological processes in the whole organism. Long-term studies of self-oscillatory processes stability parameters ratios in vigorous activity showed the importance of the electrophysiological parameters ratio for functional state diagnostics.

The technology of polyparametric diagnostic is universal and provides unity of the evaluation device for a variety of tasks when diagnosing conditions. Due to the uniform method of examination and the formalization of the obtained results, the technology allows carrying out systematization and mathematical processing of the results, allowing accumulating data and statistically valid comparative evaluations.

To construct systems of informational support for the physician's decisions, in the future, we can use logical «*images*» extracted from the knowledge base. These images serve as a standard for a particular syndrome, and can be detected with the tools of the modern informatics. Such conceptual image- standards are built in accordance with the basic model of the ideal functional status and are recorded in the assessment block. For their construction, there should be used the expert assessments apparatus, hypertexts and specially designed algorithms for the analysis of syndrome analyses.

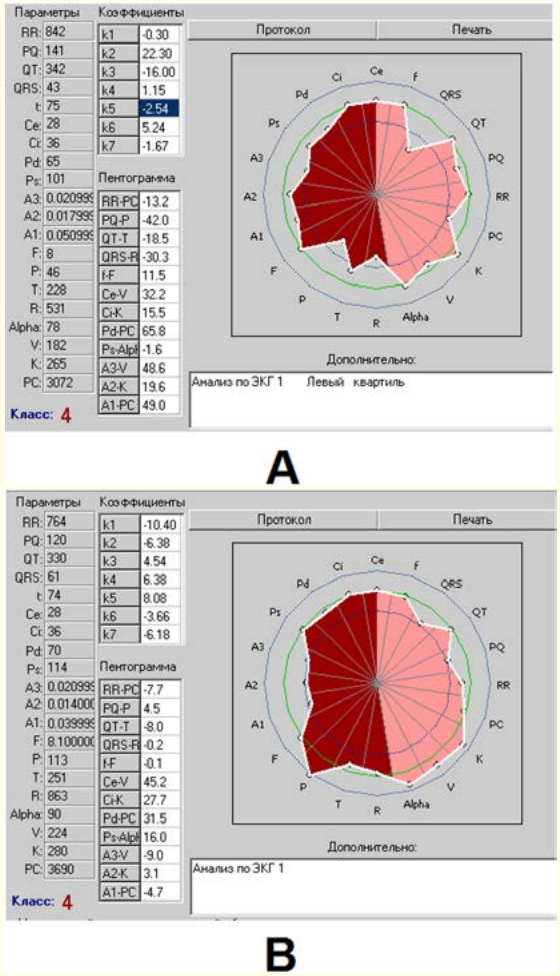

Figure 3: Dynamics of the functional state of a group of students (statistical pattern) before (A) and after (B) exam - psychological stress modeling. The designation is the same as in Figure 2.

The system is within the environment of clinical and preventive medicine. The technology is open to the development and use of the «*supervised learning*» principles based on the accumulation of data bank on the results of polymetric survey and effective correction measures of groups of homogeneous production skills of people who are in similar environmental conditions and ecological situation.

Our own rather extensive experience in implementation of polyparametric experiments and measurements is realbasis for new criteria of norm objectivization for physiology and medicine and leads to the necessity of describing adaptive norm as independent subjective domain, relevant for preventive and clinical medicine development.

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