Dynamical Theory of Information as the Basis for Natural-Constructive Approach to Modeling a Cognitive Process

Olga Chernavskaya

Lebedev Physical Institute, Moscow, Russia

olgadmitcher@gmail.com

Athens, Greece, Feb 19, 2017

To the memory of my father, teacher, and close friend

Dmitrii Chernavskii

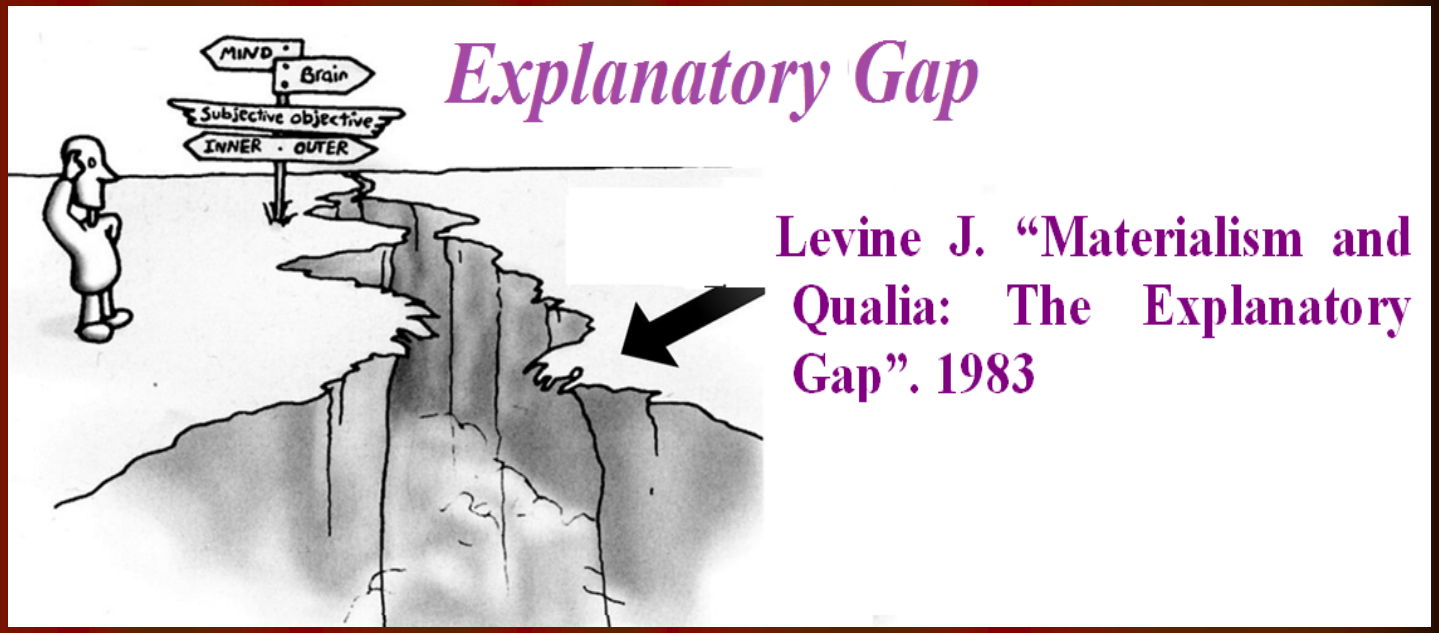
Feb 24 **1926 – June 19 2016**

Scope of interests:

- High-energy physics, elementary particles
- Biophysics
- History (Clio-dynamics)
- Economy
- **Cognitology**

Actually, the key idea is common:

What is the place and role of random (occasional, chaotic) factor in the non-living and living Nature



Explanatory Gap

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

Psychology (MIND)

- ***Consciousness***

emotions:

- ***Self -appraisal***

of current/future state

- ***Subjective***

Neurophysiology (BRAIN)

- Ensemble of ***Neurons***

emotions:

- Composition of ***Neural transmitters***
- ***Objective and measurable***

Cause: dual nature =
an opposition of "matter VS spirit"

- Dual nature of **cognition:**
  - material component — belongs to the Brain
  - virtual component — belongs to the Mind

- Dual nature of INFORMATION :
  - material — carriers (in particular, Brain)
  - virtual — content (in particular, Mind)

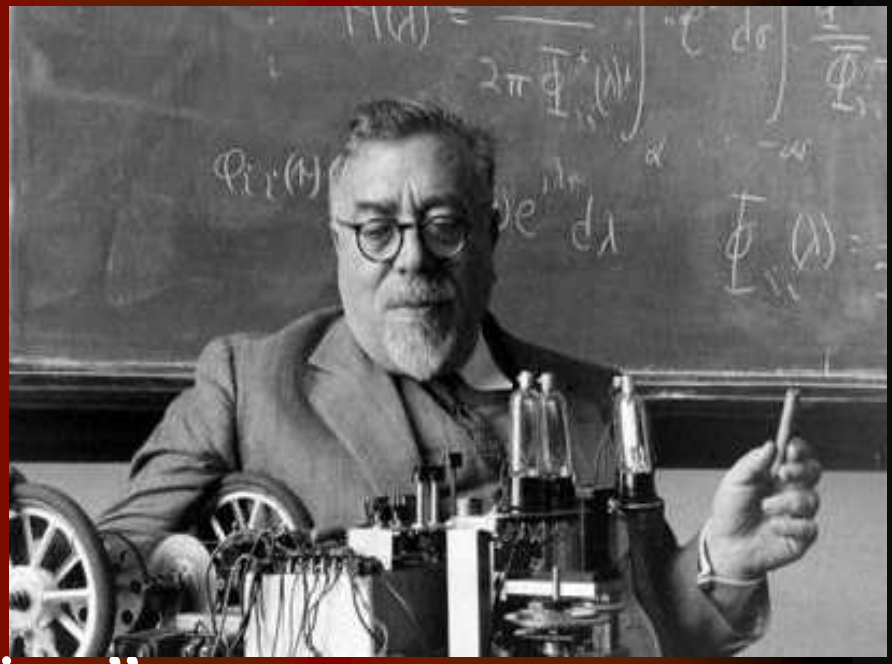
Definition of information = ?

- (General): **Inf.** is **knowledge** on an object\phenomenon\laws\... *tautology*
  - **Knowledge** = **Inf.** on object\phenomenon\laws\...
- Philosophic: reflection of Environment (?)
  - What is the mechanism?
- Cybernetic: the attribute inherent in and communicated by one of two or more alternative sequences or arrangements of something …
- ↔ Definition depends on the context
- ***The variety of definitions means itself the lack of clear one***

Definition of information = ?

- Norbert Wiener: (1948) (cybernetic)

"Information is neither matter nor energy, Information is the information"



1894—1964

Definition of information = ?

Claud Shannon:

(Communication, transmission)

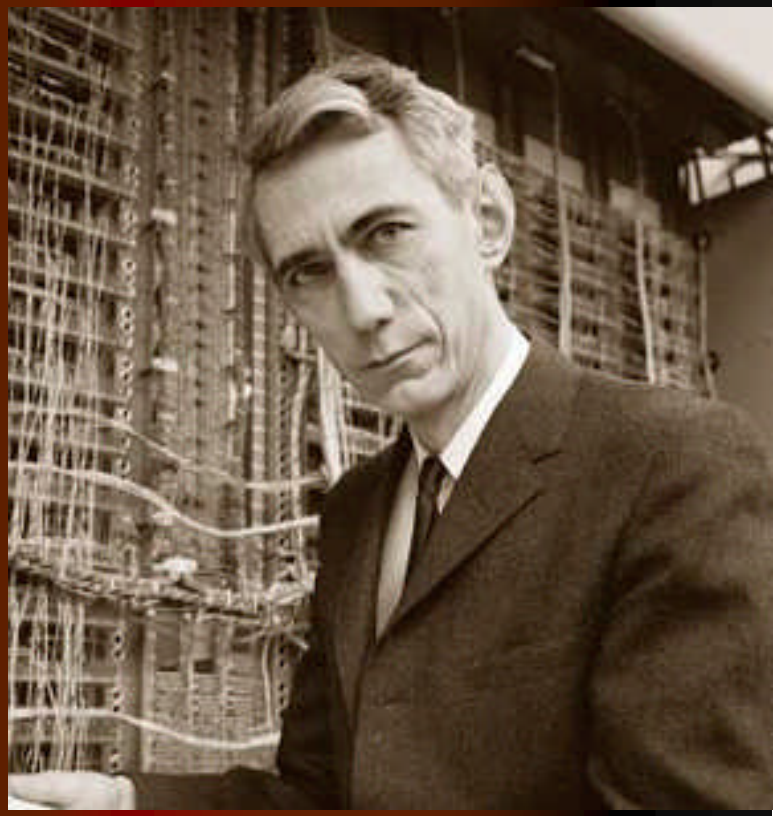
Inf. =The measure of order,

(“anti- entropy”)

- **Quantity of Inf.** :

Wi = probability of i-*th* option ; for M=2, I=1 bit

$$I = -\sum_{i=1}^{M} W_i \cdot \log_2 W_i$$



1916—2001

- **Value of Inf. =? Depends on the goal…**

  Sense of Inf. = ? Depends on the context…

Dynamical Theory of Information (DTI)

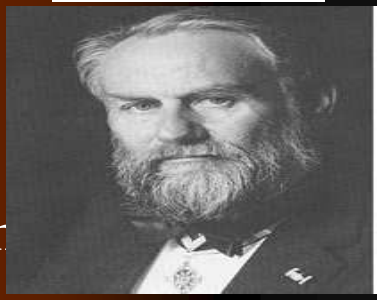
- *Elaborated by:*

- **Ilya Prigogine**, "**The End of Certainty**" (1997)

- **Herman Haken**, "**Information and Self-Organization**" A macroscopic approach to complex systems", 2000.

- **D.S. Chernavskii**, "The origin of life and thinking from the viewpoint of modern physics" , 2000; "Synergetics and Information **Dynamical Theory of Information**".2004 (in Russian).

1894--1964



1917--2001

1926--2016

- **DTI** is focused on **dynamical emergence** and **evolution of Inf.**

Definition of Inf. (!)

Henry Quastler, “The emergence of biological organization” (1964).

- **Def.: <u>Information is memorized choice of one option from several similar ones</u>**

This Def. doesn’t contradict to others, but is the most constructive one, since it puts questions:

- **WHO makes choice?**
- **HOW choice is made?**

1908--1963

WHO makes the choice?

- NATURE (**God?**) : **Objective Inf**.
  - Structure of Universe , Physical laws (energy and matter conservation, principle of minimum free energy, etc.)
  - **The best choice** (most efficient, minimum energy inputs)
- **Living objects**: **Subjective (=*conventional*) Inf**.
  - **Choice made by community (ensemble) of subjects in course of their interaction**
    - fight, competition, cooperation, convention, etc.
  - Examples: language, genetic code, alphabet, etc.
  - **NB!** This choice should not be the ***best!*** It should be ***individual for the given society***

HOW the choice is made?

- Free (random) own system' choice =

  generation of Inf.

  - ! Requires random (stochastic) conditions = "***noise***"
- Pre-determined (forced from outside) choice = ***reception of Inf. (= Supervised learning)***
- **NB!!!** These two ways are dual ***(complementary)*** → ***two subsystems are required*** for implementation of both functions

DTI: The concept of valuable Inf.

- ***Value of Inf.*** **is connected with** ***current goal***

P_0 = ***a priori*** **probability of goal hitting**

P_I = **…with given Inf.**

$$V = \log_2 \frac{P_I}{P_0}$$

- **NB: V < 0 –** ***misinformation***
- this estimation could be only *a posteriori*, one can't estimate in advance what Inf. is useful, what is misInf.

- **NB!** Inf. can seem *not valuable* for current goal, but then, it could appear very important for another goal = the concept of V.Inf. is ***not universal***

The role of random component (noise)

- In radio, technology, etc. (communications) : noise is unavoidable ***disturber (trouble)***

- **Human evolution:** ***noise is the only mechanism of adaptation to NEW unexpected environment***
  - **If You can't imagine what kind of surprise could occur, the only way – to act accidentally, chaotically**
- ***DTI: noise = spontaneous self-excitation***
- ***noise is necessary tool for generation of Inf. ,***

mandatory participant of any creative process

Concept of “Information systems”

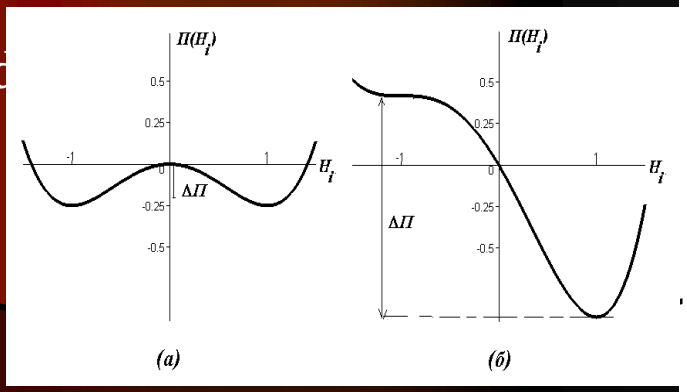
In DTI, the Inf. System = the system capable for generation and/or reception of Inf.

- ***InfSys should be multi-stationary***
- ***Unstable (chaotic) regime between stationary states***
- ***It should be able to remember chosen stationary state = able to be trained***
- ***Generation requires participation of the noise***

Example of Inf. System #1: **dynamical formal neuron**

- Formal neuron of McCalloh & Pitts: simple discrete adder
- To trace the choice' dynamics, one needs continual repres.
- Model of dynamical formal neuron
  - = Particular case of FitzHugh & Nagumo model
- Two-stationary dynamical system: active **(+1)** and passive **(-1)**_
  - Hi = dynamical variables
  - β = parameter =
    - **threshold of excitation**
    - **controls the attention: β=1 ↔determined**
  - ***Π*** = 'potential'
  - τ = character. time

$$\frac{dH_i(t)}{dt} = \frac{1}{\tau_H} \cdot [H_i + \beta_i(\{G_{(i)}^{Ra}\}) \cdot ((H_i)^2 - 1) - (H_i)^3]$$



- Enables to trace the behavior

Example of Inf. System #2: dynamical formal neuron + Hopfield-type neuroprocessor

- Distributed memory : each real object corresponds to some chain of excited neurons = "**image**"

$$\frac{dH_i(t)}{dt} = \frac{1}{\tau_i^H}\left[H_i - \beta_1(H_i^2 - 1) - H_i^3\right] + \sum_{j \neq i}^{N} \Omega_{ij} H_j + Z(t)\xi(t)$$

- **Cooperative interaction** results in protection of the image: effect of neighbors and trained connections Ω_{ij} corrects 'errors'
- **$Z(t)\xi(t)$ ↔ the 'noise' (spontaneous self-excitation)**
  - **$Z(t)$ = noise amplitude**
  - **$0<\xi(t)<1$ random** (Monte Carlo) function
- **Training principle -- depends on the goal (function)**

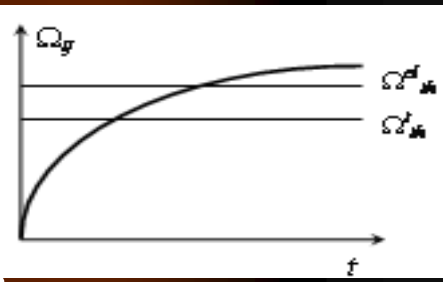
NB!

- Recording the primary (‘raw’) images actually represent the **Objective** (unconventional) Inf., since they (images) are produced as a ***response*** to the signal from ***sensory organs*** excited by presentation of some real object $\Rightarrow$ belong to the **Brain.**

Different training rules for the Hopfield-type neuroprocessor

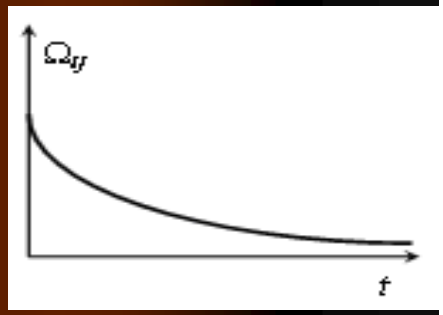
- **Recording** the ‘raw’ images = ***generation*** of Inf.
  - **Hebbian rule :** ***amplification of gen. cons.***

$$\Omega_{ij}(t) = \Omega_0 - \frac{1}{\tau_0} \int_0^t [H_i(t') + 1][H_j(t') + 1]\,dt' - \zeta(t')$$



- **Storage + processing** (***reception*** of Inf).
  - **Hopfield’s rule** = ***redundant cut-off***

$$\Omega_{ij}(t) = \Omega_0 \{1 - \frac{1}{2\tau_0} \int_0^t [1 - H_i(t')H_j(t')]\zeta(t')dt'\}$$



Irrelevant (not-needed) cons. are frozen out

- Effect of ***refinement:*** strong influence ($\Omega=\Omega_0$)
- Difficulties with recording new images

Example of **Subjective** Inf. System : procedure of image-to-symbol conversion

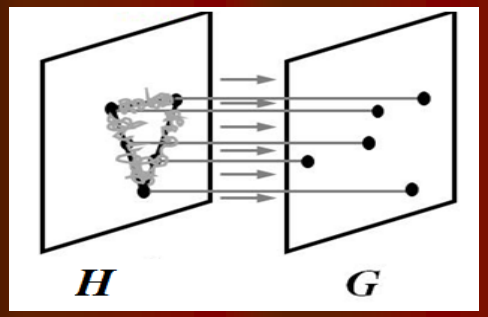
(Neuroprocessor of Grossberg' type)

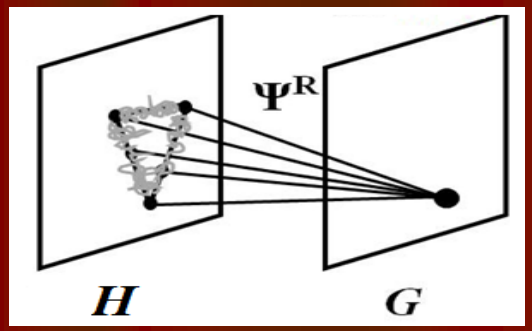
- **Competitive** interaction of dynamical formal neurons

$$\frac{dG_k(t)}{dt} = \frac{1}{\tau_k^G} \cdot \{-(\alpha_k - 1) \cdot G_i + \alpha_k \cdot G_k^2 - G_k^3\} - \sum_{l \neq k}^{n} \Gamma_{kl}(t) \cdot G_k \cdot G_l + Z_k(t)\xi$$

- G_i – neuron variable, α - parameter
  - Stationary states: **{0}** and {1};

$$\frac{d\Gamma_{kl}(t)}{dt} = \frac{\Gamma_0}{\gamma^\Gamma}\{G_k \cdot G_l \cdot (G_k - G_l)\}$$





- Ever*y but one sinks, only one (chosen occasionally!) "fires"*
- *"Winner Take All": switching the inter-plate cons. to single symbol*
- **Choice procedure is *unpredictable* ↔ individuality of Art. Sys.!**

NB!

- **Any SYMBOL belongs already to the MIND ! : it resultes *not from any sensory signal*, but from interaction (fight and *convention)* inside the given neural ensemble ↔ *individual subjective Inf. !***
  - ***Symbol represents a 'molecule of the Mind'***
- ***In DTI,* such procedure was called "the struggle of conventional Infs. "**

Definition of a cognitive process

- There is **a lack of clear and unambiguous definition** of cognitive (thinking) process, as well as of Inf.!
- ***DTI:*** *all what could be done with Inf. =*

self-organized process of recording (perception), memorization (storage), encoding, processing (recognition and forecast), protection, generation and propagation (via a language) of the

personal subjective Inf.

- ***DTI: Ultimate human goal ("sense of life") = generation, protection and propagation of personal subjective Inf.***
  - ***Propagation = proselytizing, publication, conference talk, …***

Natural-Constructive Approach (NCA)

to modeling a cognitive process

Elaborating by Chernavskaya, Chernavskii 2010—2017

Based on:

- Dynamical Theory of Information (**DTI**)
- Neurophysiology & psychology data
- Neural computing
  - Combined with nonlinear differential equation technique

Neurophysiology & psychology data

- **Neuron = complex object**
  - Hodgkin & Huxley model
  - FitzHugh-Nagumo model
  - Hebbian rule: ***learning = amplification of connections***
- **2-hemisphere specialization:**
  - **RH** ↔ «intuition», **LH** ↔«logical thinking»;
  - Goldberg, 2007 :

RH↔ learning, perception of **new Inf, creativity**

LH ↔ memorization, processing well-known Inf. (recognition, prognosis, etc.)

Example of conventional (subjective) Inf. in scientific society : **enigma of 2-hemisphere specialization**

- **1980—1990s: Specialization exists!**
  - **RH** ↔ image-emotional, intuitive thinking ??
  - **LH** ↔ symbolic logical thinking ??
  - What are the mechanisms of intuition and logic???
- **2000s: there is NO hemisphere specialization!**
  - **Main difference between frontal and ocipital zones;**
- **2010s: Specialization exists! (**Goldberg, 2007):

RH↔ **learning new , creativity = generation of *new* Inf.**

LH ↔ **memorization, processing the well-known Inf.** (recognition, prognosis, etc.) == **reception of *existing Inf.***

- **! Coincidence of neuropsychology and DTI inferences!**

Neural computing

- ***Dynamical*** formal neuron:
  - possibility of ***parametric*** coupling with symbols

- Processor = plate populated by ***n*** dynamical formal neurons;

- **2 type of processors :**

Hopfield- **type** = linear additive associative processor

each perceived object ↔ **chain** of active neurons =

image ***(distributed memory)***

Grossberg-type: nonlinear **competitive** interaction **=**

localization: ***image*** → ***symbol*****(compressed sensible inf.)**

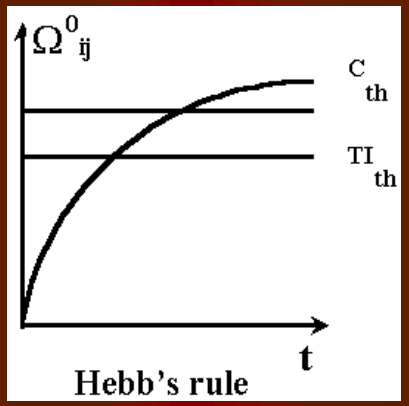
- **Information is stored in the *trained connections***

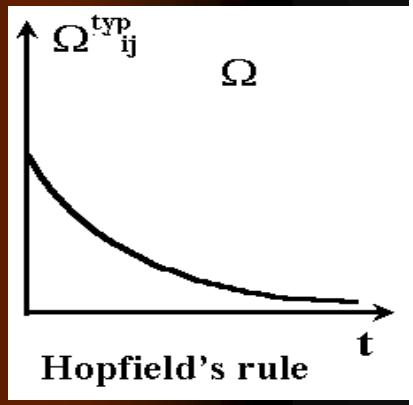
Functions of recording (perception) and storage (memorization) of "image" information :

two Hopfield-type processors, trained *differently*

- ***H^0: = "fuzzy set" : all Inf. ever perceived***

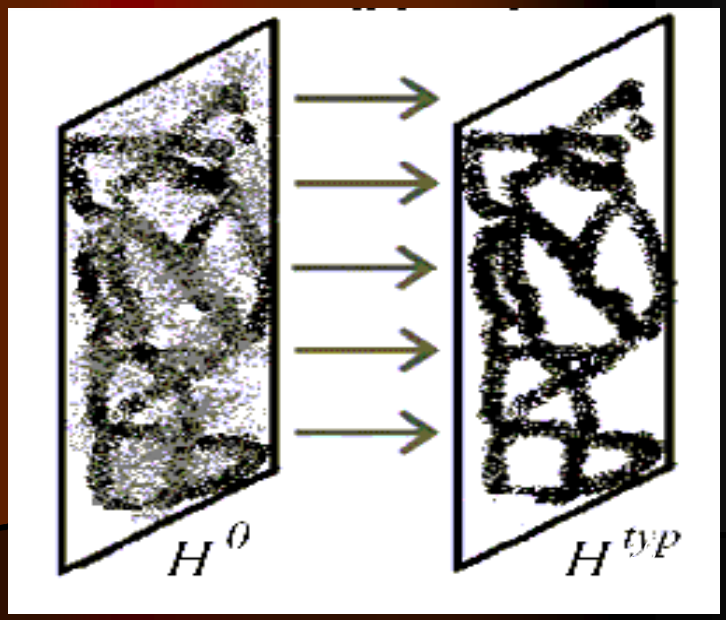
Connections Ω between active neurons become stronger (grow black) in learning process(Hebb's rule)





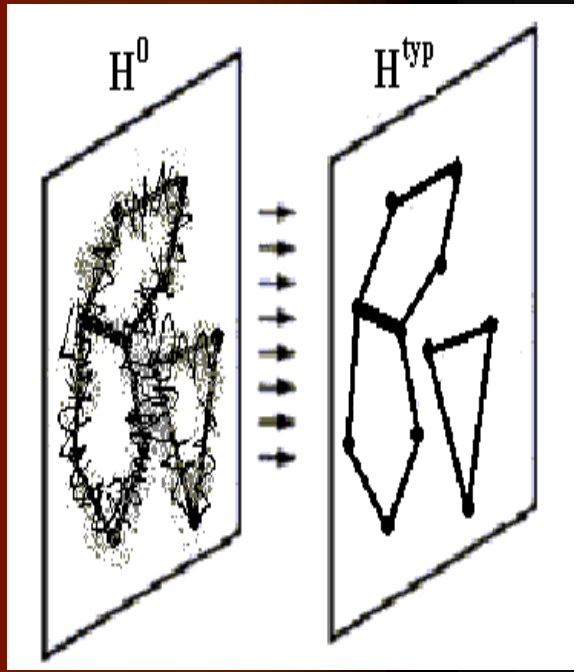
- ***H^{typ} : "Typical image" plate***
  - "**Inf**" cons. are constant, $\underline{\Omega = \Omega_0}$

  the others ***vanish:*** **"redundant cut-off" filter (Hopfield's rule)**
  - ***functions: storage, recognition***
- **"cons. blackening" principle:**
  - **"black" enough $\Omega > \Omega o$ images are transferred from *H^0 to H^{typ}***
  - **others ("grey") conenect. remain in *Ho***



Small fragment of the architecture: σ=0,1

- ***H^0 :*** each ***primary image*** involves much more neurons than typical image at ***Htyp*** : ***N0>> Ntyp***
  - ***"core"-neurons***: excited ***always*** → ***black*** cons. → **replicated** at ***H^{typ}*** → form ***symbol***
  - ***"halo"-neurons*** : weak ("grey") cons. → are ***NOT REPLICATED in LH*** = **remains in RH only**
    - **have no cons. with the symbol**
    - **= atypical (inessential) attributes**
- ***H^{typ} : typical image*** = **core** neurons (with black connections) = ***memorized***
  - ***«core neurons» = typical attributes***
- Transition from ***H_0 to H_{typ} ↔ several associative connections (grey) ARE LOST!!!*** = **remain in H_0 only!**



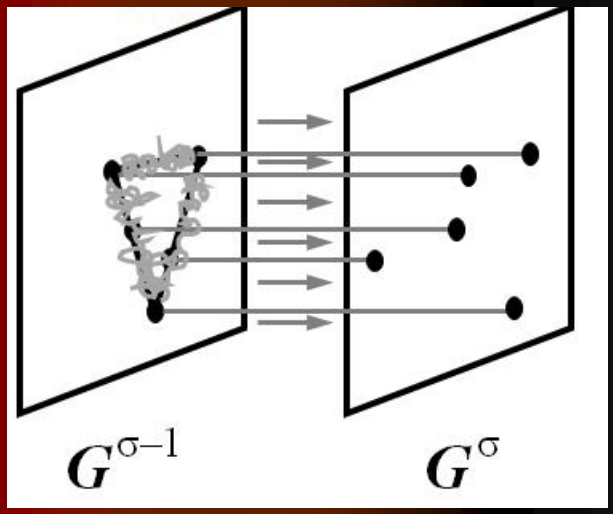
Encoding
= conversion image → symbol

- image is delivered to the plate "***G***"
- ***Competitive*** interactions:

⇒ the one ***chosen occasionally!***

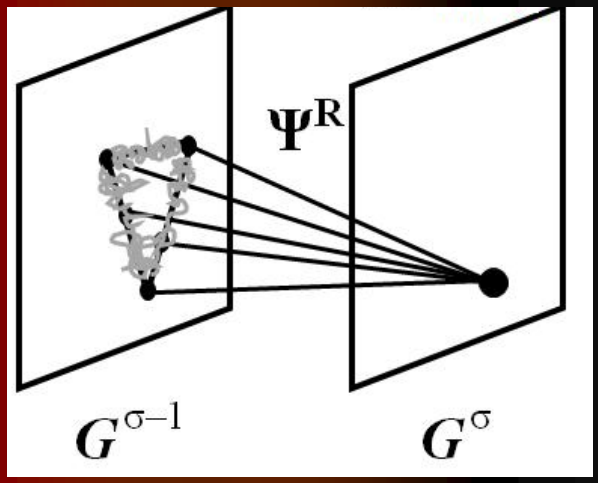
Every but one sinks, only one "fires"

this means *G → S*



- ***"Winner Take All":***

switching the inter-plate connections to the single symbol

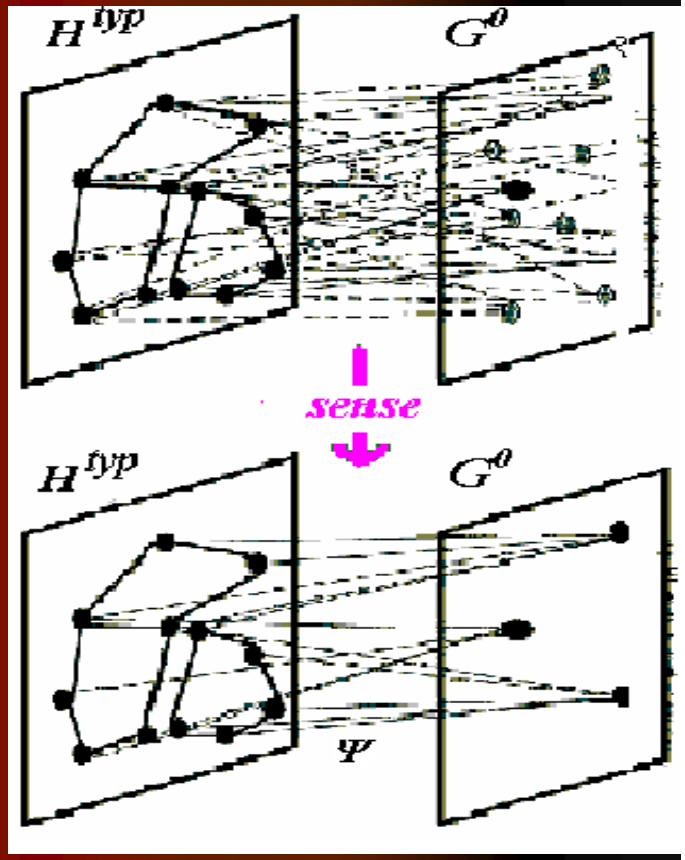


Necessity of symbol formation: internal *semantic* information

- data compression (coding)
- ***comprehension* of image Inf.:**

the very fact of G formation means that the system had interpreted the tangle of connections at $\mathbf{H^{typ}}$ as the chain that has a sense, i.e., relates to some *real object*

$\Rightarrow$ Ψ = ***semantic*** **connections**



- **Communication and propagation:**

The *words* are to be related to ***symbols***

$$\frac{dP(t)}{dt} = \frac{\Psi_0}{\tau^*} \cdot H_k \cdot G_m$$

NCA: math model for image-to-symbol procedure (neuroprocessor of quasi-Grossberg' type)

- **Competitive** interaction of dynamical formal neurons

in course of choosing process

- **parameter "learning":**

$\alpha_k \rightarrow \alpha_k(\Psi)$ **stops the competition**

- **Cooperative** ***interact. at*** $t >> \tau_\Gamma$
- **chosen** ***symbol s behaves as H-type neurons*** $\rightarrow$ **could** participates in creating '**generalized images**' **by Hebbian mechanism (=** ***image-of-symbols*****)**
- **Free G-neurons ('losers') can compete only!**

$$\frac{dG_i(t)}{dt} = \frac{1}{\tau_G}[\{-(\alpha_i - 1)\cdot G_i + \alpha_i \cdot G_i^2 - G_i^3\} -$$

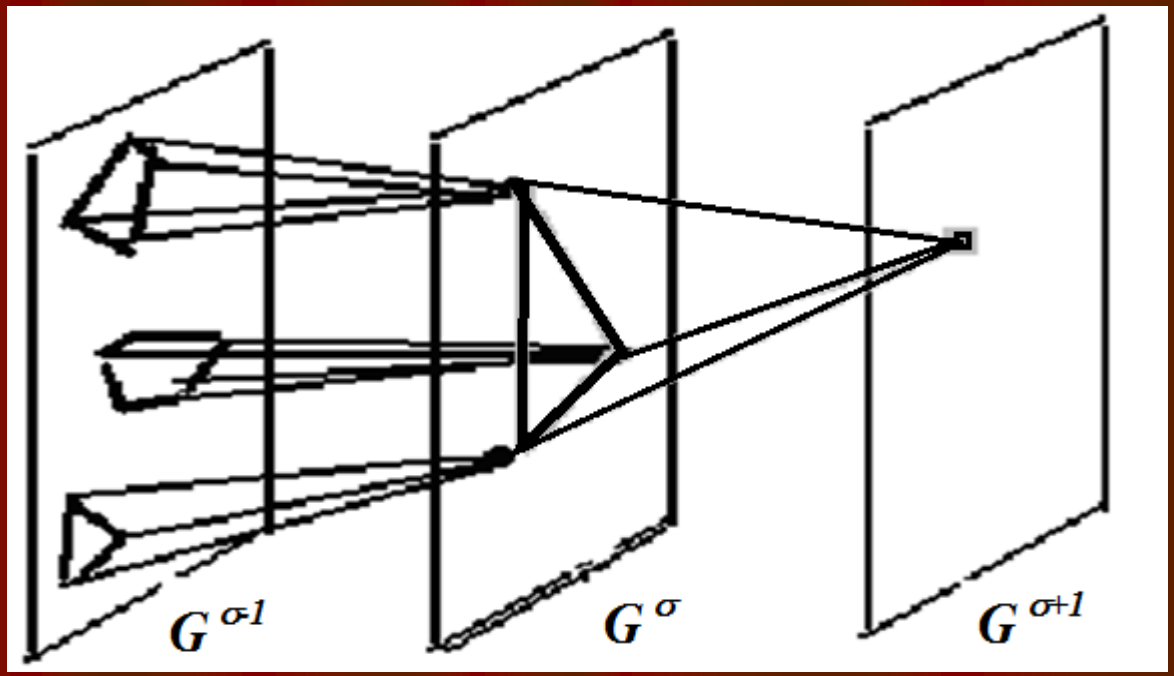
$$\theta(\Psi_0 - \Psi)\cdot \sum_{k \neq i}^{n} \Gamma_{ik} \cdot G_k \cdot G_i +$$

$$\vartheta(\Psi - \Psi_0)\cdot \sum_{k \neq i}^{n} \Omega_{ik} \cdot G_i] + Z(t)\cdot \xi(t)$$

$$\frac{d\Gamma_{ik}(t)}{dt} = -\frac{\Gamma_0}{\tau^\Gamma}\{G_i \cdot G_i(G_i - G_i)\}$$

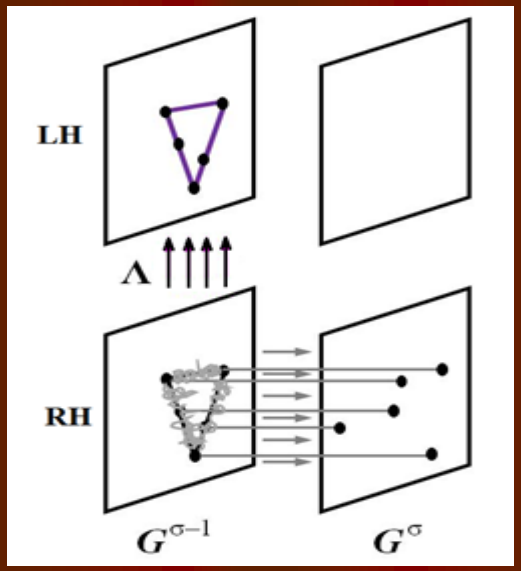
$$\frac{d\Omega^{\sigma}_{ik}(t)}{dt} = \frac{\Omega_0}{\tau^\Omega}\{G^{k\sigma}_i \cdot G^{k\sigma}_i\}$$

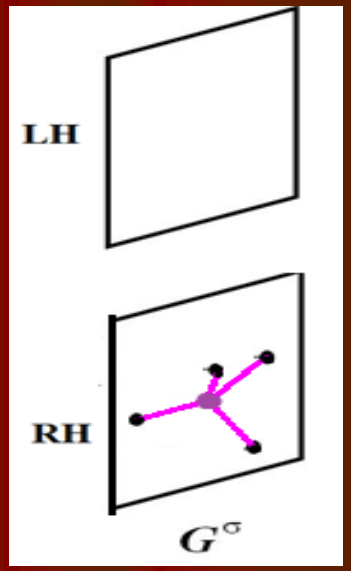
Illustration to generalized image formation

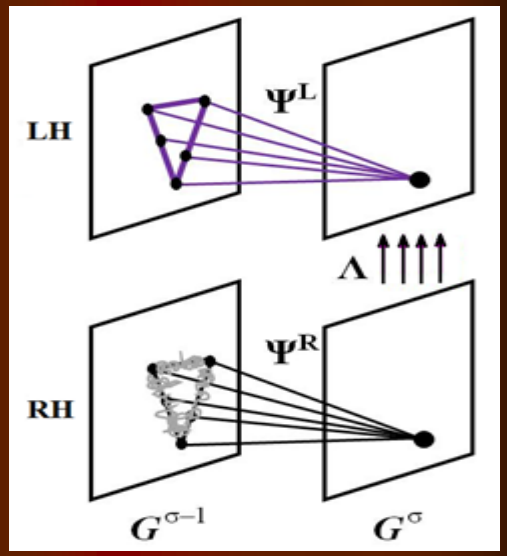


- 3 images formed at the level ***Gσ-1*** got their 3 symbols at ***Gσ***
- 3 symbols form their new 'image-of-symbols' at ***Gσ***
- '***generalized image***' gets its symbol at the level ***Gσ +1***

Elementary act of new symbol formation (learning)

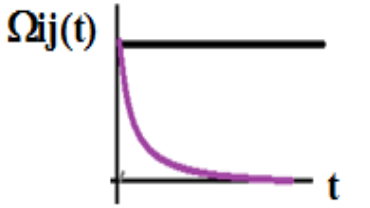




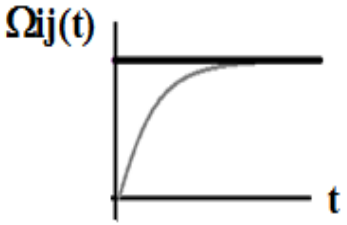


- 3 stage:
  - "image" formed in RH up to black-con. state is transferred to
    - next-level plate Gσ in RH and • to same-level plate in LH
  - Random choice of winner (=symbol) occurs in RH
  - After inter-plate (*semantic*) connections Ψ_R formed (by Hebb' mech.) the symbol is transferred to LH (Ψ_L trained by Hopfield)

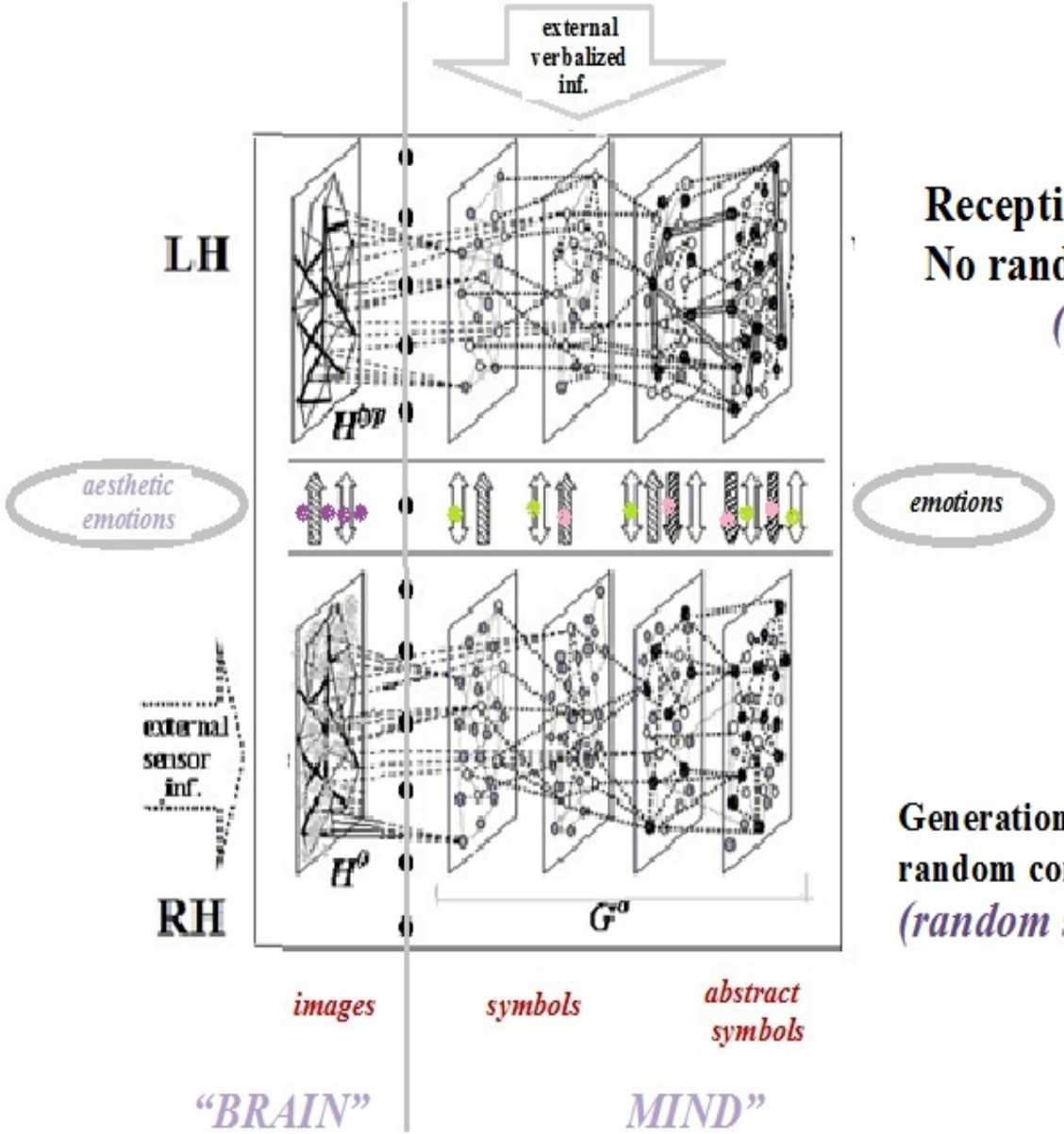
Cognitive Architecture **NCCA** (*Chernavskaya et al, BICA 2013, 2015)*



Hopfild-type training



Hebb-type training



Reception of inf.
No random factors!
(logic)

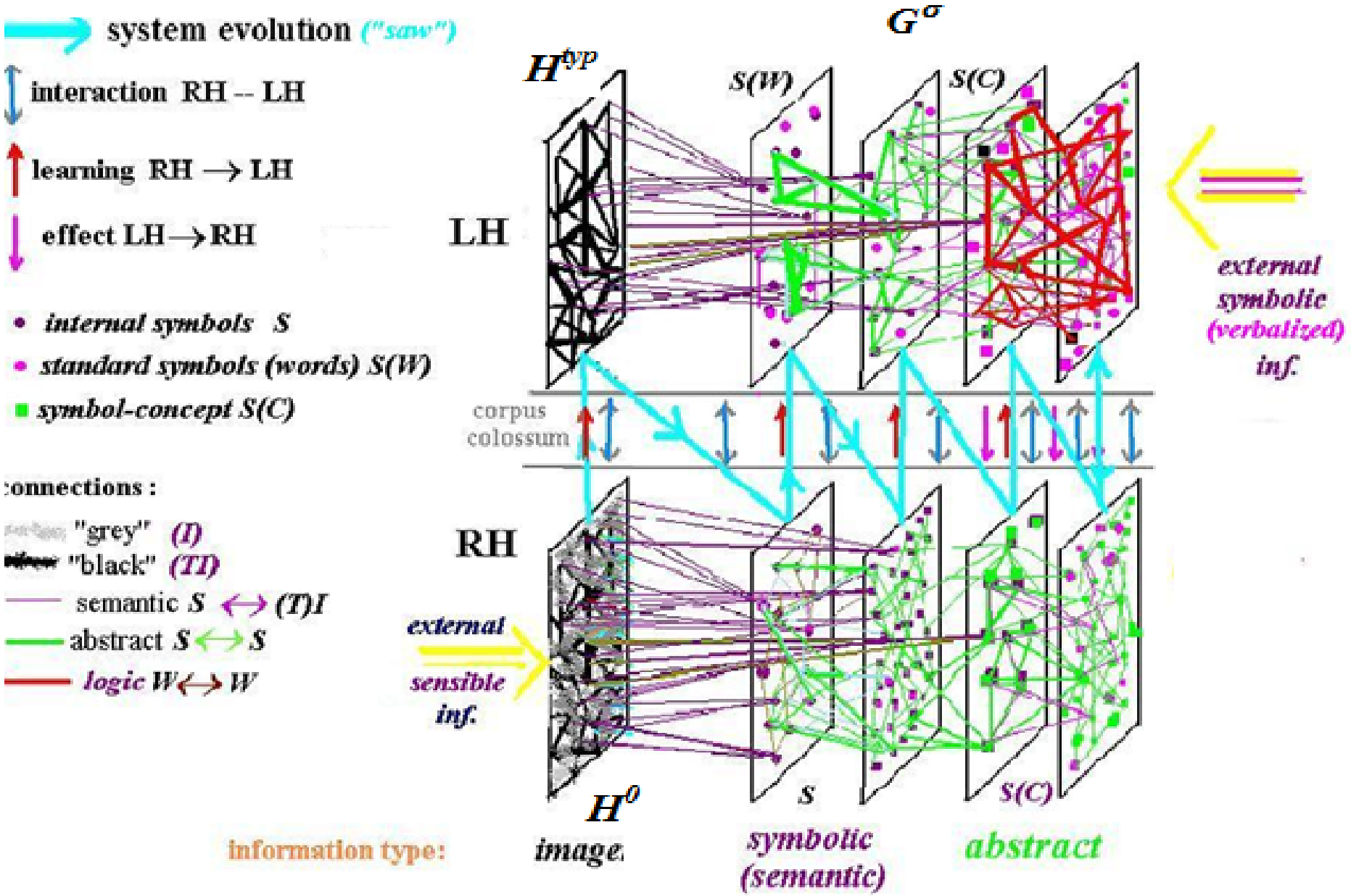
Generation of inf ↔
random component Z(t)ζ(t)
(random self-excitation)

Comments#1 to NCCA

- **2 subsystems:**
  - **RH** for **generation** (=learning) of new Inf.
  - **LH** for **reception** of already existing Inf.
- **Such specialization is provided by**
  - **Noise presents in RH only**
  - **Different training rules: Hebb' rule in RH, Hopfield' rule in LH (not the *choice*, but *selection*)**
  - **Connection-blackening principle:**

'learned' items in RH are replicated in LH = RH acts as a Supervisor for LH

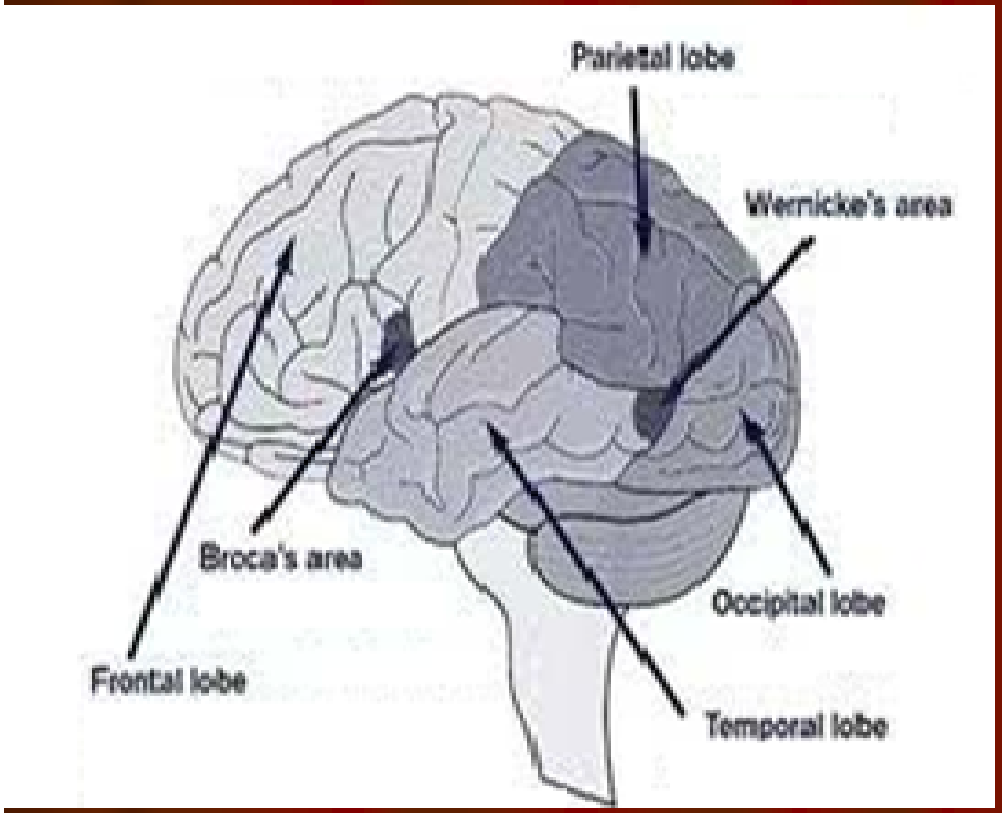
Another representation of NCCA

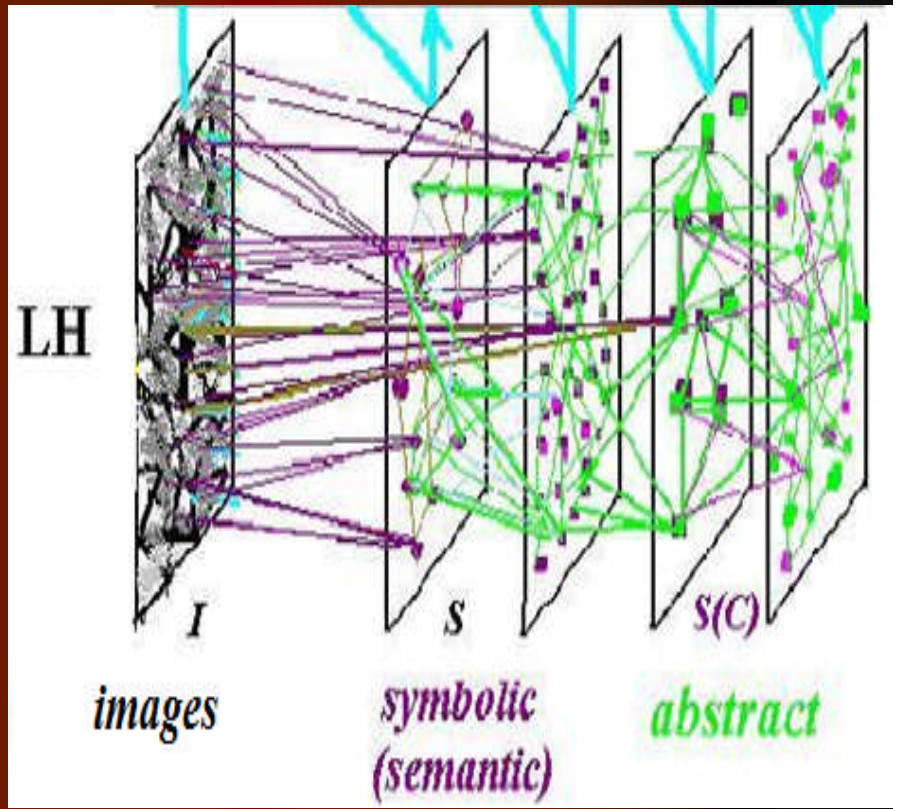


Comments#2 to NCCA

- **Complex multi-level block-hierarchical structure**
- ***Ground level = two Hopflield-type "image" plates Ho and Htyp*** **are directly connected with sensory organs ⇒ images belong to Brain**
  - **symbols belong to the Mind! produced independently of sensory sygnal**
- **System "grows": number of levels is neither fixed, nor limited, are formed "as required" successively**
- **"Scaling": the elementary learning act is "replicated" at each σ-*th* level**
  - **Generalized images** =image-of-symbols: (each **S** has "hands" and "foots")
  - with **σ increasing, Inf. becomes 'abstract'** (=no real images, but content)
  - In physics, such structure is called ***"fractal"***
- ***Symbolic verbalized information*** could be perceived outside directly by **LH (word ↔ symbol)** ***↔ semantic knowledge***
  - ***Episodic knowledge*** are formed in **RH**
- **NB!** At each step of growing, a part of Inf. recorded by weak ('grey') cons. appears to be **"lost"** = is not transferred to the next level = ***latent (hidden)*** Inf. (***individual for a given system***)

Comparison with anatomy data : the cerebral neocortex vs left hemisphere (LH)





- being posed not in parallel, but consecutively, along some surface, our NCCA represents a ***mirror reflection*** of human's cortex zones
- the system' **growth is similar to the human's *ontogenesis***

Interpretations

- ***Sub-consciousness*** = *underself*, unintentional, uncontrolled

= images recorded by "***grey" connections are***

  - ***out of control*** (connected ***with no symbol***)
  - Couldn't be formulated and verbalized
  - could be activated by ***noise*** (accidentally) only = ***insight***

- ***Intuition =*** **individual latent *(hidden)*** information
  - is *actually concentrated in* **RH**
- ***Logic*** = deduction, rational (***right***) reflection (*social mark*)

= *verbalized* stable (accepted by community) connections between *abstract symbols (symbol-concepts)*

  - presents in **LH *only***
  - **NB**: all developed abstract (symbolic) infrastructure ↔ **wisdom** (*more than logic*!)

Math & Philosophy

- Dotted line = **the border between Brain and Mind**
- Top block ↔ **'pure cognitive' relates to neocortex, Yet:**

Z(t) = model parameter , not variable

- **Λ:** the 'sewing' variable providing

the '**dialog**' between **RH** and **LH**

- **Λ=+ Λo(R →L); Λ=– Λo(L→R)**
- **Λ(t) =??? Controlled by what?**

- **Bottom block ↔ EMOTIONS :**

necessary* to provide *completeness!

- *NB: **After account for** EMOTIONS*

System is **complete** in math sense

all variables are determined via mutual interact

$$\frac{dH_i^0(t)}{dt} = \frac{1}{\tau_i^H}[\Im_H\{H, \beta_i(G^R{}_{(i)})\} + \sum_{i\neq j}^{n} \Omega_{ij}^{Hkbb} H_j^0 ;$$

$$+ \sum_k \Psi_{ik} G_k^{R,L} - \Lambda(t)\cdot H_i^{top}] + Z(t)\xi_i(t)$$

$$\frac{dH_i^{top}(t)}{dt} = \frac{1}{\tau_i^H}[\Im_H\{H, \beta_i(G^L{}_{(i)})\} +$$

$$\sum_{i\neq j}^{n} \Omega_{ij}^{Hbpf} H_j^{top} + \sum_k \Psi_{ik}\cdot G_k^{L,L} + \Lambda(t)\cdot H_i^0] ;$$

$$\frac{dG_k^{R,\sigma}}{dt} = \frac{1}{\tau_G}[\Im_G\{G_k, \alpha^{\sigma}{}_k(\{\Psi_{ik}^{R,(\sigma-1)}\}, G^{\sigma+\nu})\} +$$

$$+ \hat{Y}\{G_k^{R,\sigma}, G_i^{R,(\sigma+\nu)}\} - \Lambda(t)\cdot G_k^{L,\sigma}] + Z(t)\cdot\xi(t)$$

$$\frac{dG_k^{L,\sigma}}{dt} = \frac{1}{\tau_G}[\Im_G\{G_k, \alpha^{\sigma}{}_k(\{\Psi_k^{L,(\sigma-1)}\}, G^{L,(\sigma+\nu)})\} +$$

$$+ \hat{Y}\{G_k^{L,\sigma}, G_i^{L,(\sigma+\nu)}\} + \Lambda(t)\cdot G_k^{R,\sigma}]$$

$$\frac{dZ(t)}{dt} = \frac{1}{\tau^Z}\cdot[a_{Z\mu}\cdot\mu + a_{ZZ}\cdot(Z - Z_0) + F_Z(\mu, Z) ;$$

$$X\{\mu, G_k^{R,\sigma}\} + \{\chi\cdot(D - \omega\cdot dD/dt) - \eta\cdot\delta(t - t_{D=0})\}]$$

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

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

Representation of emotions in NCA

- Formalization of Emotions (recall Explanatory Gap)
  - "**Brain**": Composition of **neurotransmitters**
    - **$\mu(t)$ = "effective compound" = stimulants – inhibitors**
  - **"Mind": Self-appraisal** characterizes *whole system* = **?**
  - **Noise: Z(t) best candidate to "feel" the state of a system**
  - **Classification** of Emotions:
    - *Pragmatic E.*: Achieving **a goal**: **Positive** vs **Negative**

      But no direct relation with stimulants/inhibitor !
    - **DTI**: **Fixing** (for recept.) vs **Impulsive** (for generat.) $\leftrightarrow$ **Z(t)!!**

Representation of emotions in NCA #2

- **Main hypothesis of** NCA:
  - **Z(t) acts as an analogy to '*emotional temperature*'**
  - **Emotional manifestation ↔ *derivative* dZ(t)/dt**
    - **NB: derivative could be either (+) or (-) !**
  - **Mutual interaction of Z(t) and μ(t) tends to provide the *homeostasis* (normal functioning regime)**
- **"Emotional" characteristics:**
  - Zo = **normal value** ("at rest") ↔ ***individual "temperament"***
  - ΔZ = **noise excess:** *reflects* ***generating/creative activity***
  - **dZ(t)/dt abs. value:** *a lot of regimes* **↔ variety of *E. shades***

Arguments

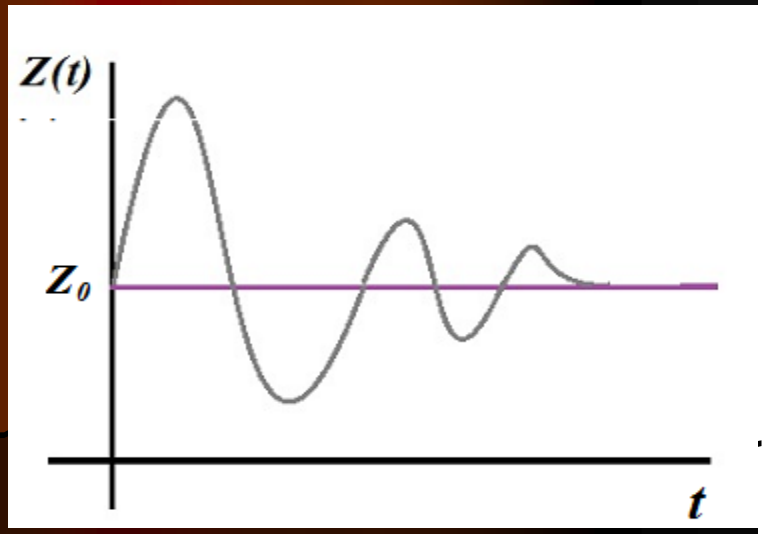
- **Role of unexpectedness** :
  - Incorrect/undone prognosis always calls for negative E.
    - (*anxiety*, *nervousness*, *irritability*, *etc.*)
  - Requires additional "hormonal" resources (stimulants)
  - ***Necessity*** of **RH** activation: **$\Lambda = -\Lambda(L \rightarrow R)$**
- **Moment of solution (comprehension)= "*skill*"**
  - Moment "***aha***" $\leftrightarrow$ ***joy!*** (*relaxation, satisfaction, etc.*)
  - Activation of **LH** : **$\Lambda = \Lambda(R \rightarrow L)$, RH** get possibility **to be "*at rest*"**

E. in problem solving#1: recognition

Solving in ***Ho***, ***Htyp*** plates ; **D≡ discrepancy Ext. Obj vs Typ. Im.**

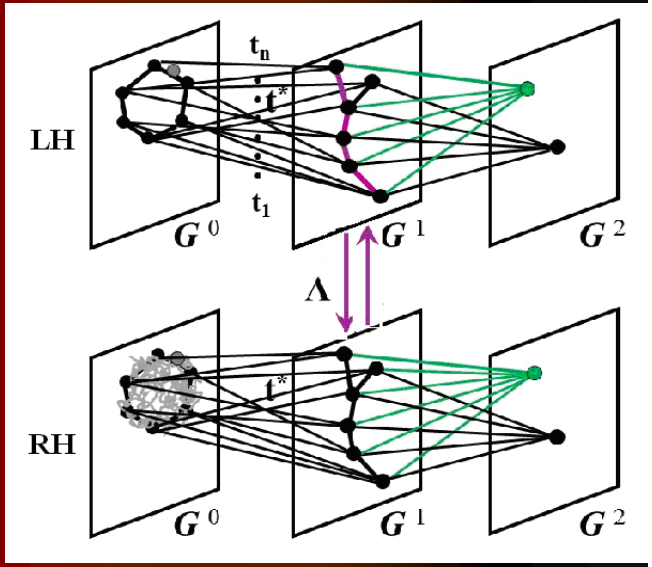
- Ext. Obj.= image (D=0) : ***Htyp*** → ***S***
  - **(Λ=0, dZ/dt=0)**
- Ext Obj. ≈image (D≠0):
  - Recurrent “loop”
- Ext. Obj. ≠ image (D>>0)
  - **New** typical image in **RH**
  - **trans to LH (Htyp) → *new S***
  - ***Positive Emo.! dZ/dt <0***

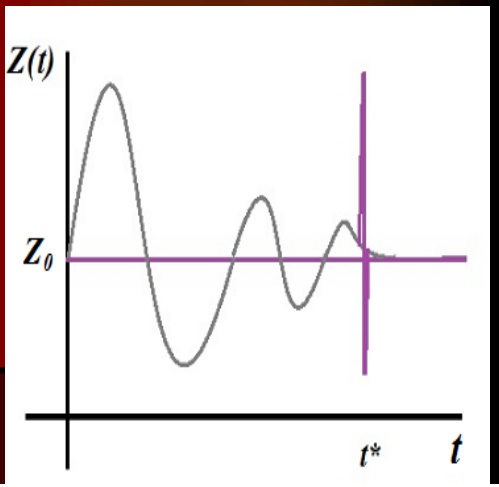
$$\Rightarrow H^{typ}(\mathrm{LH}) \rightarrow G^{L,1}(\mathrm{LH})$$
$$\uparrow \Lambda^{R\rightarrow L} \qquad \downarrow \Lambda^{L\rightarrow R}$$
$$\Rightarrow H^{0}(\mathrm{RH}) \leftarrow G^{R,1}(\mathrm{RH})$$



E. in problem solving#2: prognosis

- "Recognition" of **time-dependent** process
- Is solving in *G*-plates
- 'Sense of humor':
  - Special case of incorrect prognosis when examinee process seems familiar up to some moment *t**,
  - the next bulk of information appears to be **surprising** but **still well-known.**
  - This switches the recognition process to the other, also familiar pattern.
  - **Specific reaction:** sharp up-down jump ("spike") in the noise amplitude, which could be interpreted as human ***laughter***





Aesthetic Emotions: (general considerations)

- **Pragmatic E.** ↔ definite ***goal (e.g., to survive)***
  - ***Have rational (!) reasons***
- **Aesthetic E. (*AE*)** = perception of Art, Music, Literature, Nature phenomena
  - Have **no rational reasons**! = ***Mystery #1***
  - "physical" reasons (freq. spectra, resonance, etc.) – **NO!**
    - **(Literature??) *empathy* ↔ *personal experience !***
  - **Individual** and **sincere** ↔ ***"goosebumps" (meaasur.)***
- ***Possible*** **reasons could be: (cultural context) +**
  - **childish (?) vague impressions;**
  - **personal *fuzzy* (or "indirect") *associations*;**
  - **influence of cultural mini-media (family, messmates, etc.).**

Mystery #2: Chef-d'oeuvre = ???

- If *AE* are **quite individual**, than **WHY** some piece of Art are treated as **CHEF-D'OEUVRE ???** Why they are **ingenious?**
  - **Control by society (FASHION) : *temptation*: ↔ ChD is the result of *social convention* expressed in $ equivalent** but: **ONLY ???**
- **But WHAT is in the *ChD* itself that actually makes it ingenious?**
  - **What does differ Mozart (ingenious creations) from Saliery (i.e., solid professional work)?**

WELCOM to EMACOS (Feb 21, 10.30)

Summary: main distinguishing points of NCA

- ***continual*** representations of formal neuron (dif. eqs);
  - To trace the dynamics of single neuron (how it makes desicion)
  - Parametric modification of "trained" neurons (get some skill)
- splitting the whole system into ***two subsystems*** (**RH** and **LH**) – for ***generation and perception*** of information, respectively = is in entire agreement with the inferences of [Goldberg, 2009].
- account for a ***random component*** ("**noise**"), presented in **RH** only;
- ***instability*** of the image-to-symbol conversion procedure that leads to unpredictable patterns. This very factor secures the *individuality* of an artificial cognitive system;
- interpretation of emotions as the **noise-amplitude derivative** *dZ/dt*; this value should also control the cross-subsystem connections
- ***different training principles*** in **RH** and **LH** $\leftrightarrow$ particular hemisphere specialization: processing **new** information requires Hebbian rule; processing (**recognition**) of the **well-known** inf. needs Hopfield's rule

Conclusions

- **DTI+ NCA** provides the possibility to interpret and reproduce
  - **Intuition & logic**
  - **Individuality (instability of S-formation procedure)**
  - **Emotional manifestations+ sense of humor**
- NCA and AI : **AI ↔ LH** (“*created*” due to **RH)**
- How to **“jump” over Explanatory Gap?**
  - **Conventional (Subjective) Inf.! The process of image-to-symbol conversion !**

This inference results directly from DTI

Thanks for attention

List of references

- Bishop C.M. (2007). *Pattern Recognition and Machine Learning*. Springer
- Bongard M.M. (1970). *Pattern Recognition*, New York: Spartan Books.
- Chernavskaya O.D., Chernavskii D.S., Nikitin A.P. (2009) concept of intuitive and logical in neurocomputing. *Biophysics, 54*, 727-735.
- Chernavskaya O.D., et al. (2011). On the role of concepts “image” and “symbol” in the neurocomputing modeling the thinking system. *Izvestia vuzov. Applied Nonlinear Dynamics, 19*, 21-35. (in Russian).
- Chernavskaya O.D. et al. (2012). The Concepts of Intuition and Logic within the Frame of Cognitive Process Modeling. *Biologically Inspired Cognitive Architectures 2012. Proceedings of the Third Annual Meeting of the BICA Society* (A. Chella, R.Pirrone, R.
  Sorbello, K.R. Johannsdottir, Eds), 105-107.
- Chernavskii D.S. (2000). The origin of life and thinking from the viewpoint of modern physics. *Physics-Uspekhi, 43*, 151-176.
- Chernavskii D.S. (2004). *Synergetics and Information. Dynamical Theory of Information*. Moscow, URSS (in Russian).
- Chernavskii D.S., et. al. (2011). *Mathematical model of image localization processor*, LPI Preprints, No.9 (in Russian)
- Deacon T.W. (2011). *Incomplete Nature: How Mind Emerged from Nature*. New York WW Norton&Co.
- Fitz Hugh R. (1961). Impulses and physiological states in theoretical models of nerve membrane. *Biophys. J., 1*, 445.
- Goldberg E. (2009). *The new executive brain*. Oxford University Press.
- Grossberg S. (1982). *Studies of Mind and Brain*. Boston: Riedel.
- Grossberg S. (1987). *The adaptive brain*. Elsevier.
- Haken H. (2000). *Information and Self-Organization: A macroscopic approach to complex systems*. Springer.
- Haykin S.S. (2009) *Neural Networks and Learning Machines.* Prentice Hall.
- Hebb D. O. (1949). *The organization of behavior*. John Wiley & Sons.

- Hodgkin A.L. and Huxley A.F. (1952). A quantitative description of membrane current and its application to conduction and excitation in nerve. *The Journal of physiology*, 117, 500–544.
- Hopfield J.J. (1982). Neural networks and physical systems with emergent collective computational abilities. *Proceedings of the National Academy of Sciences*, 79, 2554.
- Izhikevich E.M. (2007). *Dynamical systems in neuroscience: the geometry of excitability and bursting*. MIT Press.
- Izhikevich E.M. and Edelman G.M. (2008) Large-scale model of mammalian thalamocortical systems. In: *Proceedings of the national academy of sciences,* V. 105, № 9.
- Kharkevich A.A. (1960). On the Value of Information. *Problemy kibernitik*i, 4, 53–57. (in Russian).
- Kohonen T. (2001). *Self-Organizing Maps*. Springer.
- Laird J.E. (2012). *The Soar cognitive architecture*. MIT Press.
- McCulloch W.S., Pitts W. (1943). A Logical Calculus of the Ideas Immanent in Nervous Activity. *Bulletin of Mathematical Biophysics*, 5, 115.
- Muller B. and Reinhardt J. (1990). *Neural networks*. Springer Verlag.
- Nagumo J., Arimoto S., Yashizawa S. (1962). An active pulse transmission line simulating nerve axon. *Proc. IRE, 50,* 2062.
- Penrose R. (1989). *Shadows of the Mind*. Oxford University Press.
- Quastler H. (1964). *The emergence of biological organization*. New Haven: Yale University Press.
- Red'ko V.G. (2012) Principles of functioning of autonomous agent-physicist. Proc. of the Third Annual Meeting of the BICA Society, (A. Chella, R.Pirrone, R. Sorbello, K.R. Johannsdottir, Eds). Springer, 255-256.
- Samsonovich A. (2007). Bringing consciousness to cognitive neuroscience: a computational perspective. *Journal of Integrated Design and Process Science, 11,* 19-30.
- Shannon C. (1963). *The mathematical theory of communication*. Univ. of Illinois Press.
- Solso R. (1998) Cognitive psychology (5th ed.). Needham Heights, MA: Allyn and Bacon.
- Turing A.M. (1950). Computing machinery and intelligence. *Mind*, 59, 433-460.