On the Possibility to Interpret Aesthetic Emotions and the Concept of Chef-D'oeuvre in an Artificial Cognitive System

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Abstract— **The problem of interpretation and simulation of the Aesthetic Emotions (not inspired by a pragmatic goal, but by impression of Artwork, natural phenomena, etc.) is considered under the Natural-Constructive Approach to modeling the cognitive process. The designed cognitive architecture is represented by the complex multilevel combination of various types of neuroprocessors, with the whole system being composed of two subsystems, by analogy with the two hemispheres of the human brain. Only one subsystem involves mandatory random component (noise), and the noise-amplitude variation controls the subsystem activity representing the emotional responses. A peculiar feature of the architecture is the fuzzy set at the lowest ("image") hierarchy level. This neuroprocessor contains images of the objects recorded by weak ("grey") connections that reflect personal (unformulated) experience. It is shown that individual aesthetic preferences arise at the border of image (fuzzy set) and symbolic internal information. The concept of Chef-d'oeuvre is associated with the "paradox of recognition", which is caused by ambiguous impression (familiar and unusual simultaneously) induced by the Artwork. These impressions could be accompanied by small oscillation (trembling) of the noise amplitude around a normal value that represents an analogue to the human "goosebumps"**.

Keywords – emotions; neuroprocessor; noise; paradox; ambiguity; weak connections.

I. INTRODUCTION

This paper represents a sequel to the series of works [1]–[4] on modeling intrinsic human cognitive features — intuition, emotions, individuality, etc., — in an artificial cognitive system. This problem is considered within the Natural-Constructive Approach (NCA) elaborated just for human-like cognition modeling on the base of Dynamical Theory of Information (DTI) [5][6], Neuroscience [7][8] and Neuropsychology [9] data, and Neurocomputing [10][12] (though based on the dynamical-formal-neuron concept, [1]). Among other popular approaches to modeling the cognitive systems, such as Active Agent models [13], Brain Re-Engineering [14][15], etc, NCA is somewhat similar to the Deep Learning paradigm [16][17] though it involves several important distinctive features.

The Natural-Constructive Cognitive Architecture (NCCA) designed under NCA represents a combination of two linked subsystems, in analogy with two cerebral hemispheres, the right (RH) and the left (LH) ones. Each subsystem represents a complex multi-level hierarchical structure of the two-type neuroprocessors. One subsystem (RH) is responsible for processing of new information and learning, while the other one (LH) refers to the processing of well-known information (recognition, forecast, etc.).

Being biologically inspired, NCCA (as well as each neuromorphic model) inevitably faced the problem of Explanatory Gap [18]. This implies that despite the huge amount of experimental information on brain neurons ("Brain" area) and on psychological reactions and rational thinking ("Mind" area), the main challenge is to reveal the mechanism of transition from neural ensemble to the consciousness and self-appraisal. It concerns rational, as well as emotional aspects of the cognitive process.

Note that one of the basic elements of NCA is DTI, the theory of information origin. It seems to be the most relevant tool to analyze the Explanatory Gap problem, since information itself represents the dual-nature object: it has material, as well as virtual nature. According to Quastler's definition [19], information is the "*memorized random choice of one option among several similar ones"*. *Objective* (material) information is the choice made by Nature; it does not depend on individuality and refers to the "Brain" approach. S*ubjective (conventional*) information represents the choice made by living subjects (people, animals, neurons) as a result of interaction within their community, which refers to the "Mind" sphere. Thus, NCA includes inherently the possibility to bridge the Gap.

The problem of incorporating the "emotio" and "ratio" in a unified cognitive (artificial) system attracts now great attention and evokes a lot of studies (see, e.g., [20]–[30]). However, the variety (great number) of different approaches itself indicates that the problem is far from being solved.

Under NCA, emotions are considered as a product of interaction of two different-nature variables. One belongs to the "Brain" representation and corresponds to the aggregated composition of neurotransmitters. The other refers to the "Mind" representation and corresponds to variation of the random-element (noise) amplitude. The activity of two subsystems is controlled by the emotional manifestation expressed via the noise-amplitude derivative. In this process, negative emotions (nervousness, fear) evoke RH activation, while positive ones (relaxation, relief, satisfaction) activate LH.

Note that the problem of integration of emotions and rational reasoning could be formulated and even solved, as far as so-called "pragmatic" emotions (those that are associated with certain goal) are concerned. In this case, quite obvious reasons should play the main role: achieving

 ISBN: 978-1-61208-531-9

the goal results in positive emotions, and vice versa [2]. But what are the reasons for so-called Aesthetic Emotions (AE), i.e., those that are evoked by Nature phenomena (sunrise, rainbow, fire, water cascade, etc.), Artwork, Music, etc.? In this case, the very concept of "positive\negative" does not work, and one could soon speak about formed preferences. These emotions are strictly individual, with the reasons for personal sympathy and antipathy being often unclear for the person himself/herself.

Seemingly, there are no rational motives for personal sympathies and preferences, and that is why formalization and simulation of AE (i.e., interpreting in terms of neurons and their interactions) represents the most difficult problem. Moreover, this area is traditionally attributed not to natural sciences, but to the Humanities and Art study. Nevertheless, this work represents an attempt to reveal possible mechanisms that could cause AE.

The paper is organized as follows. Section II is focused on the formulation of the AE problem. In Section III, the main peculiar features of NCCA are discussed. In Section IV, the hypothesis on the mechanism of AE is presented. Summary and discussion of further working perspectives are presented in Section V.

II. FORMALIZATION OF AE PROBLEM

The problem of revealing the AE nature and mechanisms should be solved again from the "Brain" and "Mind" positions together. This implies that one has to take into account neurophysiology, as well as psychology and personal experience motives.

A. General considerations

Apparently, it is the cultural context that does play a very important role here. Indeed, something quite unknown, like, e.g., Japanese music for European people, could hardly evoke sincere emotions (may be academic interest only).

The other first-glance reasons for AE (see, e.g., [31]) could be connected with:

- childish vague impressions;
- personal fuzzy associations;
- the influence of cultural mini-media (family, messmates, etc.).

Actually, all these factors produce *subjective associations*, and this is the very mechanism of the Art perception. Indeed, the lack of clear goal that could provide "rational" emotions (i.e., those that could be explained by evident reasons) should be compensated by certain excitation caused by personal indirect (i.e., fuzzy, vague) associations. Surely, they are strictly individual, and this provides the explanation of personal impression.

Note that the Art perception, being quite subjective, could be measured objectively: really deep impression produces a "*goosebumps*" (horripilation), and this feeling is quite sincere and could not be shammed. Of course, one could express admiration remaining quite indifferent, but the "goosebumps*"* could not be felt if there are none.

But then, the question arises: what is the "masterpiece", or C*hef-D'oeuvre* (ChD)? Why a certain piece of Art is perceived as ingenious by almost the whole community? Surely, there is a great influence of the mass media (fashion). Generally speaking, there is a great temptation to define ChD as a "*product of convention in the society expressed in monetary ($) equivalent*". This factor actually works, but it cannot explain the phenomenon. There should be something inherent to the ChD itself, that does distinguish the ingenious creation from a solid professional work. In other words, what factors could provide the difference between Mozart and Salieri? And is it possible to explain personal Art preferences and the phenomenon of ChD from the positions of neuromorphic cognitive modeling? This problem is the subject of the present paper.

B. Physiology & psychology

Any piece of Art is perceived as sensor information, which is obtained by sensory organs. For example, any Painting represents (roughly speaking) a color pattern. It is well known from physiology that human beings differently perceive the excitations in different parts of the color spectrum. The visual perception is most sensitive in the *green* part of spectrum where the greatest number of various shades could be distinguished [32]. Vice versa, the red part of the spectrum awakes nervousness and involuntary fear (may be associated with the dangerous fire).

As far as the music is considered, its physical effect on the human organism is obvious. Indeed, the music, — from ancient times up to nowadays, — produces a rhythmic impact that does interfere with proper rhythms of the human brain (see, e.g., [24][33]). It is well known that only a part of the acoustic spectrum is pleasant for the human ear and could be perceived as music [33][34]. Some other frequencies (including the ultrasonic and infrasonic regions) do produce a strong but destructive effect on human psychical state, with the most "soft" manifestation being the uncontrolled nervousness and fear [24].

Perhaps, these peculiarities of human perception originated from the process of evolutionary adaptation to the Environment: certain really dangerous phenomena (e.g., earthquake) are accompanied by rare and unusual visual and acoustic effects, and this circumstance is sewn in the genetic memory of human beings. However, these reasons do not explain *individual* preferences concerning normal (pleasant) spectrum region.

Finally, what about the Literature? It does produce a significant effect on many people, but is not directly related with "raw" sensory perception. Thus, only the "Brain" representation cannot explain the AE enigma.

C. Art Study

The Art study seems to be more relevant to the problem under consideration. First of all, it does take into account the role of cultural context and the mentality of a given society. This partly explains why the recognition of some Artwork's ingenuity often does not come immediately but requires certain time: the society has to be *ready* to admit the pattern. In economy, the term "competence" is used to describe the social readiness to certain innovations. But the very mechanism of the competence occurrence is not clear and even considered.

 ISBN: 978-1-61208-531-9

However, the Art study is also divided into separated branches where specific regularities (common features) had been revealed.

1) Painting, Sculpture and Architecture: From the Leonardo times, they were studied even mathematically (the concepts of "Golden Section", "3D-perspective", etc.). However, such painting schools as *primitivism* (Pirosmani, Henry Russo) and *surrealism* (Salvatore Dali) do neglect the perspective, but some their patterns are nonetheless admitted as ChD.

2) Music: European and Eastern (Japanese and China) music representations (harmony) do differ essentially, with only a small number of people paying tribute to both musical patterns. European Music School is based on the concepts of *consonance* and *dissonance*, which correspond to different and definite ratio of the note frequencies within one chord. It appears that the consonance is pleasant for perception, and vice versa. However, great (ingenious) musical compositions from Mozart, Beethoven, Chopin, etc. do involve as consonances, as well as a quote of dissonances. Moreover, the patterns of *major* and *minor* music (well defined by the frequency ratios) produce different and again individual effect. Several studies (see [23][24]) have shown that the *major* music, in spite of its *bravura* character, often is not admitted, while the *minor* music, despite its somewhat tragic shadow (like the "Funeral March" of Chopin, or "Lacrimosa" of Mozart, or "Casta Diva" of Bellini), produces strong and rather *light* emotions.

3) Literature: This is the most mysterious Art, since it does not appeal directly to any organs of sense, but does produce strong impression to the majority of people. This process requires active *cooperation* of the author and the reader, since the effect could be produced only in the case if the reader would reproduce the situation described in the literature using the elements of his own personal experience. Hence, the key words here are *imagination* and *empathy*. However, these processes should be initiated by verbal information. But what is the mechanism of such effect?

Under NCA, all these problems could be formulated and even solved in terms of neurons and their connections.

III. NATURAL-CONSTRUCTIVE COGNITIVE ARCHITECTURE (NCCA)

Let us recall briefly the main features of the architecture NCCA developed in our previous works [1][2].

A. Schematic representation of NCCA

The schematic representation of NCCA is shown in Figure 1. The whole system represents complex multilevel block-hierarchical combination of the Hopfield [10] and Grossberg [11] type neuroprocessors. According to DTI principles [6], as well as neuropsychology data [9], the system is combined of two coupled subsystems, the right Hemi-system (RH) and the left Hemi-system (LH) by analogy to the cerebral hemispheres of human brain. One of them (RH) is responsible for learning the *new* information, the other (LH) does process the *well-known* information.

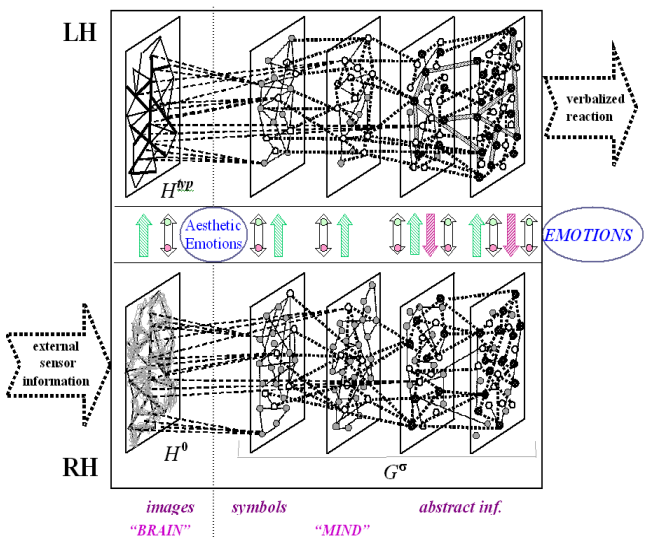

Figure 1. Schematic representation of NCCA.

This functional specialization is secured by three factors:

- the random component (noise) present in RH only;
- different training rules in the two subsystems: Hebbian principle [8] of frequently-used connection amplification in RH (providing the *choice*), and Hopfield's principle [10] of selecting relevant connections ("redundant cut-off") in LH**;**
- the "connection-blackening" principle of self-organization: well-trained images in RH are replicated in LH (see below).

According to these factors, the whole system does evolve by self-development (in Figure 1 — from the left to the right). The ground (zero) level is represented by two ***H***-type processors receiving the external information directly from the organs of sense. These "raw" images of real objects presented to the system are recorded in the form of certain *chain of neurons* (pure distributed memory).

All other levels $\sigma = 1,\ldots N$ are presented by ***G***-type processors carrying the *symbolic* information. It is necessary to stress that each generated symbol carries out all the information about its image in a compressed form [12]. Each symbol G^σ is linked by *semantic* connections $\Psi^{(\sigma-1)}$ with its "parent" image at the previous level and $\Psi^{(\sigma+1)}$ with its "child" symbol at the next level $\sigma+1$. Besides, it is linked with its neighbors by cooperative connections (which create that "current" image at the σ level).

Note that increasing level's number corresponds to increasing degree of "abstraction", that means the weaker relation with the neurons-progenitors (those directly connected with the organs of sense). The high-level symbols correspond to *abstract concepts*, which are not based on any raw image of real object, — such as *consciousness*, *conscience*, *love*, etc. It should be stressed that internal abstract symbol information can be *verbalized*, i.e., associated with the *words* by means of common *language*, and this stage represents the highest level of the system's

evolution [33]. These very levels correspond to developed human consciousness that refers to the "Mind" sphere.

However, these high-level symbols could be excited from outside by words and then, decomposed to lower-level image-of-symbols down to the lowest image level. This process represents the mechanism of imagination.

B. Mathematics &Phylosophy

The mathematical grounds for the architecture presented in Figure 1 were discussed in details in the works [1][2][4]. Let us recall the key points and present the math basis in generalized form:

$$\frac{dH_i^0(t)}{dt} = \frac{1}{\tau_i^H}[\Im_H\{H, \beta_i(G^R{}_{\{i\}})\} + \sum_{i\neq j}^{n}\Omega_{ij}^{Hebb}H_j^0 + \sum_k \Psi_{ik}G_k{}^{R,1} - \Lambda(t)\cdot H_i^{typ}] + Z(t)\xi_i(t), \quad (1)$$

$$\frac{dH_i^{typ}(t)}{dt} = \frac{1}{\tau_i^H}[\Im_H\{H, \beta_i(G^L{}_{\{i\}})\} + \sum_{i\neq j}^{n}\Omega_{ij}^{Hopf}\cdot H_j^{typ} + \sum_k \Psi_{ik}\cdot G_k{}^{L,1} + \Lambda(t)\cdot H_i^0], \quad (2)$$

……

$$\frac{dG_k^{R,\sigma}}{dt} = \frac{1}{\tau_G}[\Im_G\{G_k, \alpha^\sigma{}_k(\{\Psi_{ik}^{R,(\sigma-1)}\}, G^{\sigma+\nu})\} + \hat{\Upsilon}\{G_k^{R,\sigma}, G_l^{R,(\sigma+\nu)}\} - \Lambda(t)\cdot G_k^{L,\sigma}] + Z(t)\cdot\xi(t), \quad (3)$$

$$\frac{dG_k^{L,\sigma}}{dt} = \frac{1}{\tau_G}[\Im_G\{G_k, \alpha^\sigma{}_k(\{\Psi_{ik}^{L,(\sigma-1)}\}, G^{L,(\sigma+\nu)})\} + \hat{\Upsilon}\{G_k^{L,\sigma}, G_l^{L,(\sigma+\nu)}\} + \Lambda(t)\cdot G_k^{R,\sigma}], \quad (4)$$

$$\frac{dZ(t)}{dt} = \frac{1}{\tau^Z}\cdot[a_{Z\mu}\cdot\mu + a_{ZZ}\cdot(Z - Z_0) + F_Z(\mu, Z) + X\{\mu, G_k^{R,\sigma}\} + \{\chi\cdot(D - \omega\cdot dD/dt) - \eta\cdot\delta(t - t_{D=0})\}], \quad (5)$$

$$\frac{d\mu}{dt} = \frac{1}{\tau^\mu}\cdot[a_{\mu\mu}\cdot\mu + a_{\mu Z}\cdot(Z - Z_0) + F_\mu(\mu, Z)], \quad (6)$$

$$\Lambda(t) = -\Lambda_0\cdot th\left(\gamma\cdot\frac{dZ}{dt}\right). \quad (7)$$

Here, variables *H* and *G* refer to purely "cognitive" components, which are associated with neocortex structures. The functionals $\Im_{H,}$ and $\Im_G$ describe internal dynamics of corresponding neurons; the functionals $Y^R\{G_k{}^R\}$ and $Y^L\{G_k{}^L\}$ describe interaction of symbols at various levels.

The bottom block of equations (5)–(7) refers to representation of emotions. The variable μ(t) represents purely "emotional" component produced by sub-cortical ("Brain") structures; it represents the effective composition of neurotransmitters (the difference between stimulants and inhibitors). The variable *Z(t)* represents the amplitude of random (stochastic) component presented in RH only. The functional $X\{\mu, G_k{}^{R\sigma}\}$ refers to the process of new symbol formation; the discrepancy *D(t)* describes the difference in RH and LH records of the same real object.

The variable Λ(t) refers to the cross-subsystem connections, which provide the dialog between two subsystems. Here, $\Lambda = +\Lambda_0$ corresponds to RH→LH transfer, while $\Lambda = -\Lambda_0$ corresponds to LH→RH. Note that this is the only variable present in each of the seven equations, thus *sewing* all the components together.

This system of equations is complete (in math sense), since all the variables are determined via their mutual interactions. The first two equations refer to the lowest (zero) level of hierarchy, while the next (G^σ variables) describe σ=1,…*N* symbolic levels. Note that the dotted line between two first equations and the other equations indicates the analogy with the dotted line in Figure 1. This line symbolizes the virtual border between the "Brain" and the "Mind". Indeed, the *H*-plates (zero-level of the hierarchy) containing only the "raw images", serve to represent the sensory information received from the organs of sense. This information is (roughly speaking) objective, and this level belongs to the "Brain".

The first level (σ=1) corresponds to the symbols of typical images. It already belongs to the "Mind", since any symbol represents not objective, but conventional, i.e., *subjective* and *individual* (for a given system) information. The same is true for all other hierarchy levels, up to the highest level associated with the abstract information. Hence, any symbolic information refers to the "Mind".

Thus, we can infer that the phenomena appearing at the transition from the "Brain" to the "Mind" occur at the virtual border between zero and first levels.

C. Formation of Two Basic Levels of NCCA

Let us consider in more details the small fragment of the architecture NCCA — the lower (basic) levels corresponding to σ = 0, 1 (see Figure 2). The *H*-type plates (σ=0) are responsible for recording the raw sensory information in the form of distributed memory. This implies that each external real object presented to the system excites

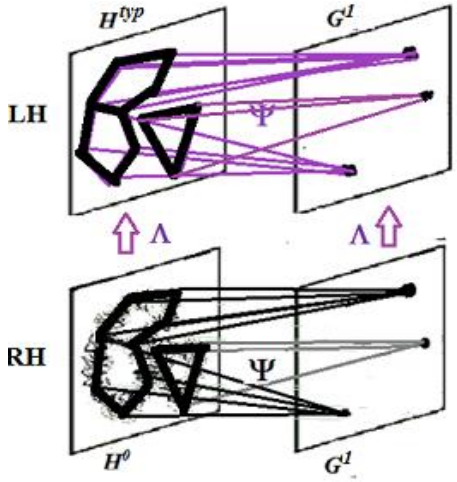

Figure 2. A fragment of two basic levels of NCCA.

a chain of neurons, which is called the "*image*". The *choice* of those neurons (i.e., generation of information) proceeds in RH with required participation of the noise. Then, the connections in the chain are to be trained according to Hebb's principle of amplifying the frequently-used connection (see Figure 3a).

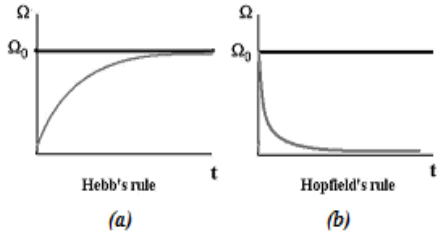

Figure 3. Dynamics of neuron's connection $\Omega(t)$ training for (a) Hebb's rule and (b) Hopfield's rule.

The plate $\boldsymbol{H^0}$ contains maximum information on each object whenever presented to the system, i.e., all generated connections, as weak ("grey"), as well as strong ("black") ones. Let us clarify this point.

Note that each presentation of the same object results in activation of slightly different set of neurons. Let us introduce the notions:

- "*Core*" neurons — the neurons that are excited at each presentation of the given object. These neurons form strong ("black") connections between them, thus providing the "*typical image*" of the object, representing its *typical attributes.*
- "*Halo*" neurons — a part (and by far not a small one) of neurons that are excited relatively rarely, at some *atypical* presenting and/or reflect *atypical* (inessential) *attributes* of the given object. The connections between them and core neurons are weaker ("grey"), so that they surround the core neurons forming a grey "halo" *blurring* the typical image (that is why $\boldsymbol{H^0}$ was called the *fuzzy* set).

The "connection-blackening" principle implies that when the main bulk of connections between the core neurons become strong enough, i.e., achieve the level of so called "black" connections Ω_0, the image is treated as learned (well-known) or "typical" one. Such images are transferred (by the direct one-to-one cross-subsystem Λ connections) to the plate $\boldsymbol{H^{typ}}$ in LH for memorization and storage. Then, all connections in LH are trained according to the Hopfield's rule that corresponds to *selection* of relevant connections at the "black" level of Ω_0, with diminishing other (redundant) connections (see Figure 3b).

The next step of the system's self-organized evolution consists in conversion of the image into symbol. It was shown in [1][4] that in NCCA, this procedure corresponds to generation of the *conventional* (*subjective*) information. After the typical image (the chain of core neurons) is transferred to the plate $\boldsymbol{G^1}$ in RH**,** the free *choice* of a single neuron-symbol occurs as a result of the competitive interaction (see Figure 2). Then again, according to the connection-blackening principle, after the *semantic* connections Ψ^R (one-to-many) between the chosen symbol and its image became strong ("black") enough, the symbol is replicated in LH. Here, it forms its semantic connections Ψ^L with the typical image according to Hopfield's training principle of selecting relevant connections.

Let us stress that only the core neurons are involved into the typical image of the given object. Under NCA, these core neurons are modified to be excited directly by corresponding symbol. Moreover, at relatively high (verbalized) levels of hierarchy, the typical images could be excited by means of corresponding *words.*

The halo neurons, in spite of their participation in the training process, are not connected with any symbol (and thus, with any word), hence they could not be controlled by the "Mind". The information on the halo neurons together with their gray connections is stored in the *fuzzy set* $\boldsymbol{H^0}$ only and could be activated just occasionally (by chance); this very process represents the "*insight*".

Finally, it is very important to stress that in the process of transition from $\boldsymbol{H^0}$ to $\boldsymbol{H^{typ}}$, a part of associative connections between the raw images also could be lost. In Figure 2, bottom part (RH), all the presented images are connected associatively. In the upper part (LH), one image appears to be quite separated from two others (connected objectively), since its connections with them were mediated only by the halo-neurons.

Thus, the fuzzy set plays a very important and enigmatic role in the cognitive process. Actually, it could be treated as the *sub-consciousness* filled with personal subjective associations and motives. Returning to possible reasons of AE listed above — namely, childish vague impressions, personal fuzzy (indirect) associations, etc., — we can infer that the source of AE is hidden just in the fuzzy set $\boldsymbol{H^0}$.

Note that hidden (latent) information appears also at the higher levels of hierarchy. Generalized images, i.e., images created by a set of symbols, also involve their core neuron-symbols, as well as halo-symbols that are presented in RH only and not transferred to the corresponding level in LH. Hence, this part of latent information (auxiliary and individual for a given system) representing its casual (episodic) experience could be associated with the *intuition.* These halo-symbols refer to not so deeply hidden information and could be activated by certain (again occasional) *words.* These triggering words may have no relation to the current problems, but could switch on the chain of indirect (personal) association and thus, lead to unexpected (intuitive) solution also looking like insight.

Thus, we infer that the motives for AE are connected with the halo-neurons (including halo-symbols).

IV. Approaches to AE Nature and Phenomenon of Chef-D'oeuvre

Any cognitive process is based on the *recognition* of an object\phenomenon\situation and its *trend*, i.e., the *anticipation* (forecast). And the forecast is based on the first impressions in the process of recognition. In the presence of a rational goal, this process always is accompanied by pronounced emotions. Under NCA, emotional manifestation is directly connected with the noise-amplitude derivative

dZ/dt defined by (6), which controls the subsystem activity (Λ). According to (6)–(7), negative emotions (nervousness, fear) correspond to incorrect recognition (*dZ/dt*>0) and activation of RH (Λ<0), consequently. Vice versa, correct recognition and prognosis results in decreasing noise amplitude (*dZ/dt*<0) with switching on LH (Λ>0), which is accompanied by relaxation, satisfaction, etc. Let us consider certain details of these processes.

A. Recognition & Prognosis

The procedures of recognition and prognosis were considered in details in our works [3][4]. It was shown that recognition goal can be achieved by means of the low levels σ=0 ("images") and σ=1 (typical-image symbols). The examinee object is recorded in $\boldsymbol{H^0}$ and compared with known (learned) typical images in $\boldsymbol{H^{typ}}$**.** Further procedure is controlled by the value of discrepancy $D_0(t)$ between the **RH** and **LH** zero-level records, which can be defined as:

$$D_{\sigma=0}(t) \equiv \sum_i \left\| H_i^{typ} - H_i^0 \right\|, \qquad (8)$$

where summation proceeds over excited neurons.

There are several typical regimes.

- The examinee object is well-known to the system, i.e., its image completely coincides with one of typical images, so that $D(0)=0$. Then, it is associated with corresponding symbol in LH, and RH does not participate further in the process. Emotional manifestations are absent (*dZ/dt*=0).
- The examinee object is *similar* to one of the known typical images (fits its "attracting area"), $D(0)\neq 0<D_{cr}$. Then, it is treated as an already known object: it has its typical image together with the corresponding symbol $G^{L,1}$. Here, however, the recognition accuracy requires verification. For this purpose, the symbol should be transferred to RH for decomposition, and the result is compared with the examinee image. Here, the discrepancy provokes repeating, and the procedure should pass over several iterations. This corresponds to dumping oscillation of the noise amplitude *dZ/dt* (see Figure 4a) representing the emotional fluctuations.
- The examinee object is unknown to the system ($D>D_{cr}$). This provokes the recognition failure, that is accompanied (depending on the final goal) by either zero, or negative emotion manifestations. Then, the full procedure of new image formation and recording to $\boldsymbol{H^{typ}}$ is to be performed.

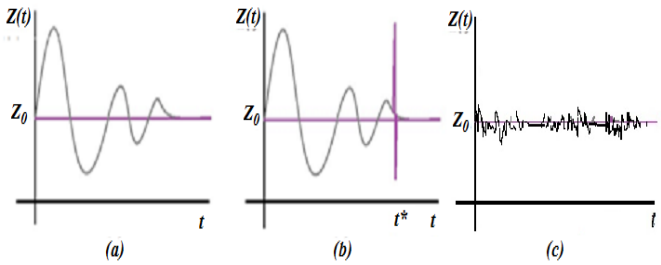

Figure 4. Typical patterns of the noise amplitude *Z(t)* behavior in the cases of (a) recognition procedure; (b) incorrect prognosis with sense of humor manifestation, and (c) Aesthetic Emotions ("goosebumps").

The *prognosis* represents the recognition of time-dependent process and proceeds in a similar way. Special case of incorrect prognosis, which activates the sense of humor has been discussed in [3][4]. It appears when examinee process seems familiar up to some moment *t**, but the next bulk of information appears to be once unexpected, but still well-known. This switches the recognition process to the other, also familiar pattern. This corresponds to the specific reaction of the system, — namely, sharp up-down jump ("spike") in the noise amplitude, which could be associated with human *laughter* (see Figure 4b).

B. Interpretation of AE: "Recognition Paradox"

Perception of any Artwork represents a particular case of recognition-and-anticipation procedure (see, e.g., [24]). Contrary to everyday life, when recognition is a part of behavioral program and connected with obvious and rational goal, the Artwork does not require any actions, so that the goal of such anticipation is not pragmatic, but rather latent. It could be connected with certain dissatisfaction, i.e., *ambiguous impression* produced by the piece of Art, which does not allow to put it in line with any known symbol (and consequently, with a certain word). Differently speaking, AE arise when the impression cannot be formulated and explained.

According with the above consideration, AE appear if the examinee object\phenomenon does excite the *halo neurons* in RH. Since they are *not* connected with any specific symbol and thus, such impressions remain unconscious, this gives rise to a "vague effect" that could not be formalized or verbalized; these very impressions produce tingling sensations called the "goosebumps" (or "horripilation"). This also implies that the discrepancy *D(t)* defined by (8) could never come to zero since information on halo neurons is absent in LH**,** but its value is small. Hence, the "goosebumps*"* correspond to small vibration (*trembling*) of *Z(t)* around the normal value (Figure 4c).

According to this hypothesis, strong AE, which can be treated as personal impression produced by the masterpiece (ChD), could be caused by the "*recognition paradox"*. This phenomenon can take place in at least two cases.

1) Recognition paradox #1: It appears if the Art object is very similar to something well known, despite some minor and even *unconscious* (by the first glance) difference (light *inaccuracy),* which involves the halo-neurons only. Then, $D(0)=D(t)\neq 0$, but this discrepancy could not be comprehended and explained by words. The most pronounced example of such painting ChD is the "Black Square" of Malevich, which appears to be neither square, nor monotone black. This pattern contains actually small (and even invisible) deviations in lines and color, and these differences could be measured objectively. Hence, the eyes (i.e., the "Brain", not the "Mind") do actually notice this inaccuracy, and this provides some ambiguous impression of dissatisfaction producing AE. Speaking picturesquely, this feeling may be expressed by the formula "*to see invisible*".

 ISBN: 978-1-61208-531-9

Thus, in this case, the paradox consists in the fact that small and incomprehensible deviations of ChD from the ordinary pattern emphasize its individuality.

2) Recognition paradox #2: ChD looks like *several* familiar patterns simultaneously, so it could not be recognized as any of them. It could be linked with all of them by associative "*grey"* connections in RH (via the "halo"-neurons), while in LH, all these patterns with corresponding symbols are separated. Such type of ChD activates fuzzy subjective associations, which were stored in RH but lost in LH. In other words, the "Brain" does know it, but the "Mind" cannot formulate and comprehend.

Perception of such ChD is to a large extent similar to manifestation of the sense of humor, but in this case, the incorrect (ambiguous) prognosis cannot be turned to a new familiar symbol and the corresponding word, i.e., again cannot be formulated and explained.

Striking examples of such type ChD are the great musical compositions of Mozart, Beethoven, Chopin, Wagner, etc., which have something insensibly in common with each other (classical), as well as with the older traditional (often folk) music (see, e.g., [33]).

Speaking picturesquely, this impression could be formulated as "*to unite unconnectable".*

3) General formula of ChD: In both these cases of recognition paradox, LH could not perform alone the recognition task, so that RH should be activated. This is the mechanism of AE appearance. Both these pathways lead to the feeling of ChD and realize the formula: "*to see invisible, to unite unconnectable*". Accounting for participation of the halo-neurons, we may rephrase this formula as "*the "Brain" does already know, while the "Mind" still cannot realize*".

Let us point out to the interesting consequence of the "halo-neuron hypothesis". It implies that halo-neurons do accompany the corresponding *core* neurons. It means that the system actually has recorded and memorized similar (but not identical) patterns. In other words, the system has its own experience with the patterns of a given type and hence, has sufficiently large *repertoire* (expertise) in such area. Nevertheless, relatively inexperienced ("green") system could perceive ChD, but only in those parts, which are familiar to the system itself. This effect corresponds to the formula "*each person has its own vision of ChD"*.

Note that the presented hypothesis provides a key to the explanation of another enigma: why the pleasure of favorite Art patterns does not lose its luster after multiple acts of perception? In contrast to a joke, which provides the impression due to an element of unexpectedness and its subsequent resolution, the recognition paradox has *no resolution:* an ambiguous feeling arises whenever this Artwork is presented.

V. CONCLUSION AND FURTHER WORK

Thus, it is shown that NCCA contains inherent possibility to reveal the mechanism of Aesthetic Emotions (AE) appearance. The whole architecture represents a combination of two multilevel subsystems, in analogy with two hemispheres of human brain. One of them (RH) processes any new, unexpected or ambiguous information. The other one is dealing with familiar (well known), i.e., clearly formulated information. The role of each subsystem in solving the current problem should be controlled by *emotions* (in particular, AE).

It is shown that the AE reasons are stored at the ground ("image") level of the architecture in the RH subsystem, which is called the *fuzzy set* $\boldsymbol{H^0}$**.** This neuroprocessor contains the whole information whenever recorded. In particular, it involves insignificant (at the first glance) information stored in weak ("grey") connections between so-called "halo" neurons, which correspond to *atypical* (inessential) attributes of real objects. This information is hidden in RH only and is transferred neither to LH nor to the high (symbolic) hierarchy levels of RH, hence could be neither formulated nor comprehended.

According to our main hypothesis, the mechanism of AE consists in excitation of personal subjective (may be *vague*) *associations* provided by weak connections via halo neurons. These associations could not be formulated and verbalized, thus, comprehended. Within NCCA, these excitations correspond to small oscillation ("trembling") of the noise amplitude *Z(t)* that could be treated as analogy to human feeling of "goosebumps".

This hypothesis provides the possibility to explain several *enigmas* connected with AE*:*

- This explains the individuality of AE;
- This involves all the intuitively obvious reasons for AE listed above — childish vague impressions, fuzzy associations, indirect influence of micro-society, etc.
- Deep AE, i.e., personal feeling of ChD could be caused by the *recognition paradox*, which arises when the Artwork seems *familiar* and *unusual* simultaneously, with this impression being not formulated and explained.
- In aphoristic form, the feeling of ChD can be presented as "*to see invisible, to unite unconnectable*".
- Perception of any Artwork requires proper personal *repertoire* (competence, erudition, etc.) stored as in episodic (RH), as well as in semantic (LH) memory. Otherwise, the system remains quite indifferent to any piece of Art including ChD. This explains the "enigma of blind and deaf".
- The mechanisms providing sense of humor and AE actually have something in common. However, the sense of humor is caused by *unexpectedness* (surprise), which could be still recognized immediately. But AE arise in the case of *ambiguous* (*paradoxical*) impression that remains unformulated (hence, unrecognized) even in the long run. That is why a joke, repeated twice, does not cause a specific reaction (laughter), while favorite Artwork (ChD) always causes another specific reaction ("goosebumps").

Returning to the Explanatory Gap challenge, we can infer that the study of AE, being seemingly not a scientific problem (rather Humanities and Art study), actually provides the possibility to "*open a gate*" to the gap between "Brain" and "Mind". It is shown that AE emerge (as indicated in Figure 1) at that virtual border. Then, general formula "to see invisible, to unite unconnectable" could be expressed in more constructive (still aphoristic) form:

"Brain does already know, while Mind cannot still realize". And this very ambiguity provides the feeling of ChD.

Let us emphasize that all these reasons are inherently connected with NCA grounds. This is DTI that point out the role of *conventional* (*subjective*) information as a whole, and the role of a symbol as a *representative* of this information in particular. According to NCA viewpoint, the symbol is the very first object that, being relied on the "Brain" area, represents a "molecule of the Mind". And this is the technique of nonlinear differential equations that enable us to describe the procedure of symbol formation and the point where weak ("grey") connections appear to be lost.

It should be stressed that all these arguments represent not an instruction for ChD production, and not the method to estimate the value of ChD. The study represents only an attempt to understand the *mechanisms of perception* of the Art as a whole and ChD in particular. Nonetheless, this study can be used in social surveys, highly targeted advertising, and other social actions.

However, we have not discussed here the phenomenon of "socially accepted ChD" — why the significant part of society (not only certain persons) does feel a "goosebumps" caused by certain (ingenious) piece of Art? The mechanism could be similar, but this problem requires further work.

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