On Modeling and Analyzing the Creativity in Art and Science

Olga Chernavskaya

P.N.Lebedev Physical Institute, Moscow, Russia

olgadmitcher@gmail.com

Olga Chernavskaya - bio

- Born on 03/30/1957
- Studied at the Physics Faculty of Moscow State University,

Department of Quantum Field Theory;

   graduated in 1980 with honors.
- Since 1980 has been working at Lebedev Physical Institute,

Laboratory of Elementary Particles, current position – Senior Researcher.
- In 1998 she defended her thesis and received a Ph.D. degree in physics-math sciences
- Since 2011 - Member of the Interregional Association for Cognitive Research
- Since 2012 – member of the Biologically Inspired Cognitive Architecture (BICA) society
- Since 2017 - Member of the Program Committee of IARIA confs COGNITIVE

Problems of interest

- Representation of Emotions in artificial cognitive systems

- The role of Emotions in efficient learning

- Social connectivity and emotions

- AGI and the theory of self-developing systems

Preface to the talk

Dear colleagues,

- I am happy to participate in this conference, as I have done every year since 2016. The last 2 years have been hard and difficult and have brought new challenges. It is no coincidence that just this time we were researching the property of Creativity, i.e., the ability to generate new original ideas in art and science (new 'personal world'). But Creativity can be viewed from another point of view: it enables us to create own virtual reality which could crowd out external chaos.

- Generally speaking, the creativity has two basic goals:
  - to express yourself (self-realization);
  - - to achieve success and recognition by society.

In today's hard conditions of self-isolation and the difficulty of communicating with the outside world, it is the creation and maintenance of your own virtual reality that comes to the fore as opposed to the external (chaotic) world. I wish to all of us fruitful creative work!

Detailes could be found in: O. Chernavskaya and Ya. Rozylo, "On modeling the creativity and the concept of Chef-D'oeuvre", Cognitive Systems Research, Volume 68, Pages 18-33.

OUTLINE

- **I. Introduction to *Creativity* and the concept of *Chef-D'oeuvre***

- **II. Main points of Natural-Constructive Cognitive Architecture =NCCA**
  - Scheme
  - Equations
  - Representation of Emotions

- **III. Nature of Aesthetic Emotions (AE)**

- **IV. Concept of Chef-D'oeuvre (ChD)**
  - ChD in Art
  - ChD in Science

- V. HOW could a ChD be created?
  - insight
  - intellectual *panic* = "throes of creativity"

- VI. Conclusion and Summary

I. Introduction 1: Creativity

- **Creativity = ability to create *NEW* = most mysterious human ability**
  - **! Creativity ≠ "aha" problem: *nobody does know* a solution**
- ***Algorithm?* Generally speaking, creative work requires** [2: E. Goldberg]**:**
  - to extract key issues and ask proper questions;
  - striving for novelty (e.g., new solutions even to the old problems);
  - to correlate old knowledge with new problems;
  - flexibility of thinking (abandon dogmas if new information contradicts them);
  - focus on solving the problem;
  - " free wandering thoughts" (imagination).

  --- not a recipe, contains paradoxes, etc. = *there is no solid algorithm!*
- ⇒ **Creativity is based on 2 cornerstones:**
  - **Skills (professionalism) ↔ hard laborious work**
  - **! *Personality:* individual deep (hidden) experience = (subconsciousness) ↔ *insight***
- ⇒ tightly connected with the "**Explanatory Gap**" problem: **Brain vs Mind**.
  - **BRAIN (*B*) = *individual* objective inf provided by Nature *(=experience)***
  - **MIND (M) = subjective inf created inside the cognitive system *itself***
    ⇒ *Understanding the Creativity* **provides** *"the gate to the Gap" : what is inside?*

Levine J. "Materialism and Qualia: The Explanatory Gap". 1983

Explanatory Gap

Psychology (MIND)   **Neurophysiology (BRAIN)**

- **Consciousness**   - **Ensemble of *Neurons***

Emotions:

- *Subjective (!) self-appraisal* of current/future *state*   - *neural transmitters* (**objective! Measurable!!**)

Introduction 2: Concept of Chef-D'oeuvre (ChD) in Art and Science

- **Creativity in Art ↔ Aesthetic Emotions (AE)**
  - why AE are **strictly individual?**
  - what is the ChD, the excellent piece of art that is accepted by the entire society (= **majority of people**)?
  - what differs a ChD from the pattern of *solid professional work*?

- Concept of Chef-D'oeuvre (ChD): 2 main questions
  - WHAT is ChD? WHY it causes goosebumps?
  - HOW it could come?

- **ChD in *Science = scientific discovery***
  - **What differs ChD in Science and Art ?**
  - **What is common**
  - **Examples of scientific ChD**

# II. Natural-Constructive Cognitive Architecture (*NCCA*)

- ## 3 cornerstones:

- **Dynamical Theory of Information (*DTI*): focus on emerge and evolution of inf**

(*Haken, 2000, Prigogine, 1997, Chernavskii, 2000*)

- Main DTI inference: *generation* of *new* inf. and *conservation* of known inf. are *dual* functions $\Rightarrow$ should be implemented by *2 different subsystems*

- generating inf requires *noise* (=random self-excitation of neurons)

- **Neurophysiology & Psychology data**
  - *E.Goldberg:* RH $\leftrightarrow$ learning (new inf.)

    LH $\leftrightarrow$ processing well-known inf. (recognition, prognosis, ...)

- **Neural computing**
  - D*istributed* memory *(Hopfield-type)* and **localization**=*WTA* (*Grossberg-type*) neural processors
  - Combined with nonlinear differential equation technique $\leftrightarrow$ *dynamica*l formal neuron concept

NCCA Scheme : **Fig. 1***(redrawn 2020)*
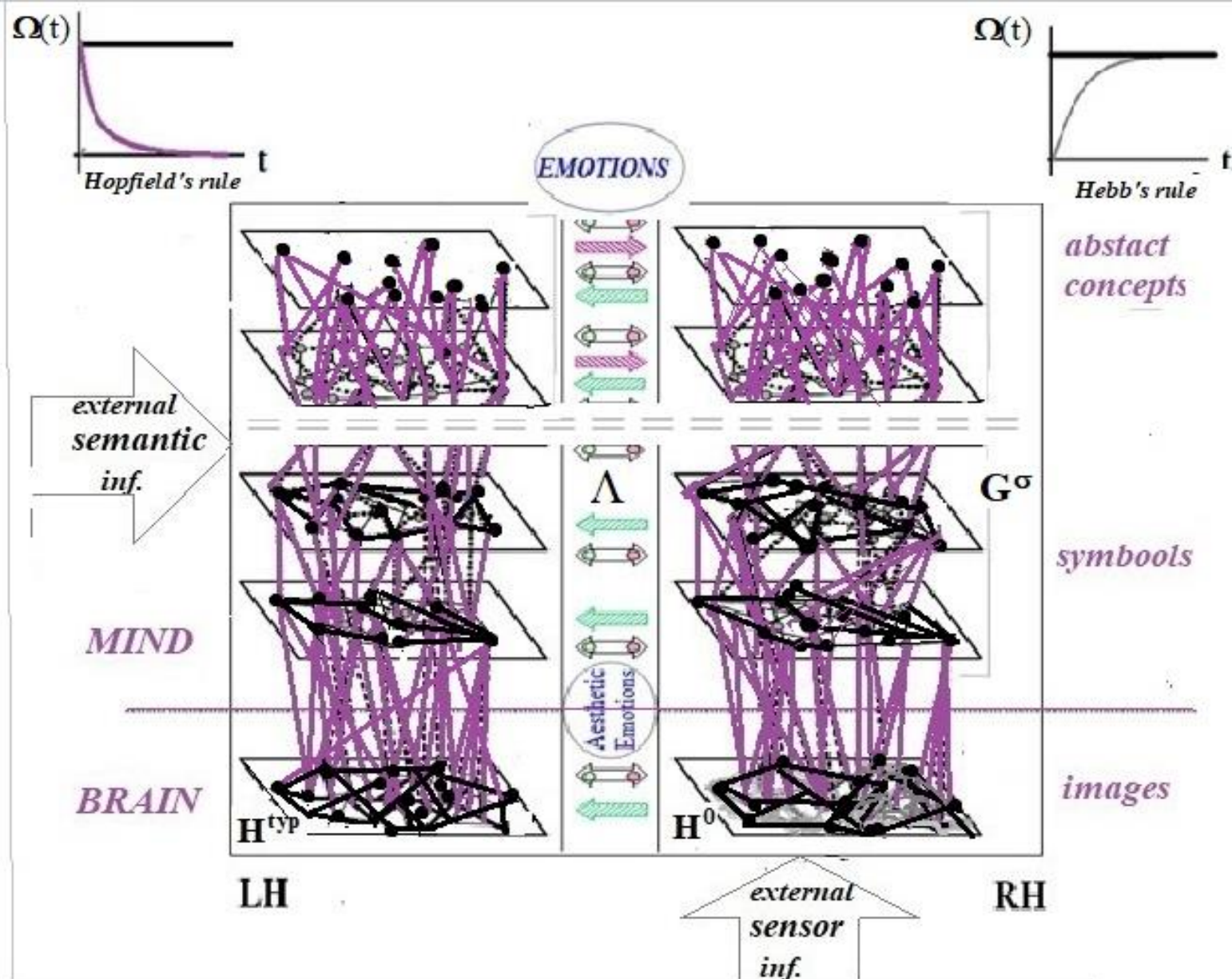
Comments to the NCCA scheme:

- **Combined *2 subsystems* (as cerebral hemispheres)**
  - **RH** ↔ generation of new inf. (=learning , creating)
    - **Noise is required!**
  - **LH** ↔ conservation and processing already learned inf = recognition, prognosis, etc.
- **Different laws of connection training for RH and LH:**
  - RH ↔ Hebbian (*amplification*) = *memorization of choice*
  - LH ↔ Hopfield ("redundant cut-off") = *selection*
- **Symbol-choosing procedure** is *unstable* (controlled by *noise*) ⟹ symbol forming = generation of *subjective inf (convention).*
- **Hierarchical structure:**
  - $\sigma=0$: images =sensory inf (objective!) ↔ *BRAIN* !
  - $\sigma=1,\ldots N$ = *symbol* inf = subjective! inf (convention) ↔ *MIND* !
    - $\sigma>1$: symbols ↔ words = verbalization → <u>consciousness</u>
  - $\sigma\gg1$: abstract (not-sensory) inf. *= symbol-concepts*

Mechanism of NCCA scheme formation: small fragment of basic levels σ=0,1 (**Fig. 2**)
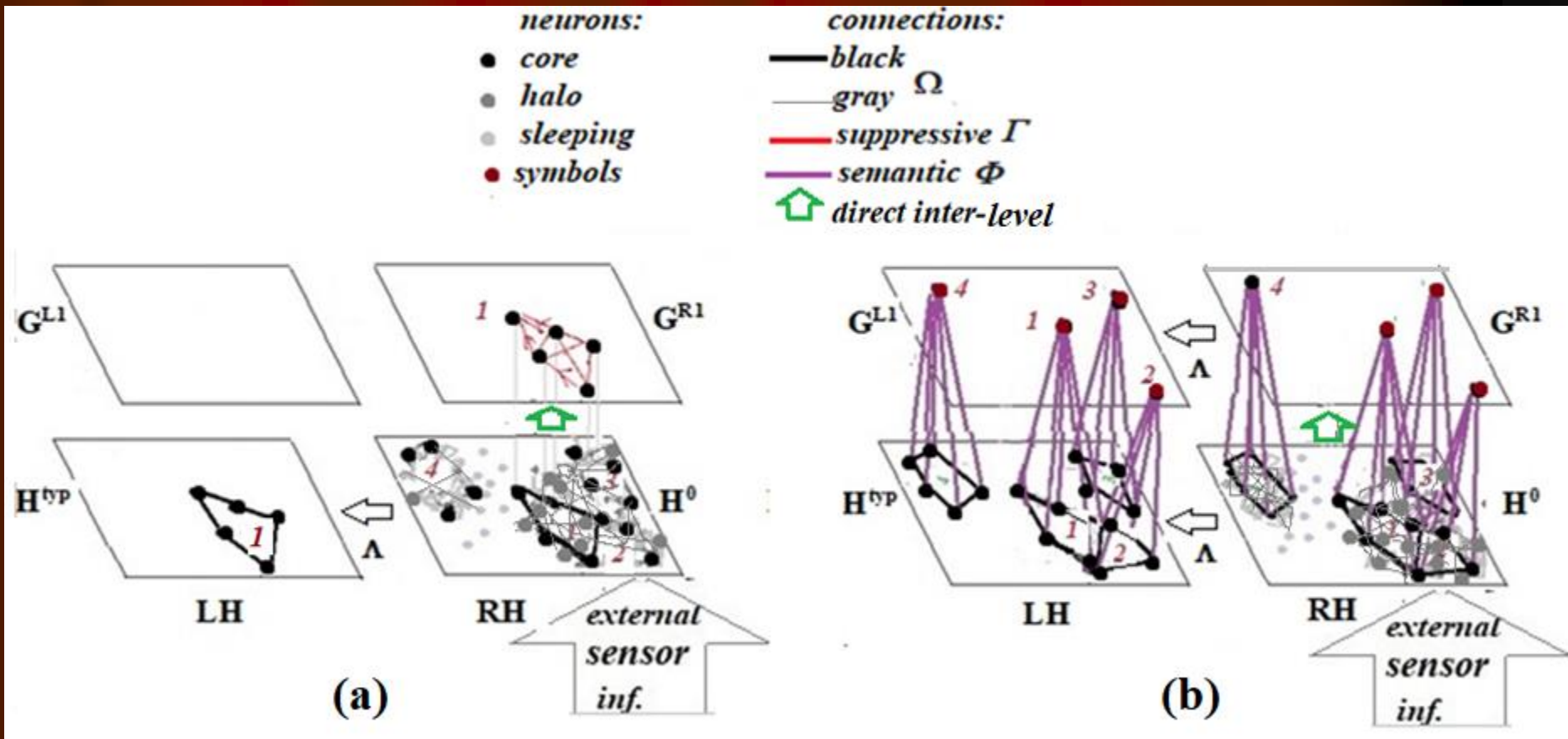
- (a): **early** stage: only 1 image in H_0 (RH) is well-learned ("typical"), it is translated to H_{typ} (LH) and G_{1R}, where the symbol is chosen (by *competition*)

- (b): **final** stage: all 4 images became typical and obtain their symbols that form inter-level *(semantic)* connections with image neurons

Comments to Fig. 2

- ***Connection blackening principle***: images are forming in H_0 (RH) by Hebbian learning mechanism up to strong ("black") connections (***typical images***) and then are translated (replicated) to H_{typ} (LH) and to G_{1R} for symbol creation (***winner-choosing procedure***)

- ***Core*** neurons $\leftrightarrow$ typical attributes
  - Provide the base for ***symbol*** formation

- ***Halo*** neurons $\leftrightarrow$ atypical (inessential) attributes and\or rare representations
  - provide **implicit (indirect) associations that are lost at the transition RH$\rightarrow$LH**
  - are hidden in H_0 (BRAIN) only

- **"*Sleeping*"** *neurons* = **never been excited in any cognitive process**
  - *not belong* **even to BRAIN experience**

- **Sub-consciousness** = variety of ***halo-neurons*** along with their weak ("*gray*") *connections* = *seemingly* unimportant ***unrealized and non-verbalized hidden personal (Brain) experience***
  - not connected with any symbol = "***out of control***" by Mind
  - ***something that BRAIN does know, while MIND can't realize***
  - source for ***creative*** solutions that could be excited only by ***noise*** (*=insight!*)

13

Master equations (details in Chernavskaya, *BICA*, 2015)

$$\frac{dH_i^0(t)}{dt} = \frac{1}{\tau_i^H}\left[\mathfrak{I}_H\{H, \beta_i\} + \sum_{i \neq j}^{n} \Omega_{ij}^{Hebb} H_j^0 + \sum_k \Phi_{ik}\, G_k^{R,1} - \Lambda(t) \cdot H_i^{typ} + Z(t)\cdot\xi_i(t)\right]$$

$$\frac{dH_i^{typ}(t)}{dt} = \frac{1}{\tau_i^H}\left[\mathfrak{I}_H\{H, \beta_i\} + \sum_{i \neq j}^{n} \Omega_{ij}^{Hopf} \cdot H_j^{typ} + \sum_k \Phi_{ik} \cdot G_k^{L,1} + \Lambda(t) \cdot H_i^0\right]$$

$$\frac{dG_k^{R,\sigma}}{dt} = \frac{1}{\tau_G}\left[\mathfrak{I}_G\{G_k^R, \alpha^\sigma{}_k\} + \widehat{\Upsilon}\{G_k^{R,\sigma}, G_l^{R,(\sigma+\nu)}\} - \Lambda(t) \cdot G_k^{L,\sigma} + Z(t)\cdot\xi(t)\right]$$

$$\frac{dG_k^{L,\sigma}}{dt} = \frac{1}{\tau_G}\left[\mathfrak{I}_G\{G_k^L, \alpha^\sigma{}_k\} + \widehat{\Upsilon}\{G_k^{L,\sigma}, G_l^{L,(\sigma+\nu)}\} + \Lambda(t) \cdot G_k^{R,\sigma}\right]$$

$$\frac{dZ(t)}{dt} = \frac{1}{\tau^Z}\left[a_{Z\mu}\cdot\mu + a_{ZZ}\cdot Z + F_Z(\mu, Z) + \Theta(Z, H, G_k^\sigma)\right]$$

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

$$\Lambda(t) = -\Lambda_0 \cdot th\left(\gamma\cdot\tau^Z\cdot\frac{dZ}{dt}\right)$$

14

Comments to the system of Equation : **1**

- *Hi, Gi* – variables representing i-th neocortex neurons (Fig. 1)
  - *H* $\leftrightarrow$ H-type proccesors *= **distributed** memory (images)*
    - ***Objective individual*** inf (sensor signals from real objects ever presented)
  - *G* $\leftrightarrow$ *G-type proc.* = *symbols* of previous-level images
    + generalized images (=image-of-symbols)
    - ***Subjective*** **inf created inside the system itself**
  - *Scaling = the same formation principle at any* σ level
- σ = level of hierarchy
  - σ =0….1 $\leftrightarrow$ ***virtual border btw. "Brain" and "Mind"***
- **Noise:** $Z(t)\xi(t)$: $Z(t)$= amplitude, $\xi(t)$ = random function (Monte-Carlo)
  - *presenting in RH **only***
- Λ: *inter-subsystem connections* $\leftrightarrow$*"corpus callosum* ": serve to provide "dialog" **RH** and **LH**
    - Λ= + Λo(R $\to$L) = Λ; Λ= − Λo= Λ(L$\to$R) : **refers to all eqs.** [15]

Comments to the system of Equation : **2**

- ***Bottom block = variables Z(t), μ(t) =refer to Emotions***
  - *μ(t)* ↔ *"deep B"* = **effective composition of neurotransmitters** (*stimulant minus inhibitors*)
  - $Z(t)$ = the "***tool*** " for self-appraisal = "*emotional temperature*"
    - Z_o = "**normal temperature**" ↔ value necessary for normal system's functioning (*homeostasis*)
- ***Final eq. : Λ(t) = activity of RH\LH subsystem is controlled by emotional tool -dZ/dt!***
  - **unexpectedness (incorrect prognosis) ↔ negative E ↔ RH activation is necessary! (= mobilization)**
  - **finding a solution ↔ positive E ↔ LH only (relax for RH)**
    - **NB: a derivative could be either (+) or (-) !**

Noise amplitude *Z(t)* = *"emotional temperature"*: *typical patterns* in solving various problems

● **Recognition** (iteration process)**: Fig. 3a**

RH puts forward hypotheses, LH tests them, etc.: **dumping oscillation around normal value Z0**

● **Prognosis (prediction):**

　　● **the same in normal mode**

　　● in the case of **joke (sudden unexpected but still familiar inf that switches to another prediction): sharp rise at t* that is immediate changing by fall down (new solution found)** ↔ *laugh* (Fig. 3b)

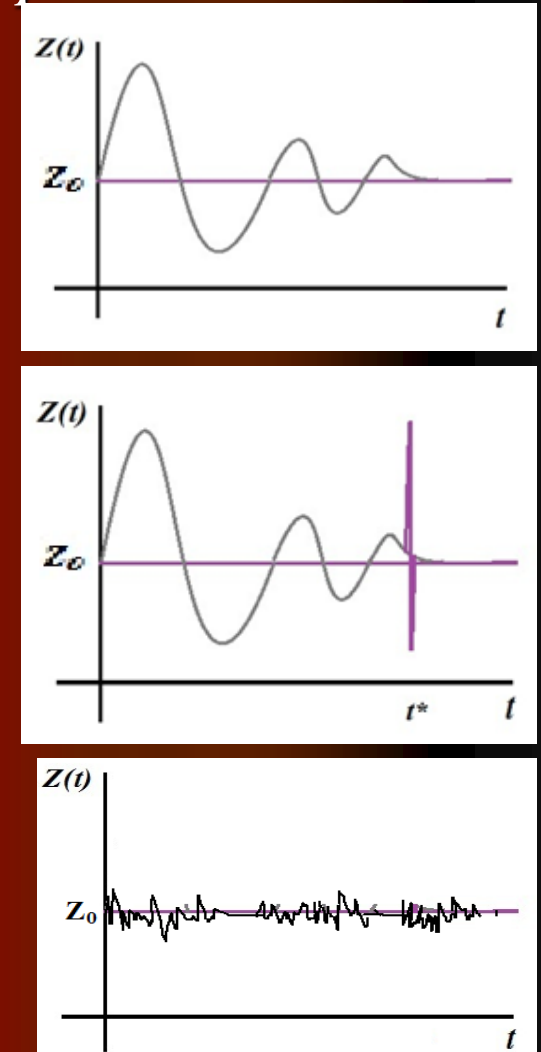● *Aesthetic Emotions* (contemplation of Art) **: goosebumps ↔ Z(t) *"vibration"* around Z0** (Fig. 3c)

Fig. 3

III. Nature of Aesthetic Emotions

- **Pragmatic E.** (*E*) ↔ definite *goal* *(e.g., to survive)*
  - *Have rational (!) reasons*
- **Aesthetic E.** (*AE*) = <u>**contemplation**</u> of Art, Music, Literature, Nature phenomena *: have **no rational reasons***!
- Great influence of society (propaganda), BUT:

- **AE** are *strictly individual = mystery #1*

  - *sincere = goosebumps* could not be *feigned*

  - subjective individual "*goosebumps*" *are objectively measurable!*

- *Possible* reasons could be: (apart from obvious **cultural context**) +
  - **childish <u>vague</u> impressions;**
  - **personal *<u>fuzzy</u>* ("implicit") *<u>associations</u>*;**
  - **influence of cultural <u>mini-media</u> (family, messmates, etc.).**
    = all related to the *subconsciousness*

Mechanism of AE in NCCA

- **AE are controlled by the value of *discrepancy D* (*influences on dZ/dt*)**

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

i.e., the difference in RH and LH records (excited neurons)**:**
- If the pattern is quite familiar (**D=0**), AE *are absent* (indifference);
- If it is quite unknown (now such records), AE again are absent;
- **bright AE** providing the *goosebumps* (in Fig. 3c – slight trembling around normal value Z_0) arise when the pattern seems *familiar* but *unusual* (*abnormal*) simultaneously, with this *illusion cannot be neither formulated, nor realized. WHY?*

- **Main inference: *AE = effect of excitation of HALO neurons: it* generates *vague **implicit*** (**individual!***) associations* (via "gray" connections).

  - this impression cannot be smoothed out, since D≠0 due to halo neurons (absent in LH).

  - *couldn't be **formulated** (**verbalized**) since halo not connected with **any symbol!***

  - *'Sub-barrier' transition* between different images (i.e., between different **symbols**)

- **Halo-neurons: <u>AE arise when Brain *does see* something that the Mind *can't realize*</u>**

- ***<u>Consequences:</u>***

  - *AE require **large repertoire** of halo neurons (= **erudition**) ↔ **episodic experience***

  - *! Impression **doesn't depend on the number** of presentations: **familiar** patterns affecting the halo-neurons still produce vague (unformulated) impression **always***

IV. Concept of Chef-D'oeuvre (ChD)

- If *AE* are **quite individual** than **WHY** some piece of Art are *socially accepted* as **ChD?** = *mystery #2*
  - **Great influence of mass media (FASHION)** $\Rightarrow$ *temptation (delusion)*: " **ChD is the result of *social convention* expressed in $ equivalent**"
                        but: **ONLY ???**

- **But *WHAT* is it in the ChD itself that makes it ingenious?**
  - **What does differ 'Mozart' (= ingenious creations) from 'Salieri' (= solid professional work)?**

Chef-D'oeuvre ↔ «*RECOGNITION PARADOX*»

- *ChD* **causes the** *PARADOX of RECOGNITION: arise when the pattern seems familiar but unusual,* **with this** *illusion cannot be neither formulated, nor realized (affecting the halo neurons of people).*

- *at least* **2 possibilities:**

  - **#1.** **ChD** <u>**differs but slightly**</u> (*by few halo-neurons*) **from certain familiar object ==** c*orresponds to: « …to see invisible..»*
    - "*Black square*" of Malevich: is not neither black, nor square"
    - "*Mona Lisa*" **Leonardo: a person passed through the stroke (insult, or plastic surgery)**
  - **#2. ChD** <u>**resembles**</u> *a lot of familiar patterns :* "*to combine the incompatible*"

    = *Implicit associations* **via** *HALO* **neurons =** "*sub-barrier transition*"

    - Great composition Mozart, Beethoven, Wagner, etc.: *something insensibly in common with each other (classical), as well as with the older traditional (folk) music*
    - **Analogy: ChD is similar to the** *AIDS virus* **: have attributes (signs) of many others, but couldn't be reduced to them**
- *General formula for ChD:*

  "*…to see the invisible, to combine the incompatible*"

# ChD in Science = scientific discovery

- *Professionalism* come to the fore, but still *fantasy* is needed
- *Evolution of Science* proceeds in analogy with formation of NCCA
  - *early stage*: formation of *typical images + symbols*
  - *later stage*: *relations* (possible *contradictions*) between *abstract concepts* = ?
- The concept of ChD in science *depends on the stage of development*
  - early stage: *revealing basic links* (laws) = "*to see the invisible*"
  - later stage: *interdisciplinarity* = resolution of *scientific paradoxes* (contradictions) = "*to combine the incompatible*"
- Examples of famous scientific ChD
  - *Newton's law* : to see invisible link between force and acceleration (not speed)
  - Quantum Mechanics: *Complementary principle* (Bohr vs Einstein)
  - *Classical Mechanics VS Thermodynamics* (Boltzmann, Krylov)
  - *Mendeleev's Table:* double ChD: he *saw invisible* (unknown) chemical elements and *combined* them according to *atomic planetary model* discovered 50 years later! (after his death)

The Mendeleev's Table

Dmitrii Mendeleev had *created* famous **Table of chemical elements,** which further turned out to be consistent with the "*planetary model of the atom"*, which is accepted to this day, and was developed ~50 years later (after his death)

= an example of "*combined the incompatible".*

- The day before the discovery Mendeleev was in the state of *intellectual panic (throes of creativity):*
  - *deadline !*
  - *problem:* some chemical elements did not want to take needed places.

- The decision came to him **a *dream*** = *on the brink of consciousness.*
- *Solution* was **ingenious** and *paradoxical*: he left *empty places* in the Table for elements that *should* occupy them but *were still unknown*. == he had *seen the invisible* **elements**

DOUBLE ChD
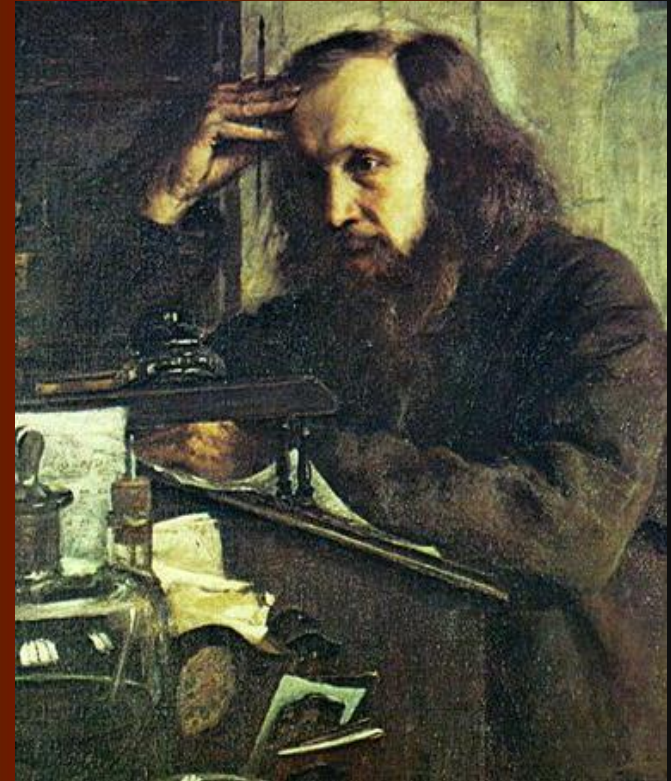
V. HOW could be created a ChD? Intellectual panic:
throes of creativity

- Creativity = the challenge to *extract* the vague associations\patterns from personal *halo* ("Brain") experience and *formulate* it by *any common language* (e.g., music, mathematic, poetry, etc.). In aphoristic form, this implies: "*to bring a piece of personal "Brain" into the "Mind" and World*".

- **How** could it come?
  - Suddenly, by *pure insight* – *very rarely* (almost improbable)
  - Usually, insight is preceded by *hard laborious work* implying mobilization of all resources (= *throes of creativity*).

- Efficiency of creative work depends on the *emotional temperature Z(t):* *mobilization* requires *increasing Z(t)*

- Intellectual panic (=throes of creativity) could be caused by necessity to solve some **creative** problem *urgently (***e.g., before certain *deadline)*
  - *could arise in any creative work: Art as well as Science*
  - is characterized by unpredictable (*chaotic*) behavior and *jumps* in mood [4] from *euphoria to despair*

Simulation of *throes of creativity*

- "Mobilization of all resources" = increase of **noise amplitude Z(t)** *(= increasing probability of halo-experience excitation)*

- When $Z(t)$ exceeds some critical value $Z^{**} >> Z_0$, system falls into **chaos:** chaotic jumps around abnormally high value results in **noise dominating** in RH and **mixing all known images** (like the effect of "*shaking + quenching*")

- It could result in either:

  - sudden solution *(insight)* at t^{**} that is accompanied by **emotional *Eureka!* burst (**similar to *laugh* (Fig. 3a))

  - deep long *depression* if **Z=0**: the system *can't neither perceive nor generate new inf* (Fig. 4b)

- At $Z > Z^{**}$ the probability of *waking up "sleeping" neurons* can provide new **implicit associations** that could lead to new solution **unexpected** for the system itself even at the Brain *(halo)* level! (see Fig. 2) ↔ *enriching the individual Brain experience (sub-consciousness)*

(a)

(b)

Fig. 4

25
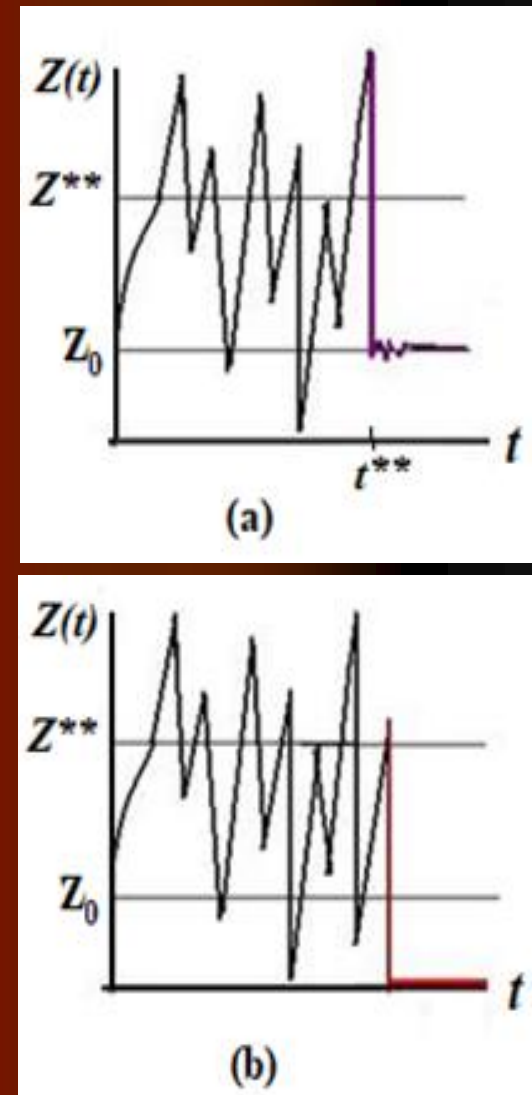
VI. Conclusions

- The source for creativity is hidden in the *subconsciousness* = personal episodic vague *unrealized* experience
  - Genius should have broad experience (= '*rich inner world*')
- Moment of creation = insight = is *occasional* act
- HOW could the insight come?
  - *Inspiration?*
  - *Throes of creativity* (**panic**)
- Our study = an attempt to understand the *nature of AE and the impression* produced by great **creations** (ChD)
  - *What differs ChD from* 'solid professional work'? The latter should be *perfect*, while ChD should contain small *deviation from perfection*
- *Creativity still remains to be a mystery…*
  - *at what moment* insight could come? *Dream?*
  - why the *throes of creativity may* **NOT** to lead to insight?

etc**...**

Summary

- *Subconsciousness* = personal episodic experience which was not realized, comprehended, and formulated (verbalized)
- Creativity = a challenge *to bring the piece of personal Brain (sub-consciousness) into the Mind (consciousness) and World*
  - *genius* can '*dig out*' from his personal 'deep inside' something that will *resonate* in the subconsciousness of people
  - each ChD contains the chance to contact with genius *at the deep inside* (sub-consciousness) *level*
- Recognition *paradox*: *Brain does know, while Mind doesn't realize*
  - ⇒ *AE (goosebumps) 'arise from Explanatory Gap'*
  - ⇒ *AE* arise when one has *no words* to describe the impression
- ChD is a **condensed capacity** *to see the invisible, to combine the incompatible ,* which is *inherent* in genius and *inspired* in people
- Key point for Creativity = *PARADOX*
  - "*You* **have to have** *chaos inside* **you to give birth to a dancing star**" *(Nietzsche)*
  - *Chaos around* **could be** *overcome* **by creativity inside**

Thanks for attention

References

1. Goldberg E.: The new executive brain. Oxford University Press, 2009
2. Coldberg E.: Creativity: The Human Brain in the Age of Innovation. Carlisle, NY (2018).
3. Levin, J.: Materialism and Qualia: The Explanatory Gap. Pacific Phil. Quarterly, 64(4), 354–3611 (1983).
4. Quastler H.: The emergence of biological organization. Yale University Press, NH (1964).
5. Solso, R.: Cognitive psychology. 5th edn., Needham Heights, MA: Allyn & Bacon (1998).
6. Chernavskaya O.D. et al. : An architecture of thinking system within the Dynamical Theory of Information. *BICA* 6, 147-158 (2013).
7. Chernavskaya, O. D. et al.: An architecture of the cognitive system with account for emotional component. BICA 12, 144—154 (2015).
8. Chernavskaya, O., Rozhylo, Ya.: The Natural-Constructive Approach to Representation of Emotions and a Sense of Humor in an Artificial Cognitive System. IARIA Journal of Life Sciences, 8 (3&4), 184—202 (2016).
9. Chernavskaya, O., Rozhylo, Ya.: On the Possibility to Interpret Aesthetic Emotions and the Concept of Chef-D'oeuvre". In: 9th Int. Conf. COGNITIVE 2017, pp. 24—31 (2017).
10. Chernavskaya, O., Rozhylo, Ya.: On the Possibility to Interpret Aesthetic Emotions and the Concept of Chef-D'oeuvre in an Artificial Cognitive System. In: 9th Int. Conf. COGNITIVE 2017, pp. 24—31 (2017).
11. Chernavskii, D. S.: The origin of life and thinking from the viewpoint of modern physics. Physics-Uspekhi 43, 151-176, (2000).
12. Hebb, D. O.: The Organization of Behavior: Neuropsychological Theory. Wiley & Sons (1949).
13. Hopfield, J. J.: Neural networks and physical systems with emergent collective computational abilities. PNAS 79, 2554—2558 (1982).
14. Grossberg, S.: Studies of Mind and Brain. Riedel (ed), Boston (1982).