

COMMON MECHANISMS OF DIFFERENT FUNCTIONAL LEVELS OF SELF-ORGANIZATION

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Fields of interest: neurofeedback, self-regulation of physiological functions, applications of theory of chaos in biology.

Publications: Effects of naloxone on the neuropsychiatric symptoms of a woman with partial adrenal 21-hydroxylase deficiency (with I. Blum et al.), *Am. J. Psychiatry* (1983) 140, (8); Sudden death, neuroleptics and psychotic agitation (with J. Leria and A. Elitzur), *Prog. Neuro-Psychopharmacol. & Biol. Research* (1995), 19, 229-241; Stress management for psoriatic patients. the effectiveness of biofeedback and relaxation techniques (with G. Keinan, U. Gal and S. Brener), *Stress Medicine* (1995), 11, 235-241.

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Abstract: *Possible common mechanisms of self-organization of bioelectrical activity in visual cortex and in simple in vitro protein-water systems (under non-equilibrium conditions) are discussed in the light of experimental data obtained.*

In our collaborative study a question of common mechanisms of self-organization of extremely different physiological systems (in terms of hierarchical levels of function) was investigated experimentally. Bioelectrical signals of visual cortex of learning brain (occipital lead of EEG in the process of thermal biofeedback) were compared with protein film formation in a protein-water system under certain in vitro non-equilibrium conditions.

Thermal biofeedback for many years is known to be a well-established therapeutic procedure (Schwartz 1995) but relatively little is known yet in terms of central mechanisms

of its action. In this study we tried to learn some aspects of this question in terms of central nervous system activity along the process of therapeutic skills acquiring.

This subject might be viewed as well as a deviation in chaotic quasisymmetric order in electrical brain wave activity and its dynamic characteristics may be compared with those achieved by altered conditions in self-organizing systems of different hierarchical levels.

METHODS

Five subjects (four women and one man, ranging between 20 and 48 years of age) were involved in this study. All of them were suffering from a kind of a disorder in which thermal biofeedback was indicated as a therapeutic procedure. Three had vascular headaches, one was suffering from anxiety and one young woman had unstable essential hypertension. We decided to conduct this pilot investigation on clinical population in order to have a good back up in terms of patients' motivation. All the patients after a clinical intake procedure were given a session of combined Jakobson - Schultz relaxation and were instructed to proceed with this 15-minute relaxation three times a day. Then thermal biofeedback half an hour sessions were conducted on a twice a week basis. Two of the participants underwent 20 sessions each. Three others had received altogether 23 sessions. The number of all the sessions which had been conducted and analyzed was 63.

For physiological data acquisition The API Neurodata Physiograph was used. It has the possibility to monitor, store and process the thermal and the EEG information concomitantly. The EEG recordings were obtained from dominant occipital area. They were performed unipolarly and the patients were sitting with open eyes. The thermal biofeedback training was conducted classically by attaching the dominant index to a thermistor. The data was processed and presented in statistical charts. Correlational analysis of various variables was applied in order to determine possible statistical bonds between different phenomena.

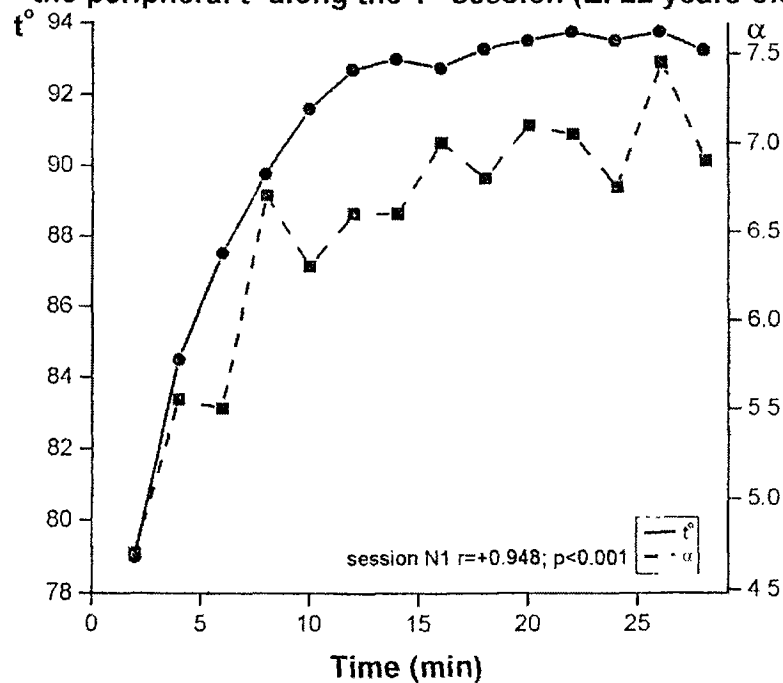
RESULTS

As we knew already from our previous clinical work in biofeedback the majority of our patients are able to elevate the peripheral temperature of their hands or in other words, they are able to diminish the sympathetic flow. Therefore they relax the smooth muscles of the arterial vascular bed in the extremity attached to the thermistor. The overall

change across all the 63 sessions was about 3,7 degree F. The main gain was obtained at the very beginning of the learning process (the very first couple of sessions). The time span from the start of the session up to the maximal elevation was shortened gradually from session to session from 15 to 7-8 minutes and remained so after session 11-12. The base line temperature of the dominant hand was climbing slowly up. The alpha-wave energy changes during the process of thermal training were even more demonstrative. At the first session across all 5 cases studied the gain during the session exceeded 100% (from 4,3 to 9,0 units of Neurodata scale). At the point of the 5th session this difference did not exceed even 1,5 units and this number was kept more or less on the same level up to the end of the procedure. No significant changes were observed in other aspects of brain-wave activity.

The direction of the change in temperature and in alpha-wave energy along the starting sessions was similar and the correlation between those variables appeared to be very high.

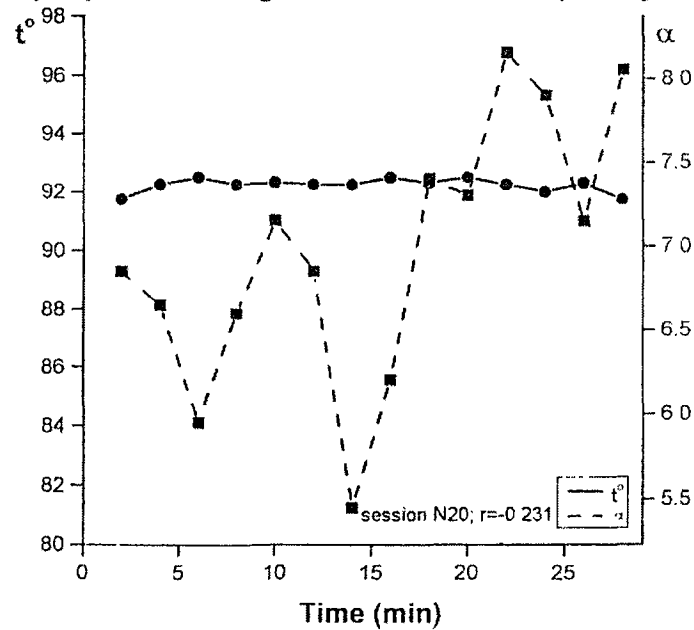
The dynamics of change of α -band and the peripheral t° along the 1st session (E. 22 years old)



x-time in minutes
y1-temperature
y2- α band energy

Those strong correlations had undergone very significant changes and as a paradigm the last 20th session of the same patient witnesses this fact: there is no correlation at all between those 2 parameters.

The dynamic of change of α -band and the peripheral t° along the last 20st session (E. 22 years old)



x-time in minutes
y1-temperature
y2-alpha band energy

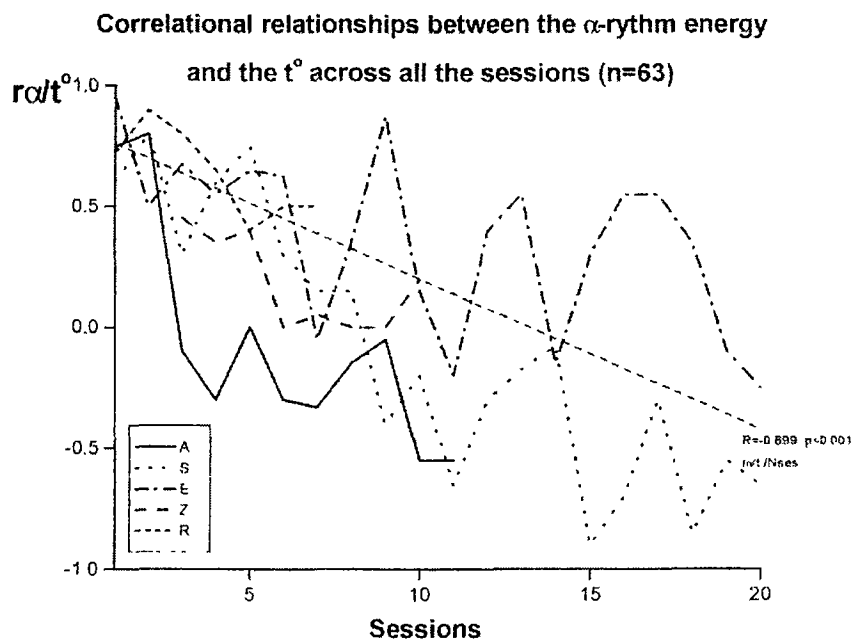
In general, the alpha-wave energy changes preceded the changes in temperature.

The second part of the study was conducted in an open protein-water system where non-equilibrium conditions were created in vivo by rapid water evaporation. In a series of experiments (more than 150) different systems of protein-water were placed on a solid substrate (glass, plastic etc.) and the process of protein-condensing was visualized in dynamics by means of several kinds of microscopy (for details see Rapis 1995a, 1995b, 1997).

The qualitative results of the experiments were repeated with high accuracy. The experiments showed the following dynamics of protein condensing: front movement of self-supporting oscillations (autowaves) has been constantly observed with alterations

of attraction and relaxation zones. In liquid crystal phase at critical increase in density the appearing structural defects created spontaneous intermittent spiral and chiral symmetry and self-assembly nucleation of three-dimensional protein cluster film. Morphological structures of "cells" with nuclei or domains have been formed in them. In denser material avalanche-like spatial sharp-ended dissipative structures or folding films-solutions with fractal properties appeared suddenly. Uniting around the nucleus, they formed pairs of whirl tunnels. In liquid crystal phase jump-like correlated color changes (red, yellow and green) have been observed. Those changes were reflecting pulsating in film elasticity or reverse elasticity inherent to biopolymer gels (Aggeli 1997; Pouline 1997). On the whole we succeeded to find out a non-linear, chaotic condensation process dynamics and 3D protein film self-organization. This spontaneous dynamic process had a lot of properties inherent to biological living objects: morphological self-similarity, spontaneity, fractality, coherency, synchrony, intermittent spiral and chiral symmetry etc. The picture of such self-organizing protein-water films generally might be characterized as "chaotic symmetry".

DISCUSSION



x-number of sessions

y-correlation coefficient between α band and peripheral temperature

As can be concluded from our material the peripheral temperature changes along the thermal biofeedback training are accompanied from the very beginning by a concomitant and significant elevation in alpha-wave energy in the visual cortex of the brain. Those strongly bound statistically relationships relatively early underwent dramatic changes: the correlational index drops promptly reflecting, most probably, a different (comparing with the very beginning of the temperature learning) functional state of the occipital cortex.

We feel that at the initiation of the learning process the brain has to work deterministically but very quickly its activity returns to its previous patterns (attractors) in spite of the fact that the learning process is still going on. The statistical bonds between alpha energy and the peripheral physiological signal disappear. The whole-body homeostatic obligations are obviously far more important than serious devotion to a local peripheral task. Low dimensional goal-oriented activity is promptly replaced by a highly dimensional and functionally flexible state of high performance (Heffernan 1995). The chaotic and quasisymmetric equilibrium returns to dominate in the picture of EEG.

From the other hand, the self-organizing process in non-equilibrium systems "protein-water" suggests strongly that it follows the same rules of the theories of fractals and chaos (Rapis 1995a, 1995b, 1997). Because the fact that protein films and membranes are one of the milestones of almost any living organism we can suppose that its rules of self-organization determine the fundamental laws of self-organization in higher functional levels of hierarchy.

Such a postulate seems to be obvious because if a lower level and a higher one would not obey the same rules – the system would not be able to function properly. This study gives us some experimental evidences supporting this idea.

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