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Multidimensional approach for evaluation of system activity of the brain by EEG

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Abstract. The way of investigation some fundamental properties of integrative brain activity was worked out. Within the framework of the qEEG system for computer diagnostics of EEG NeuroResearcher™'2001 (Version 7.5) is created modules for investigation of multivariate neurodynamic systems of the brain on the base of multidimensional spectral EEG and ESCoG analysis. It is intended for doctors and neuroscientists who use mathematical methods (classical correlation and spectral analysis and newest methods of multidimensional analysis of neurodynamic systems of the brain) for quantitative EEG (qEEG) successfully.

1. Introduction.

Modern views on neurophysiological mechanisms of emotions, motivations, memory, thinking and so on are based on the ideas about the system principle of brain functioning. So neuroscience's achievements allow considering a system character as the main principle of brain activity.

The functional unification of brain formation and their functional state find the reflection in an EEG (ESCoG). But traditional methods of cross-correlation, spectral or cross-spectrum (pair coherent) analysis are of little use to evaluate these mechanisms. In all known qEEG systems investigate two (but not more) brain structures by turns. In fact, only hypothetical assumptions about the system activity character are made on this ground. In other words, there is a lack of characteristics allowing to evaluate and to quantitatively measure a degree of functional organisation of investigated brain mechanisms in unified systems. Methods of application of mathematical theory and applied apparatus of multivariate spectral analysis of multidimensional neurodynamic systems on the basis of EEG (ESCoG) analysis, received from many brain formations, have not been practically worked out.

2. Method.

To solve the tasks described above the theoretical approach worked out by us [1,2], calculations algorithms, new secondary EEG (ESCoG) indices and their physiological interpretation [3-8] are proposed to use.

The systems analysis of EEG is realised in the framework of *NeuroResearcher™'2001* by application program package *"NeuroResearcher™'2001*Multivariate Analysis"*. This

application consists of following units: 1.Elucidating systems. 2. Blocking influences. 3. 'Pure' pair interactions. 4. Detection of "Contributions".

It is intended for doctors and biologists, EEG specialists, neurobiologists, neurophysiologists, neurology and psychiatry investigators, psychopharmacologists, students - for all who wants to investigate biosignals (EEG) by multidimensional spectral - coherence analysis. This approach is modern development of possibilities of classical methods - correlation and spectral-coherence analysis, practical implementation of that has become possible with appearance of modern powerful computers.

3. Results.

The direct use of auto-spectra and cross-spectra, even taken together to judge properties of the structures system seems to be of little promising. Transition from a system of spectra of EEG-signals to generalised indices functioning of sets of brain structures calculated on the basis of these spectra allows to get more stable and more sensitive characteristics of essential factors of man and animal state. In those generalised indices there is information, presented in all spectra. The method is the basis for creating of qualitatively new approach for investigation neurodynamic structure of cerebral mechanisms.

3.1. Elucidating systems of the brain.

This unit serves for investigation of neurodynamic systems of the brain (Fig.1). It makes possible: 1) to detect complex of the structures that takes part in the investigated system activity; 2) to investigate simultaneously the interaction of several (more than 2) formations of the brain; 3) to study systems including up to 256 brain formations; 4) to study the mechanisms of brain system activity; 5) to investigate the neurodynamic structure of normal and pathological processes of sleep, emotions, motivations, thinking, memory and motions; 6) to determine 'input', 'output' and 'relay' elements of neurodynamic systems, detect fine neurodynamic structure of brain interactions; 7) to solve problems of identification signal recognition channels, location of one or more signal sources.

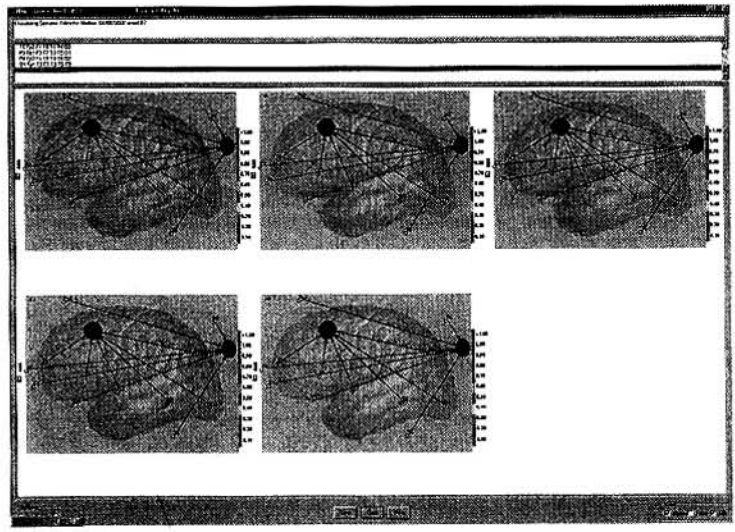

Fig.1: Elucidating Systems.

3.2. Blocking influences.

This unit serves for investigation of system interactions in 'pure' form, excluding (blocking) influences of separate structures or whole systems on INTRA/INTER-system interactions (Fig. 2). In other words: simulate mathematical "cutting" of INTRA- and INTER-system mutual influences. This unit allows: 1) to estimate in 'pure' form the intra-system interactions and inter-system influences; 2) determine 'input', 'output' and 'relay' elements of neurodynamic systems; 3) detect fine neurodynamic structure of brain interactions; 4) to solve problems of identification of signal propagation channels, location of one or more signal sources.

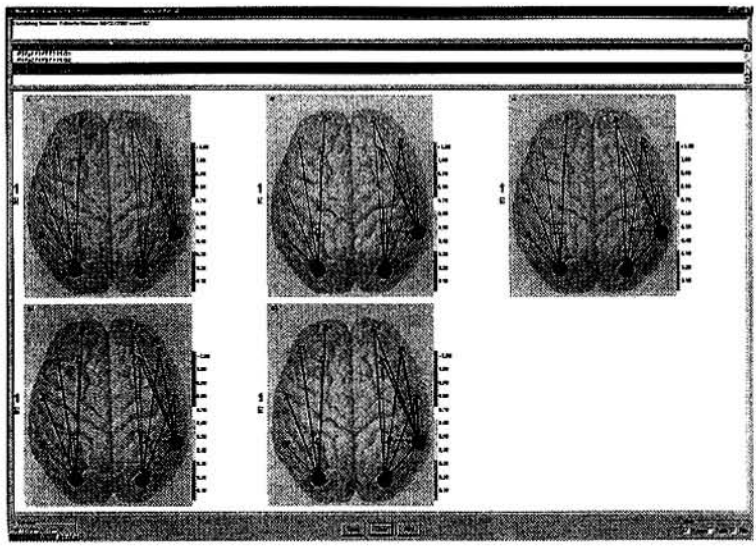

Fig. 2: Blocking Influences.

3.3. "Pure" pair interactions.

This unit intends for investigation of an interaction of a pair (two) structures or regions of the brain in 'pure' form, which is achieved by eliminating the influence of all other investigated regions of the brain on the interaction of this pair. It allows investigating INTRA-system interactions and INTER-system influences in 'pure' form, eliminating ('blocking') the influence of separate structures or whole systems on pair interactions. In other words, to simulate mathematical 'cutting' of INTRA- and INTER-system influences on the investigated pairs of brain formations. "Pure" pair interactions unit makes it possible: 1) to estimate in 'pure' form their interactions; 2) to determine 'input', 'output' and 'relay' elements of neurodynamic systems; 3) to detect fine neurodynamic structure of brain interactions; 4) to solve problems of identifying signal propagation channels, locating one or more signal sources.

3.4. Detection of "Contributions".

This unit serves for investigating neurodynamic systems of the brain (Fig.3, 4). It is recommended to use this mode after "Elucidating Systems" and "Blocking Influences" modes. "Contribution" determination unit allows: 1) to estimate quantitatively the

'contribution' of separate structure in system activity under investigation; 2) to detect a set of structures that actually take part in system activity under investigation; 3) to determine 'input', 'output' and 'relay' elements of neurodynamic systems, reveal fine neurodynamic structure of brain interactions; 4) to solve problems of identification of signal propagation channels, locating of one or more signal sources; 5) to investigate simultaneously an interaction of several (more than two) brain formations; 6) to evaluate 'contributions' to systems comprising up to 64 brain formations; 7) to investigate a neurodynamic structure of normal and pathological processes of sleep, emotions, motivations, thinking, memory and motions.

4. Conclusions.

Circumscribed "System analysis" approach for investigation of system neurodynamic allows to apply methods of quantitative EEG analysis (qEEG) and to understand influence of brain bioelectrical activity character on modifications of secondary EEG indices. Experienced clinician can use this approach for best interpreting of outcome investigations of neurodynamic system of the brain. Besides it has allowed inserting in clinical practice and researches of the brain new potent mathematical methods.

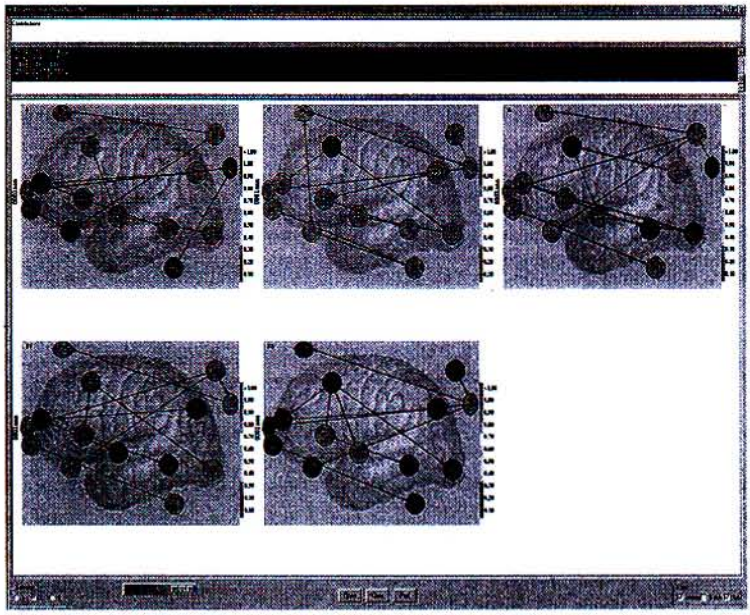

Fig. 3: Detection of "Contributions".

5. Summary.

Thus, this method is perspective direction for brain system neurodynamics investigations by new medical computer technologies. This approach for study of system activity of the brain successfully use in diagnostics of nervous, mental and endocrine diseases in last 10 years in the Institute of Children and Adolescents Health Protection of National Academy of Medical Sciences of Ukraine.

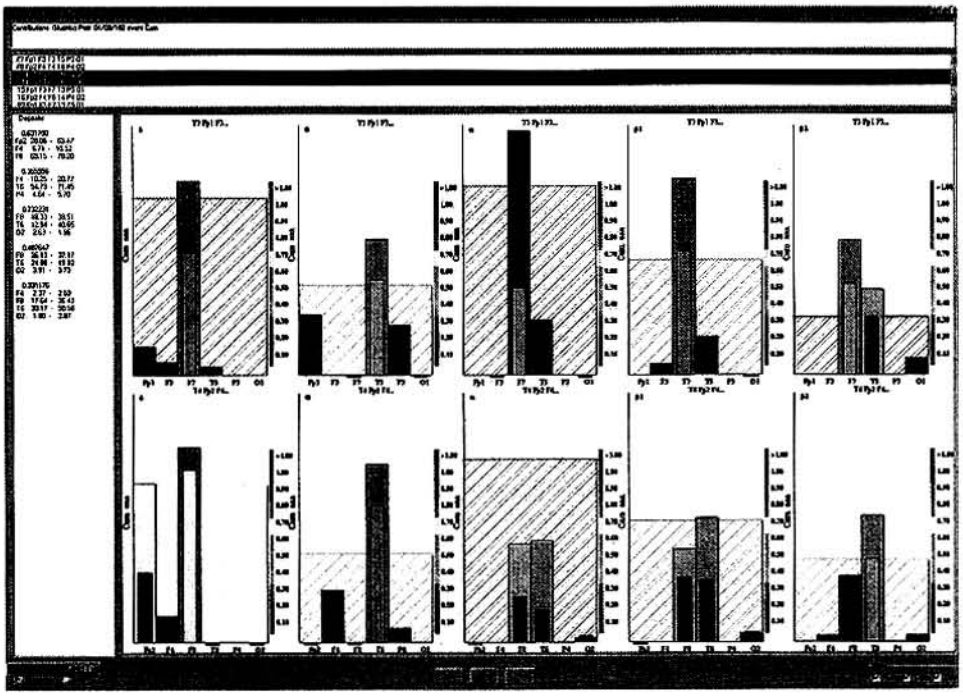

Fig. 4: Detection of "Contributions" (diagrams).

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