Energy - Entropy Compensation as a Universal Order Creating Principle in Self-Organizing Systems : Results from the Thermodynamic analysis of EEG data

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Abstract

A universal principle of order creation in terms of Energy - Entropy Compensated Transitions is postutated as the underlying and unifying concept for the formation of orderly states in biology. This is demonstrated by deriving a linear correlatory relation between Energy and Entropy for the EEG transition dynamics using simple thermodynamic arguments. The consequent analysis of the EEG numerical data verifies the relationship derived.

1 Introduction

Concepts from Thermodynamics and Quantum theory have already been used widely and successfully to describe biological phenomena. Important approaches are the Irreversible Thermodynamics developed by I.Prigogine, the Synergetics of H.Haken and the Biological Thermodynamics of K.Trincher. One principle of Thermodynamics has been mostly neglected in the analysis of Life, namely the Third Law of Thermodynamics. This Third Law of Thermodynamics is the universal principle of creating order by reducing the temperature. One consequence of this law is that the total entropy (disorder) of a substance goes to zero as the temperature approaches absolute

zero(= zero degree Kelvin). We here in this article study the application of the Third Law of Thermodynamics to Biology in general and to Neurobiology in particular, in terms of a thermodynamic analysis of the electrical brain activity. Through a simple oscillator model of the brain activity first proposed by C.Tourenne (1981), an EEG-entropy and an EEG-temperature for the different brain areas are defined. The defined EEG-entropy measures the degree of order and the EEG-temperature the state of the activation of the EEG, for only one specific area of the brain at a time.

Tourenne in his approach left open the question of defining an EEG-temperature for all the brain areas at once, for such a definition would have to take into account correlations between different areas of the brain. In this contribution, we by defining EEG-entropy, and EEG-temperature for all the areas at once, derive a hidden linear correlatory relationship between EEG-energy and EEG-entropy. The slope of the linear relationship between EEG-Energy and EEG-entropy has the dimension of a temperature and defines the iso-equilibrium temperature which measures the activation of the brain as a whole. According to Linert (1985) "the primary signature of the iso-equilibrium temperature is ... to characterize the thermodynamic behavior of the system within the temperature range investigated, so as to afford the proportionality constant between enthalpy (energy) and entropy".

Energy - Entropy compensation as measured by the iso-equilibrium temperature is an indication that

1. a single source of energy is responsible for the EEG activity related to different areas of the brain (Tourenne, 1981).

2. the total brain EEG-activity is governed by the Third Law of Thermodynamics for the newly defined quantities. Thus the lower iso-equilibrium temperature the higher the state of the total order of the brain.

As a consequence, the iso-equilibrium temperature can be understood as a measure which allows to specify an evolutionary direction for the brain behavior.

Such indications were independently suggested by EEG coherence research (D.Orme-Johnson, et.al. 1981, M.Dillbeck, et.al. 1986, C.Gaylord, et.al. 1989).

2 The Thermodynamic model of brain activity

To define an EEG-entropy and an EEG-temperature, Tourenne assumed that the EEG corresponds to electrical oscillations around a thermodynamic equilibrium state of an ensemble of oscillators. This simple model of the electric brain activity is in accord with the understanding of the EEG developed by Thatcher(1977) and Schmidt(1978). It is further assumed that the EEG as measured at different areas on the surface of the head is the result of the functioning of a finite number of harmonic oscillators. This assumption allows the application of the formulas of statistical thermodynamics for each of these oscillator ensembles representing the electrical brain activity as monitored at the six different EEG leads (Frontal-F3,F4; Central-C3,C4; Occipital-O1,O2).

Now we give a short sketch of the thermodynamic model developed by Tourenne. We will restrict ourselves to the formulas necessary to understand the energy-entropy correlations studied in the present paper.

Let p_{ik} represent the probability for the energy of the oscillator having a frequency f_k to be E_i. This probability is determined via the number of energy values related to a specific frequency, f_k. The energy E_i characterizes the state of a particular oscillator with the frequency, f_k. This energy is derived from the power spectrum of the EEG.

In the thermodynamic model, the energy of the oscillator with frequency f_k is given by the relation:

$$E_k = \sum_{i=1}^{n_k} p_{ik} E_i \tag{1}$$

where n_k is the total number of energy values related to the oscillator with the frequency f_k.

The corresponding entropy of the oscillator with frequency f_k is given by:

$$S_k = -\sum_{i=1}^{n_k} p_{ik} \ln p_{ik} \tag{2}$$

The EEG temperature T_k for each oscillator is introduced via the distribution law:

$$p_{ik} = \frac{1}{Z_k} \exp(-E_i/T_k) \tag{3}$$

with Z_k given by

$$Z_k = \sum_{i=1}^{n_k} \exp(-E_i/T_k)$$

which defines the EEG temperature corresponding to the energy sustaining the oscillator with frequency f_k.

Tourenne also defined an avearge entropy and an average temperature over all frequencies of every EEG lead:

$$S = \frac{1}{N-1} \sum_{k=0}^{N} S_k; \qquad T = \frac{1}{N-1} \sum_{k=0}^{N} T_k; \tag{4}$$

Tourenne then found his data empirically obeying a single linear relationship between the above S, and T pertaining to a local area of the brain, confirming his oscillator model. However he could not derive a theoretical relationship between the quantities owing to the difficulty of the local assumption. But in the present paper by extending the above definitions globally for the whole brain, we are able to derive the required linear relationship theoretically. And, Tourenne's experimental data confirm the derived relationship.

In order to derive the linear relationship between E_k and S_k, we consider the definition of free energy $F(T)$ which is given by (Kirkpatrick et.al., 1983):

$$F(T) = -K_B T \ln(Z) = E - TS \tag{5}$$

From the above by simply rearranging the terms we obtain easily the following linear correlatory relationship between E_k and S_k:

$$E_k = T_k(S_k - \ln Z_k) \tag{6}$$

where k stands for the individual group index.

If we consider the limit $T- > 0$, the term TS approaches zero much slower than $K_B \ln(Z)$ although it involves E and T. Thus in the limit $T- > 0$ we can write the limiting correlatory linear relationship:

$$E = T_{limit} S \tag{7}$$

Comparing the definition of isokinetic temperature which is given by (Linert and Jameson, 1989):

$$\frac{\partial E}{\partial S} = T_{iso} \tag{8}$$

we immediately identify that T_{limit} is nothing but the T_{iso}. Here the ∂ operator represents the variation of discrete values within the considered series; in our case the variation of the energy-entropy pairs is related to the different EEG leads.

3 Materials and Methods

3.1 Data aquisition

The thermodynamic EEG analysis of the brain activity presented in this paper focuses on the energy-entropy correlation in the EEG. We use Tourenne's data to demonstrate the relationship derived in equation (5).

Tourenne analysed the EEG of ten male students(mean age 25). All the subjects have been practising Transcendental Meditation for an average of 6 years. Transcendental Meditation is a simple mental technique to experience a state of least excitation of mental activity, a state of restful alertness or pure consciousness. Tourenne in his study analysed the EEG of the ten subjects in series of four-second-epochs during: (a). a period of 5 minutes with eyes open(EO) followed by (b). a period of 5 minutes with eyes closed(EC) and (c). a period of 15 minutes during which the subjects practiced Transcendental Meditation(TM).

In each EEG recording, the records were taken from the six electrodes F3, F4, C3, C4, O1, and O2 of the 10-20 system with linked ears for reference electrode.

3.2 Data Evaluation

The evaluation of the data starts with the power spectrum analysis of the EEG:

The continuous EEG signal of every lead is subdivided into what are called epochs. Tourenne used a subdivision into 72 epochs for a 5 minute experimental period. Each epoch is again subdivided into $2N$ discrete points taken at regular intervals Δt. The length of an epoch is $2N\Delta t = 4$ seconds. Epochs are signified by the index j which runs from 1 to 72.

The fundamental frequency of the EEG signal is defined as $f_1 = 1/2N\Delta t$ and every other frequency f_k is given by $f_k = kf_1$ with $k = 0, 1, 2, \ldots, N$.

For each time t, in an epoch j, the value of the amplitude of the EEG signal is calculated according to the formula:

$$V_j(t) = \sum_{k=0}^{N} V_{jk} \exp(j2\pi f_k t) \tag{9}$$

Then the power $P(j, f)$ for an epoch j at a frequency f is:

$$P(j, f) = |V_{jk}|^2 \tag{10}$$

This power is considered in the present thermodynamic model as the energy characterizing the state of an oscillator with frequency f_k of the respective epoch j. This energy is represented by E_{jk}.

An another useful information is the probability for the energy of the oscillator with frequency f_k to be E_i. This probability p_{ik} will be derived in the following analysis.

All the experimental values of E_{jk} are distributed as a set of intervals of constant width E_0 and centered at a specific value E_i such as:

$$E_i = E_0(i - 1/2) \tag{11}$$

The width of each interval is choosen in such a way to minimize the standard deviation of the temperature which is assumed to be constant for every energy interval. The number of such intervals n_k depend on the specific frequency f_k.

Let N_{ik} be the number of experimental values E_{jk} contained in every interval for a specific frequency f_k. Then the probability for the energy of the oscillator with frequency f_k to be E_i is:

$$p_{ik} = \frac{N_{ik}}{p} \qquad with \qquad p = \sum_{i=1}^{n_k} N_{ik} \tag{12}$$

This probability is necessary for calculating the entropy S of the oscillator with frequency f_k, but also used in the calculation of the energy of the oscillator (f_k).

The energy and the respective probability are two different entries for the thermodynamic EEG analysis. They are related to each other but do not represent the same information. This point is important because it establishes the reality of the resulting energy-entropy compensation.

4 Results and Discussion on the thermodynamic EEG-Analysis

From the data of six EEG-leads(F3,F4,C3,C4,O1,O2) of 10 human subjects the average energy and entropy of these EEG-signals were computed according to the thermodynamic model. The resulting values of the EEG-energy and EEG-entropy for the ten subjects were again averaged to arrive at one value of EEG-energy and EEG-entropy for every EEG-lead and all the subjects. By plotting the energy against entropy for the six EEG leads F3, F4, C3, C4, O1, O2, a linear energy-entropy compensating behavior results (figures 1-3).

Of course further research will be necessary to derive the established linear relationship from concrete theoretical reasoning supported by a suitable biological modelling of the brain activity and the data acquired using more subjects and rigorous statistical testing procedures. The findings of our research are pointing in the right direction and therefore are opening a new area of EEG research.

The iso-equilibrium temperature varies from a higher value to the lowest among the three states of conciousness studied in the following order: 1) eyes open (EO) - highest, 2) eyes closed (EC) - intermediate, and 3) Transcendental Meditation (TM) - the lowest. The lowest iso-equilibrium temperature of Transcendental Meditation (TM) confirms the high degree of coherence in phase relationships found through other electrophysiological studies of TM (Dillbeck et.al, 1986, Orme-Johnson and Haynes, 1981).

The present analysis purports to indicate that all these findings can be interpreted as the result of the Third Law of Thermodynamics applied to brain activity. The iso-equilibrium temperature is on a hierarchically different level then the temperature defined through the thermodynamic model of the EEG. Therefore it is possible that the iso-equilibrium temperature approaches absolute zero while the thermodynamic temperature remains much above the absolute zero. This is a hint towards a possible "two-fluid" state of brain activity if one follows the phenomenological description for ordered systems developed by Enz (1974).

5 Simulated annealing and Optimization in brain activity

The thermodynamic formalism of an iso-kinetic EEG model of brain activity presented in the paper can be extended into a simulated annealing scenario of optimization of brain activity. This results directly from identifying equation (3) as the probability for a configuration in the brain activity space which involves many variables in the present oscillator model. Here T_{iso} becomes sequentially lowered as order increases.

Thus the essential lowering of the "effective temperature" in the annealing procedure of optimization is achieved by the lowering of the iso-equilibrium temperature.

Energy-entropy compensation as generalised by E.Peacock-Lopez and H.Sohl (1982) includes also in a generalized form the "iso-inversion temperature" describing the selection dominated bio-molecular synthitic activities in a hierarchy from more to less entropy controlled chiral reaction channels (Buschmann et.al., 1989, 1991). (2) In amphiphile self-organisation (Evans and Ninham, 1986) and in protein dynamics (Lumry and Rajender, 1970) as well as in reaction kinetics (Slanina, 1989) compensation is the general case.

In the open living system structures, flows of energy, matter and low entropy nutrients entail expansion of the zero-entropy, zero-kelvin, iso-kinetic, iso-enthalpic case of Energy-Entropy compensation (Linert et.al., 1985) represented by parallel lines in the Arrhenius plot of quantum chemical tunneling states into greater spactio temporal stability.

Fluctuations of high and low energy in compensated self-organising systems seperate out problems / activities on different scales linked to different T_{iso} values. In high energy phases, high entropy states of variation as novelty creation are possible. Of these novelties, in low energy phases only low entropy states confirming to the iso-kinetic scenario can continue, and the other states requring more energy natually die out. Only this allows for the lowering of the iso-equilibrium temperature as a sufficient condition for the maintainance of the coherent ground states of living matter (Del Givdice, 1988, 1991) as indicated by EEG compensation and in contrast to the existing understanding based on chaotic dynamics (M. Palus et.al., 1992, R.M. Duñki, 1991).

6 Summary of Results and Conclusion on the compensation between EEG-energy and EEG-entropy

The most important conclusion one can draw from this observation of a linear relationship between energy and entropy of the EEG is that all the EEG oscillators are sustained by a single energy source(Tourenne, 1981). Energy-Entropy Compensation defines the iso-equilibrium temperature as slope of the linear relationship between energy and entropy. This iso-equilibrium temperature can be used to classify different states of orderliness (health) of the brain and can therefore be understood as an objective measure for the different states of consciousness.

From the actual distribution of the energy-entropy values on the linear compensation graph the following conclusions can be drawn: the closeness of the occipital energy-entropy values to the low entropy regime(fig.2) is indicative of a high state of order in the optical cortex region during the eyes open period. An even higher level of orderliness is found during Transcendental Meditation in the frontal and central regions. The related cortex areas have been strongly emphasised in theories on the evolution of the human brain. Our findings could prove to be most valuable in understanding the evolutionary origin of species specific morphology, the high degree of cognitive ability and creative intelligence in the speech of men from an inate de-activating "diving" response (Bujatti Narbeshuber, 1987, 1988, 1989 and 1992) in symbol self-elicitation. In the light of our study, this is related to the lowering of T_{iso} and meditation physiology.

The optimization characteristics of the linear relationship between energy and entropy is also seen to hold on the macroscopic-morphological optimization level of life.

This is manifested in the phylogenetic evolution of mammals e.g., in the brain-weight to body-size relationship multiplied by the weight specific metabolic rate (E. Armstrong, 1983). It shows isometry of the two information and energy linked parameters characterized by an allometric equation with a close similarity to equation (6).

In this ultimately quantumfield theoretical frame for consciousness describing for the first time the energy-entropy compensating microprocessor of life, stemming from isoenthalpic proton tunneling transitions of the solvent, the neo-darwinian theory is a necessary but not sufficient subtheory describing the fabrication of the data carrying discettes as genes.

The observed Energy-Entropy Compensation could play the role of the long searched inner selection mechanism of biological organization (Bujatti-Narbeshuber, 1976) instrumental in the biological realization of the Third Law of Thermodynamics. The entire compensation process operates through a bipolar brain mechanism of activation and deactivation which repeatedly raises (corresponding to creative variation) and lowers (corresponding to inner selection) the iso-kinetic temperature that is very much similar to the process of simulated annealing (Kirkpatrick, S., et.al., 1983) for optimization in physical systems. The selective role of energy-entropy compensation which until now has been mainly substantiated in the field of chemistry (see for example H.Buschmann, et.al., 1991) can be extended to general biology as our research indicates.

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8 References

[1] Bujatti-Narbeshuber,M., Riederer,P. J.Neural Transm., 39 (1976) 257-267.

[2] Bujatti-Narbeshuber,M., Preprint, The Paper read at the 9th International Congress on Dental Morphology, Florence, Italy Sep. 3-5, (1992) .

[3] Bujatti-Narbeshuber,M., Int. J. Neuroscience 32(2) (1987) 315-.

[4] Bujatti-Narbeshuber,M., Int. J. Neuroscience 32(2) (1987) 520-.

[5] Bujatti-Narbeshuber,M., A Unified Theory of Life (Transition theory of Evolution) Vols.I, II, and III Intra-Publication Vienna-Stockholm ISBN 3-9008 14-007 (1989) .

[6] Dillbeck,M. and Vesely,S.A., Intern.J.Neuroscience 29 (1986) 45-55.

[7] Enz,C.P., Reviews of Modern Physics 46 (1974) 705-753.

[8] Gaylord,C., Orme-Johnson,D.W., Travis,F., Intern.J..Neuroscience 46 (1989) 77-86.

[9] Linert,W. and Jameson,R.F., Chem.Soc.Rev. 18 (1989) 477-505.

[10] Linert,W., Schmid,R., and Kudrjawtsev,A.B., Aust.J.Chem. 38 (1985) 677-688.

[11] Orme-Johnson,D.W., Haynes, Chr.T., Nueroscience 13 (1981) 211-217.

[12] Schmidt,R.F., Fundamentals of Neurophysiology, Springer, New York (1978) .

[13] Thatcher,R.W., Functional Neuroscience, Vol 1 and 2, Halsted Press, John Wiley and sons (1977) .

[14] Tourenne, Ch., Paper presented at the 93rd session of the Iowa Academy of Sciences, 25th April, Cedar Rapids (1981) .

[15] Armstrong, E. Science 220 (1983) 1302.

[16] Kirkpatrick,S, C.D.Gelati Jr., and M.P.Vecchi. Optimization by simulated annealing. Science, 220 (1983) 671-680.

[17] Peacock, E, Lopez and M.Sohl. Physical Review B, 26(7) (1982) 3774-3782.

[18] Palus, M, I. Dvorak and I. David. Physica A, 185 (1992) 433-438.

[19] Dunki, M Bulletin of Mathematical Biology, 53(5) (1991) 665-678.

[20] Buschmann, H., H-D.Scharf, N.Hoffmann, P.Esser Angew. Chem. 103 (1991) 480-518.

[21] Buschmann, H., H-D.Scharf, M.W.Plath, J.Rvnsik, J. Am. Chem.Soc. 111 (1989) 5367-.

[22] Del Giudice, E Physical Review Letters 61(9) (1988) 1085-1088.

[23] Del Giudice, E., J.C. Dore and Teixeira (eds.,) Hydrogen-Bonded Liquids, Kluwer Academic Publishers. (1991) 211-220.

[24] Lumry, R., and Rajender, S. Biopolymers 9 (1970) 1125-1227.

[25] Slanina, Z. Z. Phys. Chemie., Leipzig. 270 (1989) 81-88.

[26] Evans, D.F. and B.W. Ninham. J.Phys.Chem., 90 (1986) 226-234.

Caption to Figures.

INTRODUCTION TO FIGURES 1 to 4

Data were taken from a computerised statistical EEG - analysis of 6 EEG - leads (F3, F4; C3, C4; O1, O2) averaged over all frequencies in 10 human subjects and transformed to energy-entropy values for us by C.Tourenne. See text for details.

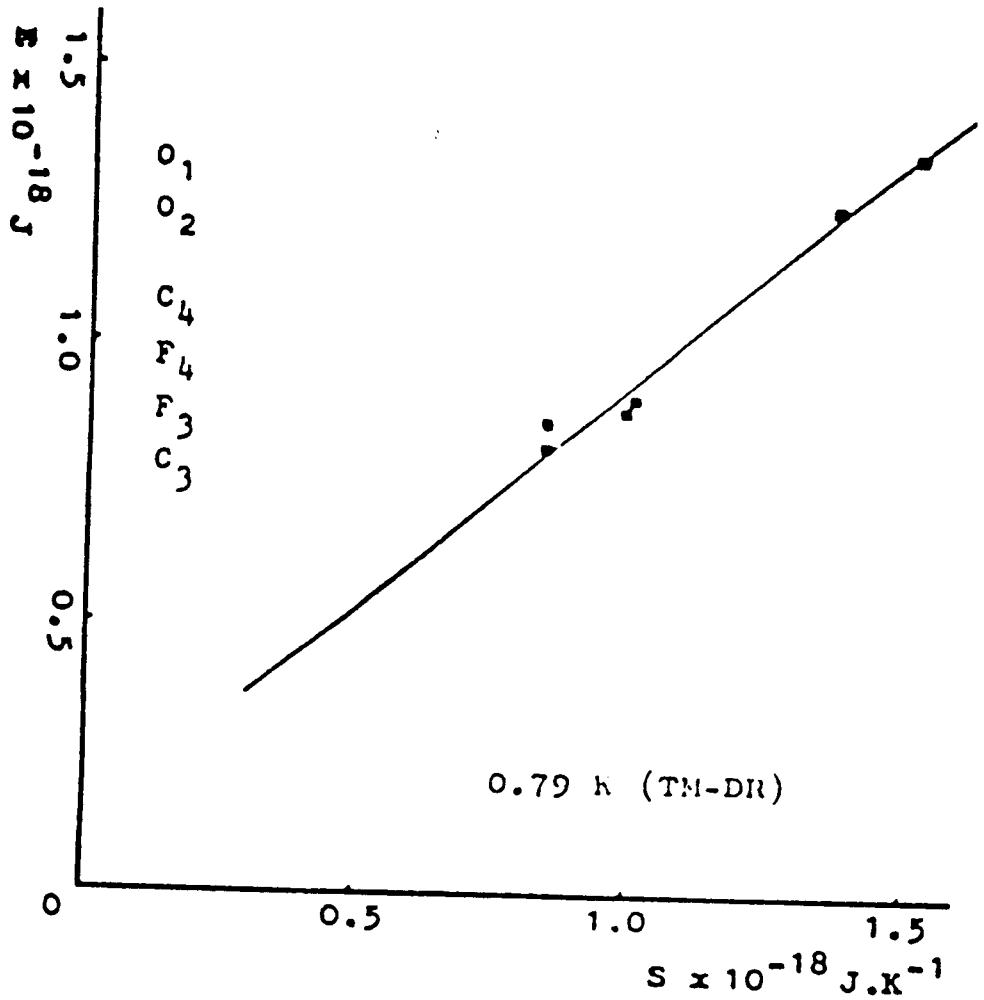
The preliminary result is the most compressed EEG-data representation, the compensated Iso-Equilibrium Encephalo-Graph (IEEG). It is interpreted on epistemological grounds. They are based on bio-evolutionary bottom up bio-chemical kinetical as well as on top down teleonomic brain-behavior compensation arguments for IEEG as the statistical physical representation of the consciousness experience.

This interpretation finds a first preliminary experimental confirmation here, requiring further rigorous statistical testing. The indication is that the diversity of EEG- data has an underlying linear pattern. It is characterisitic of the holistic self-interacting unity O that is defined according to onto-epistemology as ontic invariant consciousness here. It is directly measurable by: the IEEG-self- (interaction)-awareness-parameter of linearity. Consciousness consists further of 1. an observer- or subject- aspect : IEEG-vigilance-parameter of T iso. 2. an observation- or interaction- process aspect: IEEG-attention-parameter of lowest entropy domain EEG-leads. 3. an observed- or object- aspect: IEEG-content parameter of brain area represented by that EEG-lead.

Figure.1

TM - DR: EMPHASIS ON THE SELF, THE OBSERVER AS PURE TRANSCENDENTAL CONSCIOUSNESS AT IEEG T_{limit}

0. Best linear regression result (full line) or Energy - Entropy Compensated Transition (EECT) in the IEEG - results (squares) during Transcendental Meditation - Diving Response (TM - DR). It indicates the highest holistic


E x 10^-18 J
1.5
1.0
0.5
0
O1
O2
C4
F4
F3
C3
0.79 h (TM-DR)
0.5
1.0
1.5
S x 10^-18 J.K^-1

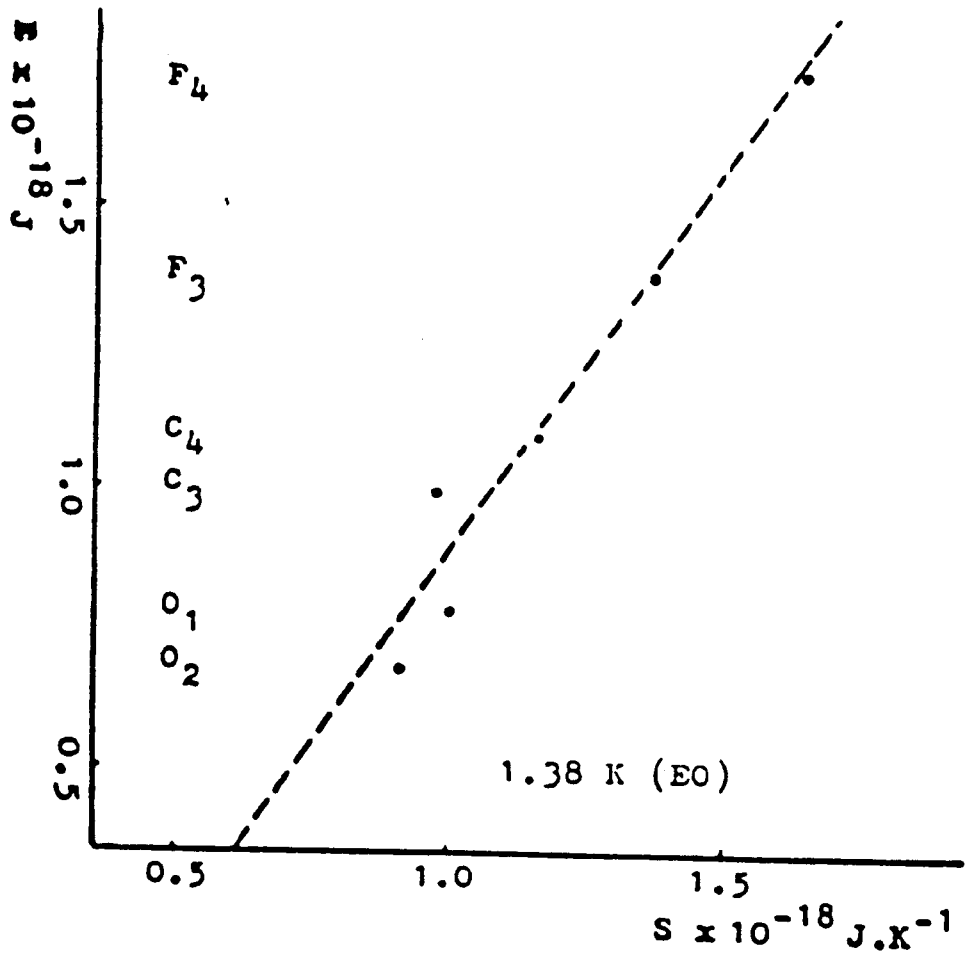
self-(interaction-) -awareness or consciousness (IEEG-self-interaction-awareness parameter).

1. The iso-equilibrium temperature (T iso = 0,79 K) of TM-DR is the lowest of the compared three states (TM-DR, EO, EC). It is marked in the graph as the holistic vigilance parameter or clarity parameter for the sensitivity of the pure observer or the pure subjectivity aspect of consciousness. In the TM - DR state indeed the sensitivity and the pure observer or the subjective aspect of consciousness is dominant (IEEG-vigilance parameter).
2. On the IEEG-graph during TM-DR the C3, F3 EEG-leads compared to the other EEG-leads (F4, C4, O1, O2) is in the domain of lowest entropy. This lowest entropy domain position is the position highest in the hierarchy of EEG-self-organisation. It defines in the hierarchical attention-interaction parameter the focus of the "observation- interaction"- process aspect of consciousness (IEEG-attention parameter).
3. During TM-DR the above low entropy left hemispheric frontal and central (F3, C3) EEG-leads of the human brain record activity of the brain areas under highest selective pressure during hominid evolution whose content is closely related to speech. These brain area activities, represented by the respective EEG-lead are the content parameters for the objective or observed aspect of consciousness (IEEG-content parameter).

Figure.2:

EYES OPEN: EMPHASIS ON THE OBSERVED WITHIN THE OBSERVER OBSERVED AND OBSERVATION PROCESS UNITY OF CONSCIOUSNESS

0. Medium linear regression result (dotted line) or Energy-Entropy Compensated Transition (EECT) in the IEEG-results (dots) during the eyes open (EO) period. EO reproduces and confirms the TM - DR result of linearity but with a lower IEEG holistic self-interaction-awareness parameter as in Fig 1. This is conceptualised as due to the constraints imposed on unimpeded self-interaction from the observed (optical) data.
1. During eyes open the iso-equilibrium temperature (T iso = 1,38 K) is the highest: consciousness as the observer is least vigilant or pure. This falsifies


E x 10^-18 J
1.5
1.0
0.5
F4
F3
C4
C3
O1
O2
1.38 K (EO)
0.5
1.0
1.5
S x 10^-18 J.K^-1

intuitive hypotheses but is easily understood since this EO-state is both more constrained and damped in its sensitivity or amplification as vigilance. This is a necessity since emphasis is on the more unpredictable, the observed, as compared to the relaxed-vigilant emergency-state of TM - DR with highest emphasis on the most predictable, the observer himself, allowing highest self-referential awareness and vigilance for amplification.

2. Compared to the other EEG-leads (C3, C4; F3, F4), this relative shift to the lowest entropy domain of now the optical region (O1, O2) during eyes open (EO) confirms the interpretation of the equivalent shift in hierarchy of the sensori-motor speech-region (C3, F3) during TM-DR. This confirms further the IEEG-attention parameter role as indicator of the focus of the attention or observation process of consciousness.

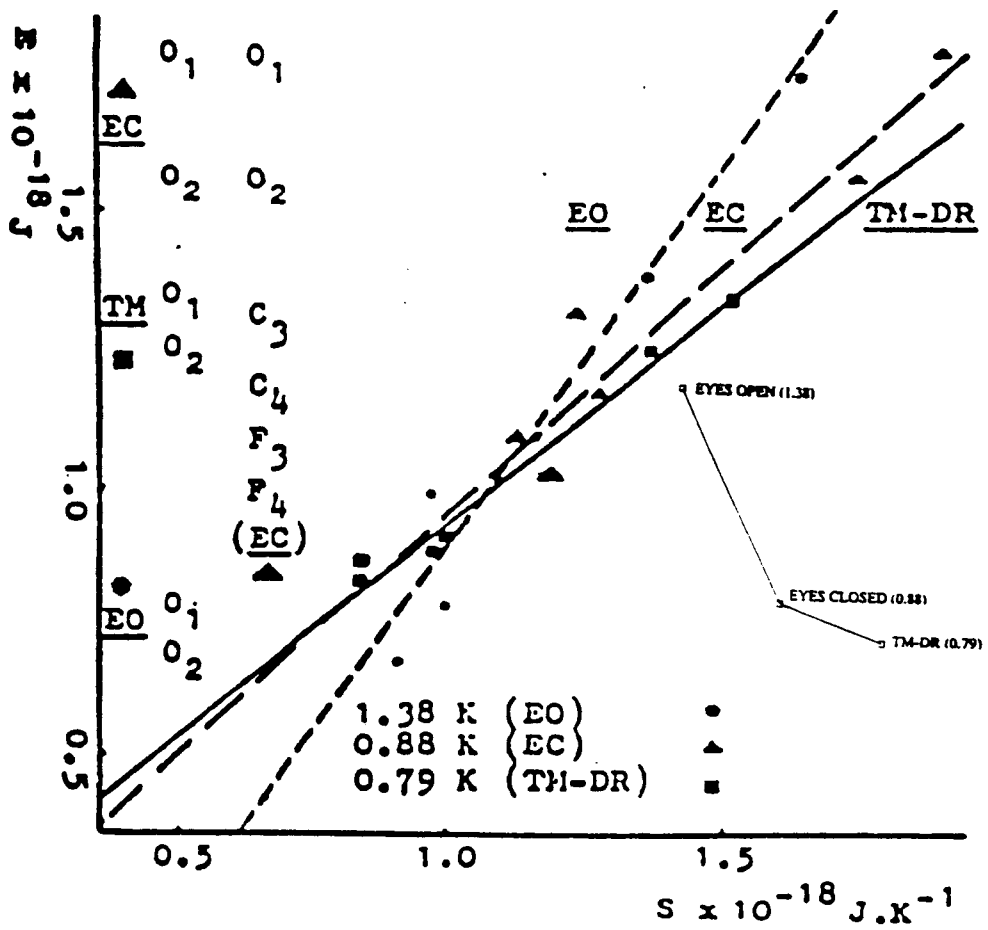
3. As expected during an EO-period, the content parameters (O1, O2) representing optical region contents, now shift into the domain of lowest entropy. During TM-DR the speech centers occupy this hierarchical position and during EC the frontal region (a suggessted transition brain guiding the inter- hemispheric and sensori-motor and spino-cortical observation-interaction activity).

Figure.3

EYES CLOSED: EMPHASIS ON THE OBSERVATION-INTERACTION PROCESS WITH MINIMAL ATTENTION IN MEDIUM VIGILANCE & MAXIMUM RIGHT HEMISPHERIC CONTENT OF CONSCIOUSNESS

0. Minimal linear regression result (broken line) or Energy-Entropy Compensated Transition (EECT) in the IEEG results (triangles) during the eyes closed (EC) period. The Self as self-referal consciousness or the holistic self-interaction awareness is minimal if compared to EO and TM-DR.

1. The iso-equilibrium temperature (T iso = 0,88 K) is higher, indicating a less vigilant or sensitive consciousness compared to TM - DR. But this higher T iso is not as bad as could be expected, since most probabely most practitioners slip into the clearer TM-DR state already during this EC-period before.


E x 10^-18 J
1.5
1.0
0.5
EC
TM
EO
O1
O2
O1
O2
O1
C3
O2
C4
F3
F4
(EC)
Oi
O2
EO
EC
TM-DR
EYES OPEN (1.38)
EYES CLOSED (0.88)
TM-DR (0.79)
1.38 K (EO)
0.88 K (EC)
0.79 K (TM-DR)
0.5
1.0
1.5
S x 10^-18 J.K^-1

2. For easy comparison a superposition of the EC -graph with TM - DR (Fig. 1) and EO-graphs (Fig. 2), allows to demonstrate the relative hierarchical progression of the optical region (O1,O2) to the low entropy domain from EC to TM-DR to EO. This increasing self-organisation interpreted as an increasing focus of attention on this region in the progression of the states as measured by this parameter is empirically thus fully justified.
3. During EC right hemispheric content as reflected by frontal, central and occipital EEG-leads (F4, C4, O2) is in the attention parameter slightly dominant over the left hemisphere represented by leads (F3, C3, O1). This form of right hemispheric (especially frontal and central) self-organisation is contrary to that of the also much more pronounced attention of the TM - DR state confirming the latters speech centered nature.

Figure .4

Tiso LIMIT: EMPHASIS ON TELEONOMY AND CONSCIOUSNESS AS HIDDEN PARAMETERS OF CHEMICAL EVOLUTION

This graph, by showing the iso-equilibrium temperature (Tiso) decline towards T limit (Tlimit > O K), in three EEG-states studied experimentally, brings out the salient theoretical results of the paper.
This result suggests EEG-self-organisation as a simulated annealing process that leads to macroscopic stabilisation in space-time of microscopic zero entropy components (Bujatti-Narbshuber and Riederer, 1976) of coherent aquatic solvent quantum-states. This microscopic solvent two-fluid stabilises this zero-entropy component via solute dynamics. As the essence of bio-evolution this happens in a solvent-solute co-evolution involving isokinetic transitions beginning with compensated proton tunneling of hydrogen bonding in hydrophobicity up to the IEEG-dynamics. This initial state stabilisation defining teleonomy for biological purposes is parameterised as Tiso lowering towards T limit .
Teleonomy progresses through the characteristic fluctuations of the simulated annealing procedure. These fluctuations are e.g. at first high energy phase kinetics with increased reaction product variations as mutations (creativity) and secondly this variety of reaction products is brought under

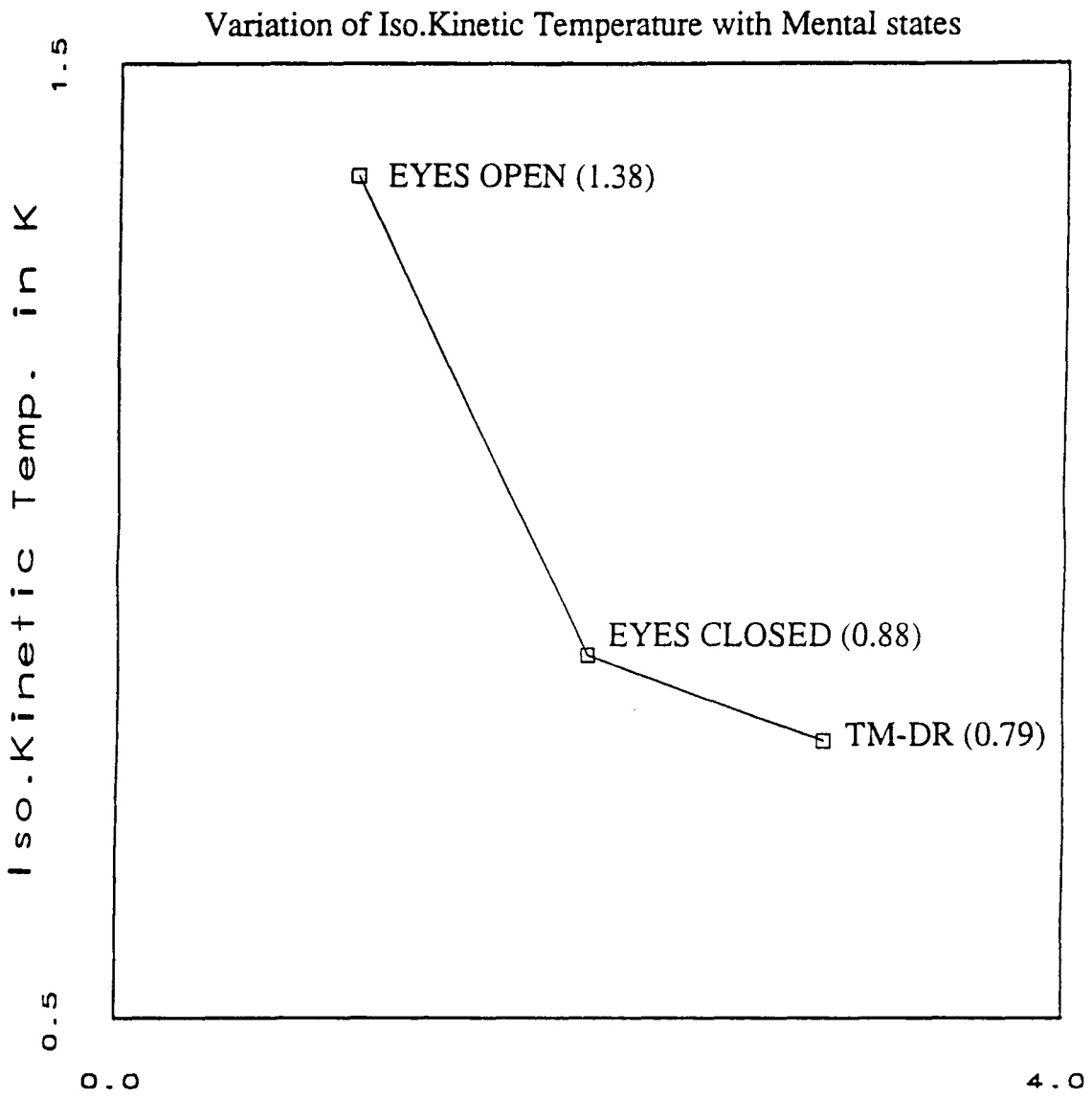

Variation of Iso.Kinetic Temperature with Mental states
Iso.Kinetic Temp. in K
1.5
0.5
0.0
4.0
EYES OPEN (1.38)
EYES CLOSED (0.88)
TM-DR (0.79)

Fig. 4

selection (intelligence) in the ensuing low energy phase that allowes only the more energy independent auto-catalytic reaction products in compensated transitions (teleonomic consciousness) to reproduce.