Research Article

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Nonlinear mathematical modeling of creativity

Abstract

A nonlinear mathematical model is offered to describe the process of conscious creativity, which is product of our conscious brain, and the role of emotions in it. Emotional individuals have more neurotransmitters of excitation, glutamates, released. Since research found that emotions enhanced memorizing, emotional individuals will have better memory and larger memory storage with a denser set of neurons and neuronal junctions. This combined with their abundant neurotransmitters' release will help them achieve easier the state of global excitement of the conscious. The state of enlightenment is synchronous work of the digital computer of our conscious brain and the quantum computer of our subconscious, which works with the waves of our nonlinear electromagnetic field (NEMF). This synchronous work is called full intuitive creativity. In a state of full intuitive creativity, the subconscious and the conscious are entrained to work at the same level of overexcitement. Since research found that the brain waves are coherent in a state of intuitive creativity, soliton waves can be expected. If so, the number of soliton waves and their speed of propagation extracted from the low intensity waves of magneto encephalograms (MEG) can be a good way to identify a state of full intuitive creativity.

Keywords: conscious creativity, intuitive creativity, emotionality, glutamates, creativity evaluation

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Introduction

Conscious creativity is a product of our conscious mind and our conscious mind is a product of our brain, which has inhomogeneous structure[1] and exhibits nonlinear characteristics - such as hysteresis (Figure 1) and multiple frequencies (Figure 2). Based on this, both conscious mind and conscious creativity could be expected to require a nonlinear description. In this article, a nonlinear mathematical model is offered for description of conscious creativity, which explains the nonlinear characteristics of the brain and helps interpret frequency changes observed during pathology.

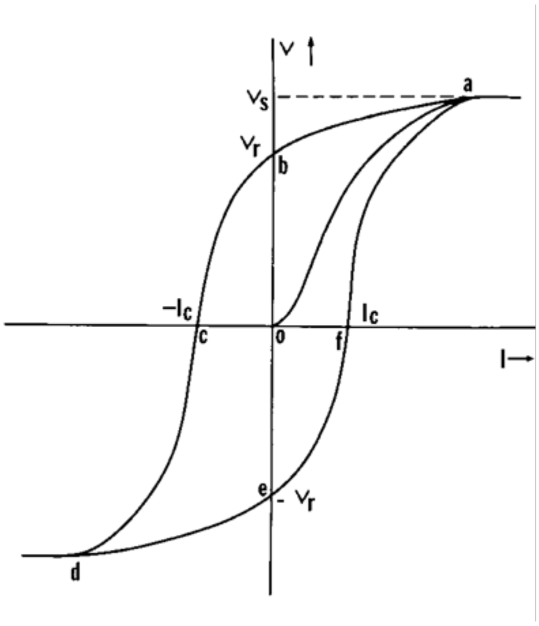

Figure 1 Volt-ampere "hysteresis" properties, which means the "history is important" or that the medium has recorded past influence.

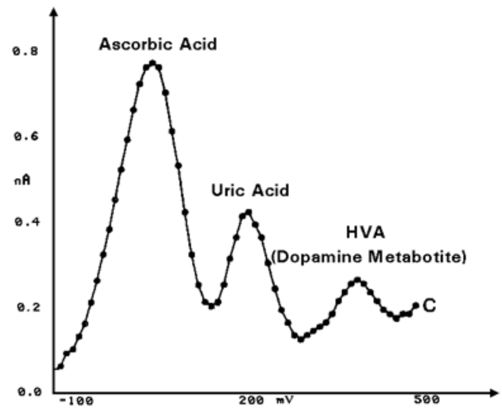

Figure 2 Volt-ampere frequencies' (singularities') characteristics of the brain of rats measured with implanted electrodes.

In a state of full intuitive creativity, the conscious and the subconscious are entrained to work at the same level of over-excitement (Appendix 4).[2] Since only nonlinearly related units can be entrained, obviously the conscious and the subconscious are related in a nonlinear way. This is another indication that intuitive creativity would also require a nonlinear description.

Entrainment is specific only for nonlinearly related units

Only nonlinearly related units can be entrained to work in synchrony.[3] Huygens first observed entrainment of two clocks more than 200 years ago. Normally running differently when separated, they were becoming synchronized when placed next to each other on a wooden surface. This synchronization was called later entrainment.

Reason for the entrainment is the wooden material, which had retained the nonlinear properties of the living tree. Entrainment is usually specific for living systems (people and plants), which are self-organized systems. Here are a few examples of entrainment of living beings:

Entrainment wife – husband: After sleeping together for a period of time, the stages of sleep of the husband and wife become synchronized.[4]

Entrainment child – mother: If a blind child is raised separately from the mother, his circadian rhythms do not have fixed 24-hour periodicity - at times they have periodicity of 23 or 25 hours. However, if the blind child sleeps with his mother, and she is hugging, petting, and caressing him, their biorhythms become synchronized, and the blind child have the fixed 24-hour periodicity of his mother's biorhythms.[5]

Intuitive creativity is a far-from-equilibrium state (FES)

Creativity is unthinkable without excitement and over-excitement (see Pienchovski and Cunningham, 1985). If the conscious and the subconscious are entrained to work at the same level of over-excitement, according to the non-equilibrium theory of Prigogine, over-excitement means that the mind is in a far-from-equilibrium state (FES), which can be described only by nonlinear equations.[6]

A nonlinear mathematical model of intuitive creativity

Intuitive creativity starts at subconscious level in the larger upper ring of the limbic system related to positive emotions, which projects onto the cortex of the left hemisphere (Chapter 3 and Appendix 1).[2] However, intuitive creativity also involves the spatial and associative imaging of the hippocampus and amygdala of the subconscious, which are projected onto the cortex of the right hemisphere. Through these projections the excitements of the subconscious are transferred into the conscious.

Located nearby in the hippocampus are different kinds of emotional memory - of exciting surroundings, motor activity, and behavior sequences. They are excited through the release of neurotransmitters of excitation glutamates. If the individual is emotional, each of the memories will be easier excited because larger amount of glutamates is released at each neuronal junction.

Also highly emotional individuals have better memory and since memorizing involves formation of new neuronal connections, an emotional individual will have a denser set of neurons and neurosynaptic junctions. Combined together, this means that emotional individuals will have abundant amount of glutamates released at a denser set of neurons and neurosynaptic junctions. As a result the emotional individuals will achieve easier a state of over-excitement, and they will be more intuitively creative.

Let us concentrate on the excitation of each of the memories in the hippocampus. The neurotransmitters are electrically charged substances and when released they will convert the different memories in the hippocampus into conducting zones. This will allow us to consider each excited memory in the hippocampus as a neuronal pool or neuronal continuum instead of a discrete set of neurons.[7]

The integration of these excited neuronal pools into a global excitation could be explained by the system theory.[8] The system theory, applied to a chain of neuronal pools, gives for the output potential v the following nonlinear expression (an der Heiden):

$$v_i(t) = v_i(0) + \int K_{ji}\left(x_i(t'), t, t'\right)dt' \quad (1)$$

Where Kji is the nonlinear kernel of interaction of two adjacent neuronal pools i and j (x_i - input current of excitation). According to Miller,[9] the linear system, which corresponds to the nonlinear equation (1), has a solution

$$z(t) = f(t) + \int g(t-t')z(t')dt' \quad (2)$$

This is a linear Volterra integral equation, which can be expressed in terms of a resolvent $R(t-t')$ and a function $f(t')$,

$$z(t) = f(t) - \int R(t-t')f(t')dt' \quad (3)$$

The resolvent R, corresponding to a continuous matrix kernel g, is

$$R(t) = -g(t) + \int g(t-t')R(t')dt' \quad (4)$$

A simple condition on the resolvent R of the linear system is sufficient to guarantee asymptotic stability of the steady states of the nonlinear system.

$$lim \int R(t)\, dt = \sim I .$$

In the neighborhood of a steady state v, the stability of the system is determined by the roots of the characteristic equation

$$D(k) = det\left(I - g^*(k)\right) = 0, \quad (5)$$

where $g^*(k) = exp(-kt)\, g(t)dt$ is the Laplace transform of the kernel g .

The equation (2) is linear because the nonlinear kernel $Kij\left(xi(t'), t, t'\right)$ has been replaced by a linear one

$$g_{ij}(t) = u_{ij}'(v_j)h_{ij}(t) \quad (6)$$

Here $h_{ij}(t)$ has the meaning of a weight function. It describes the distribution of v_j around an average v_j– with a normalization condition

$$\int |\, h_{ij}(t)|\, dt = 1 \qquad u_{ij}'(j) \geq 0 \quad (7)$$

which implies

$$|\, h_{ij}(k) \;| \leq 1 ,\ if\ Re\ k \leq 0 \quad (7')$$

as a condition for stability.

Unstable stationary solutions can be used to describe the regions of attraction of stable states. A question arises: With time which of the constant states will realize - a global excitation or a global inhibition?

The system theory has a theorem An der Heiden:[8] A local excitation of sufficient strength will spread out to a global constant excitation, i.e.

$$lim\ v(s,t) = 1\, for\ all\ s\ if\ v(0) < v(1)$$

As said, each highly emotional individual will not only have large amount of glutamates released at each neurosynaptic junction at each excitation, he will have larger memory storage, which means a dense set of neurons and neurosynaptic junctions in his brain. Such emotional individual will achieve a state of over-excitement or ecstasy easier and quicker.

Since the neurotransmitters are electrically charged, when the local excitations of different memories have sufficient strength, their strong nonlinear electric fields become integrated, which leads to excitation or enlightenment of the whole conscious brain. This is the state of creative ecstasy, in which all conscious brain is excited and over-excited. But only the conscious brain of highly emotional individuals can reach this level of over-excitement.

However, as said in Kuman,[2] Chapter 3, the excitation starts in the subconscious where the emotional brain is. It starts with excitation of emotional memories in the subconscious, which become integrated. After a critical level of excitation is reached, the whole subconscious becomes excited and it entrains the excited conscious of the emotional individual to work at the same level of overexcitement.

The final metabolite of the glutamates is the gas nitric oxide (N_2O) called laughing gas, which is known to enhance creativity. Probably, the process of global excitement is facilitated by the fast diffusion of this gas. PET (positron emission tomography) could be used to monitor the excited brain during creativity. It could be done through radioactive labeling of the final product of the metabolism of the glutamates - nitric oxide (N_2O).

Radioactive labeling of the final product N_2O will be easy and safe because the half-life time of the radioactive nitrogen is 2 minutes and of the oxygen - 10 minutes. This means that after 10 minutes the radioactive oxygen will be 50% decayed and hopefully it wouldn't do much harm for such a short period of time. Anyway, radioactive labeling should be done only in the initial research until correlations among PET scanning, EEG, and MEG are found.

PET scanning with the use of radioactive substances shouldn't be used on children because their bodies still grow and their cells divide. Then if one cell is damaged by radiation (mutated cell), this will lead to many damaged cells, which will substantially increase the chances for cancer. For that reason, radioactive labeling would damage the growing children bodies much more than the bodies of adults.

Mental rehearsal

Mental rehearsal is a powerful tool for tremendous boost of performance. It is done through mental emotional reviving of previous successful performances, which leads to nonlinear integration of these different excited memories of environment (applauding audience), emotional excitement from the successful performance, etc. Mental rehearsal is a powerful booster for highly emotional individuals with large memory storage and large amount of neurotransmitters of excitation released at each neuro-synaptic junction. Mental rehearsal would also require nonlinear description.

Volt/Ampere characteristics of the brain in norm and pathology

If the chain of excited memories is represented by an electric circuit scheme, the output voltage will be expressed in the following way:

$$\begin{aligned} v(t) = \Sigma\, [\left(\alpha_k(T_k)/\left(1+ T_k^2\omega_k^2\right)\right] \sin \omega t \, + \\ + \left[T_k\omega_k\, \alpha_k\left(T_k\right)/\left(1+ T_k^2\omega_k^2\right)\right].\cos \omega t \, + \\ + \left[T_k\omega_k\, \alpha_k(T_k)/\left(1+ T_k^2\omega_k^2\right)\right] \exp\left(-t/\, T_k\right) \end{aligned} \qquad (8)$$

The measured brain volt/ampere characteristics show singularities O'Neil & Fillenz.[10] The three singularities (peaks on Figure 2) found in rats' brains were interpreted as caused by oxidation of ascorbic acid (related to glutamate release), uric acid, and homovanillic acid (HVA), which is a dopamine metabolite. Since measurement of volt/ampere-characteristics requires implantation of electrodes, it cannot be applied to humans.

To mathematically describe these singularities, we need to investigate the conditions for stability (7'). The system under consideration will be unstable if

$$hij(t) \;\geq\; 1;\; Re\; t \;>\; 0.$$

A network with only excitatory interactions is always associated with a real positive root of the characteristic equation. Excitatory networks are predestined for hysteresis effects, while inhibitory influences (Re t < 0) seem to facilitate the occurrence of oscillatory behavior (limit cycles). This could prove useful in investigation of psychological instability.

In the case when $D(k)$ in (4) has purely imaginary roots $i\omega_k$,

$$D(k(\,\delta)) \;=\; 0; \qquad k(\,\delta_0) \;= i\;\omega_0; \qquad \delta \;=\; u'(\,v); \qquad (9)$$

the nonlinear system described by equation (1) will show singularity at the roots of the characteristic equation

$$D(i\omega_{0,k}\,,\, d_0) \;=\; 0 \qquad (10)$$

or at the points $i\omega_{0k} = 1/T_k$, where T_k is the relaxation time of the area with characteristic frequency ω_k . These points are the normal modes of the nonlinear system, received as singularities of the solutions of the linear equation.

The equation (2), offered above, can be written in two different representations: v- (volt) and x- (frequency) representations. This allows the volt/ampere characteristics (which require electrode implantation) to be replaced by frequency characteristics (which can be measured on the surface of the head) such as EEG (electroencephalogram) or MEG (magneto encephalogram).

Unfortunately, at the present moment, the basic EEG-frequencies alpha, beta, tetha, and delta remain uncorrelated to the release of neurotransmitters or some other active brain substances.

By introducing a conversion function $T:\; T_j\left(v_j\right) = x_j$ (where v is the potential, x - the frequency for area j), we can transfer the potential representation (2)

$$v_j = v_{j0} + \, u_{ji}(vi) * \, h_{ji} + \, u_{jj}(vj) * \, h_{jj} \qquad (11)$$

into an *frequency* x_j *-representation*:

$$x_j \;=\; T_j\left(v_j + \, S_{ji}(xi) * \, h_{ji} + \, S_{jj}\left(x_j\right) * \, h_{jj}\right). \qquad (12)$$

($S_{ji}(xi) * \, h_{ji} = \int S_{ji}(x_i(t')h_{ji}(t-t')dt'$, where S_{ji} is the average generator potential produced in j by x_i. The third term represents self-inhibition).

The potential representation

$$v_j \;=\; v_{j0} + \, S_{ji} \bigcirc \, T_i\left(x_i\right) * \, h_{ji} + \, S_{jj} \bigcirc T_j\left(v_j\right) * \, h_{jj}, \qquad (13)$$

can be written in the form (11) after substitution $u_{ji} \;=\; S_{ji} \bigcirc \, T_i$, where u_{ji} and u_{jj} are monotone increasing, nonnegative, and bounded functions.

Further modifications of equation (11) transform it to a form formally identical with Fitzhugh-Nagumo equations (An der Heiden, p.123), which have solutions of the type wave-train and traveling-pulse solutions (see an der Heiden, p.133).

Evaluation of creativity and ingenuity with EEG, MEG, and PET scanning. prediction of soliton waves

Can creativity or ingenuity be seen on EEG or MEG records? According to Gray Walter for most people an EEG-record of 30 seconds was enough to provide a good sample. "In that time left to itself, the brain goes through its modest repertory of motions. But in an efficient genius brain ... several minutes are needed before the picture begins to repeat itself, even in the most tranquil conditions...".[12]

Thus even in tranquil conditions the EEGs of a genius and normal individuals are different. How about EEG in a state of intuitive creativity, which is a state of over-excitement achieved through abundant release of neurotransmitters of excitation, glutamates? Their release is expected to increase the inhomogeneity of the brain.

Since in the case of organic polymers, doping changes both the inhomogeneity of the material and its frequency characteristics,[1] we can expect in the state of intuitive creativity the abundant release of electrically charged neurotransmitters of excitation, glutamates, to change the inhomogeneity of the brain and its frequency characteristics.

Indeed, the EEG of a creative brain during creative process shows dominance of alpha waves, as reported in the review paper of C Martingale.[12] Hence, a creative brain indeed exhibits different frequency characteristics. But unfortunately, the information presently extracted from EEG and MEG is very limited. Their characteristic frequencies remain unrelated to specific neurotransmitters' release.

What needs to be done is to measure the main differences between a normal brain and a brain in ecstasy flooded with glutamates. The observed frequency difference in EEG- or MEG-characteristics will be caused by the neurotransmitters (NTs) of excitation, glutamates, and can be used to identify the state of ecstasy or creativity.

However, volt-ampere characteristics of animal brain have been already correlated with metabolic changes in the brain. What needs to be done on monkeys is to measure their volt-ampere characteristics with implanted electrodes and compare the results with measurements of EEG, MEG, and PET-scanning on the same animals. Then inject glutamates and do the same measurements again.

Another specific feature of creativity is increased coherence of the brain waves, as reported by Karl Pribram in 1990,[13] which indicates nonlinear-wave propagation. Since the brain is inhomogeneous media (conducting nerve pathways and ganglia imbedded in semi-conducting brain tissues), the propagation of waves in it will lead to formation of solitons (nonlinear waves) and ripples Hirota and Suzuki.[14] The presence of solitons (and their speed v_s of propagation) can be expected to be higher in a state of ecstasy, when the brain is flooded with glutamates, than in a normal brain.

If so, the higher speed of propagation v_S of these solitons could be used as a measure of creativity. Since in material science, information about soliton type waves and their speed of propagation is extracted from the noise type waves in NMR (nuclear magnetic resonance) spectrum of the material, we believe that information about soliton waves in the brain and their speed of propagation could be extracted from the noise-type waves in the MEG (magnetoencephalograms) of the brain in the same way.

Impact on artificial intelligence

Understanding the process of creativity is a step toward building artificial intelligence with creative abilities. Once the mechanism of integration of different excited memories is known, the nature of the process of creativity will be known. This knowledge will allow modeling of the process of creativity and eventual building of robots with creative abilities.

Special attention requires the Quantum Computer in the Subconscious, which works with the waves of our nonlinear electromagnetic field (NEMF). As hypnosis showed when the hypnotist puts the conscious to sleep to access the subconscious, the person can do calculations 10,000 times faster. So, the recent efforts to create Quantum Computers are going to be a technological jump into creating much faster and much smarter computers, which are expected to be the basis of the future artificial intelligence.

Conclusion

A nonlinear mathematical model of creativity was offered with emphasis on the role of emotions in it. First, the more emotional an individual is, the larger the amount of neurotransmitters released at each neurosynaptic junction. Second, it was found that emotional individuals have better memory.[15] Since long-term memorizing is done through a new set of neurons and neurosynaptic junctions, the more information is memorized, the denser is the neuronal set and more numerous the neurosynaptic junctions.

The presence in emotional individuals of both: dense set of neurons and neuronal junctions and abundant amount of glutamates (neurotransmitters of excitation) released at each junction, will make it easy for them to achieve the state of global excitation of the conscious brain (see the system theory). Since the excited areas are related in a nonlinear way, they will become integrated even before their boundaries touch each other leading to a state of global excitation of the conscious brain.

The state of ecstasy or state of enlightenment is simultaneous synchronized work of the over-excited conscious brain and the over-excited subconscious. The excitation of different types of emotional memories in the subconscious will lead to their integration. When excited to a level higher than a critical value, these emotional memories will bridge, and this will lead to a global over-excitation of the whole subconscious, which is now ready to work in synchrony with the over-excited conscious. In this article, we emphasized that creative individual have: 1/ dominant alpha waves in their EEG[12] (which are higher when the person have done more meditation) and 2/ increased wave coherence (specific for both – meditation and the state of ecstasy).[13] This coherence means that more nonlinear waves (solitons) should be expected to propagate in the brain of creative individuals.

As a new *measure of creativity,* we offered measurements of these soliton waves and their speed of propagation, which can be expected to be higher in a state of ecstasy. We suggested the speed of propagation of soliton waves to be extracted from the noise type waves in MEG. Also, measurements of solitons (nonlinear waves), with their ability to travel long distances without dissipation and distortion, could also prove useful in explaining events like telepathic communications, which are long-distance transfer of images and emotions between individuals.

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Conflicts of interests

Author declares that there is no conflict of interests.

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