Some system comments on the work of the brain hemispheres

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Abstract: Even though it is known from physiology that despite the strong separation of the functions of the brain hemispheres, they do not work completely independently, we first suggest a simple physical and some "system" arguments for the mutual dependence of the hemispheres, which may be of some heuristic interest. An unusual point is that the *distinction* between the functions of the hemispheres is methodologically represented by two different (also in the frequency sense) "inputs" that the brain receives from the external world. This is a simplification that allows us to: (a) formulate the problem of frequency relations along the thinking process, and to thus come to the conclusion that for treatment of the information, brain must *generate* some electrical signals/processes; (b) consider the (unhealthy) case when the input can cause overburden of the right hemisphere. Regarding the latter, we see *agreement between a signal and a system* to be a natural requirement also in the biological case, and, in general, we see "system approach to biology" not just as something auxiliary, e.g., electrical modeling of a cell, but as an independent research tool, and believe that the suggested phenomenological point of view may be a motivating supplement to a standard biological consideration.

1. Introduction

A heuristic pre-phrase to all what follows may be the introductory words by Riemann about "synthetic" and "analytic" methods in his classical study of hearing [1].

First of all, Riemann notes the distinction between the structural character of the synthetic method and the empirical observations that defines the nature of the analytic method. Then, Riemann argues that no *real study* can be limited by one of the methods, and one method initiates the other, i.e. the methods are *mutually connected* in a real study.

This comparison in [1] of the two different methodologies, united in their relation to the study of real problems, is a part of the motivation for the discussion of the *distinction and union* in the operation of the brain hemispheres, which we are occupied with in the present work, even though one can associate today the "*analytical method*" more with an input-output map of a block-scheme than with immediate fitting to the observations some analytical model equations.

Applying system outlook, we somewhat unusually use the concept of "input" which lets us observe, at the very start, that a simple physical argument explains interaction of the brain hemispheres *just because their basic informational functions are different.* Then, some frequency relations are considered, and it is used that some

conclusions re a nonlinear system may be obtained by studying of a linear time-variant model. The most important conclusion here is that in the thinking process the treatment of the input signals must involve some internal brain generators of auxiliary time functions (processes), i.e. treatment of the information by the brain cannot be the matter of only some logical algorithms.

Finally, motivated by some its external behavioral exhibitions, we consider the serious problem of fitting by the input "signal", given by the external world, the brain system, especially the very important case of overburden of the right hemisphere. This reference on the behavioral (even social) topic, stressing *importance and urgency* of the study of the brain, is legitimized here, while the "system thinking" which is naturally concerned with fitting by a signal the given system, most well represents the "bridging" nature of the system outlook.

The brain is purposed to understand the external world. This world is composed of physical nature and human society with its psychology, and it is our "system responsibility" that the signals coming from the society be proper.

2. On the actions of the hemispheres

2.1. The basic functions of the brain hemispheres

As is well known (e.g. [2-4]), the functions of the human brain hemispheres are very distinct. The right hemisphere is responsible for our creativity (spiritual education), while the left one – for some more primitive features, like simple counting and feeling time and distance intervals. That is, from the positions of human moral and behavior, one can say that the right hemisphere is responsible for "important things", while the left – for "urgent things". This classification already points at different *rates* of the processes in the hemispheres, -- an important fact for what follows.

Of course, when speaking about the distinction between the functions of the hemispheres, we mean the basic "defined" functions, which does not contradict the necessary for thinking interaction of the hemispheres.

2.2. The "inputs"

Adopting a system point of view, we represent the fact of the informational distinction of the hemispheres' operations by saying that the hemispheres (and the brain seen as a whole) have two essentially different, independent *inputs*. Of course, nature does not create different physical signals for the different hemispheres. There is some preliminary classification (treatment) of information, in which the action of the eye retina, and other "smart sensors" have to be more directly associated with the input for the *left hemisphere*. We cannot consider this natural "multiplexing" of the input information here; what is more important for us, however, is that human society (and not physical nature!) may create excessive informational burden for the brain so that the right hemisphere will be inevitably overloaded. As was already noted, and will be touched on in more detail in Section 6, the latter can have bad consequences for the development of the hemispheres, dangerously influencing human behavior.

It is very suitable for development the argument of Section 3 and the whole line of thought to schematically present the different functions of the hemispheres, using different "inputs".

3. The argument of electrical potential providing the mutual dependence of the hemisphere's operations

Since the physical activity of both of the hemispheres is electrical, we can speak about somewhat smoothed distribution of electrical potential $\varphi(\vec{r})$ over the whole brain. This natural possibility (necessity), together with the assumed independence of the input signals, makes it possible to apply an elementary argument that is very similar to the argument appearing in Fourier method of separation of variables, when linear PDE-s are solved. The non-essential distinction is that here the separated independent variables are not spatial, but some functional/logical ones.

Let is denote the (somewhat averaged) potentials, $\varphi_{right}(\vec{r})$ and $\varphi_{left}(\vec{r})$, of the hemispheres as:

$$f_r(A) = \varphi_{right}(\vec{r})$$

where '*A*' denotes the "intellectual input(s)" of the right hemisphere, and as

$$f_l(B) = \varphi_{left}(\vec{r})$$

where '*B*' denotes the "simple-activity input(s)" of the left hemisphere.

Since the hemispheres are physically connected, no significant distinction between the averaged potential of the right and left hemispheres is permitted, i.e.

$$f_r(A) \approx f_l(B)\,. \qquad (1)$$

The mutual independence of '*A*' and '*B*' obviously makes equation (1) to be the requirement of *constancy* of each of the side. However, this requirement is unacceptable, because there is no physical reason for a certain value of the common potential, i.e. this value cannot be calculated.

This non-physical result forces us to conclude that the hemispheres cannot work completely independently, i.e. the informational variables/arguments, *A* and *B*, have to appear in each side of (1).

3.1. A comment re material compactness, i.e. physiology (thinking cannot be defined on an abstract set)

The role of the physical closeness of objects in the above proof of the mutual dependence of the hemispheres already touches on physiology, because without seeing the role of the closeness for performing informational operations, it is even impossible to understand why we need two distinct hemispheres. Indeed, such construction of brain does not increase its mechanical strength, and if the physiological necessity were not associated with the informational treatment, the different logical functions would not need be so macroscopically (i.e. just between the hemispheres) separated in the brain. *Each* set of the responses, e.g. that which is associated with the right hemisphere, might belong to *several mutually separated*, relatively much smaller parts of the brain. As an informal comparison, -- in the parliament of your state all those who support the "right" ideology need not sit at the right side of the hall. It even seems that the two-hemisphere structure of brain,

together with the necessity of the spatial closeness for the electrical processes, *encourages* the functional separation.

4. On the interaction of the hemispheres

4.1. The roles of thinking and memory

According to the above conclusions, there *must be* some interaction between the hemispheres, which would cause the assumed $f_r(A)$ to be, in fact, some

$$f_r(A+\hat{T}B),$$

and the assumed $f_l(B)$ to be some

$$f_l(B+\hat{T}A),$$

where $\hat{T}$ is some operator of interactions of the hemispheres, which thus causes, in some physical way, the "inputs" of the right hemisphere to influence the left hemisphere, and conversely.

Remark 1: Supporting the argument of Section 3, it is very easy to find examples (think, e.g. how to help one get married) showing that without the combining of the basic functional features of the hemispheres, -- those "important" and those "urgent", -- we would be absolutely helpless as re *making decisions which is the main purpose of thinking*. That is, for the hemispheres working independently any serious thinking would be avoided and no developed brain needed. It has to be stressed that the basic functional distinction between the hemispheres, which is associated with the different characters of *A* and *B*, is *not* doubted here. However, the *thinking*, necessarily associated with operator $\hat{T}$, requires involvement of the "inputs" of both kinds for analysis of real objects/problems, similarly to the involvement of both the (itself well distinguishable) synthetic and the analytic methods in the analysis of real problems, stressed by Riemann.

We observe, furthermore, that for *each* hemisphere a good *memory* is needed, since estimation of time and space intervals cannot be done without comparison with some such known (i.e. held, as some image, in the memory) intervals, and any moral problem also requires analysis of the past. Thus, the hemispheres must be functionally connected if only via the use of memory. However, memory is an organic part of thinking, which is well seen, e.g., via the example of old people who after a stroke always exhibit *both* strong reduction of memory and strong reduction of the thinking ability. That the movement actions of such people, which we associate with the functions of left hemisphere, are also strongly reduced, can be finally associated with the damage caused to the memory by the stroke. *The role of memory must be central in any brain activity relevant to thinking.*

4.2 Thinking and the frequency parameters

Regarding the interaction of the hemispheres, an immediate "system" point is that the thinking, having some *typical* frequency of its generation, involves the operations of the hemispheres, which (inherently) occur at *very different typical (basic)* frequencies of the brain responses to *A* and *B*. Of course, some processes in the *interacting* hemispheres should be of the same frequency range, but, according to the

very definitions of the inputs in Section 2.2, we have to start from the different typical frequencies, related to the hemispheres *per se*, seen as working independently.

Remark 2: For such separate consideration of the hemisphere responses, we observe, for instance, that an on-line-decision of the ping-pong playing, associated with the estimations by left hemisphere of time and space intervals, is obtained much quicker than, e.g., understanding (mainly by right hemisphere) what is clear conscience.

Denoting the typical frequencies of the right hemisphere as ω_A, and of the left as ω_B, let us consider that the frequency of usual thinking, denoted as ω_C, is different from ω_A and ω_B.

The very existence of the new frequency ω_C, which is not that of any input, requires the describing equations to be *either nonlinear or linear time variant* (LTV).

For the LTV case, the changing in time parameters/coefficients of equations should have some *known* frequency features. (Think, e.g., about a time-dependent coefficient of a forced Mathieu equation.) For this case, we can consider the logical scheme of the brain as a *multi-port* having some controls of the coefficients of the equations (or structural parameters of some schemes) as the additional (internal for the brain) *known*, auxiliary non-constant inputs. At this point, we cannot immediately exclude the LTV case, and the obvious fact that it requires existence of some internal generator(s) of the brain, is very important.

One can assume that nonlinear modeling would be more adequate (flexible), as re the transform of the frequency range, however the LTV systems can be close in their frequency features to nonlinear systems. Moreover, as is explained in Section 5, making the coefficients of the equations (or the structural parameters of the schemes) controlled not by the internal generators, but by the input time functions, we pass on from an LTV to a nonlinear system.

The schematic Fig. 1 fixes the argument, without showing any auxiliary internal generator, as it is developed in the above.

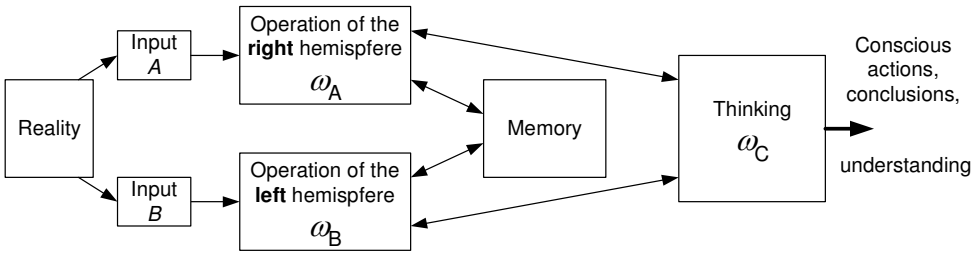

Fig. 1: The scheme (without the auxiliary internal generator shown) to which we came. That the "inputs" *A* and *B* are different, *schematically* expresses the fact that the functions of the hemispheres are different. The thinking requires the actions of the hemispheres to be mutually connected. Memory is an organic part of the thinking, and each of the hemispheres must use the memory. Creation of the frequency of generation of "thinking", ω_C, using the very *different* frequencies of the operation of the different hemispheres, ω_A and ω_B, remains a constructive point for further research. Additional (morality) comment is that the input "Reality" is partly created by us (the society), which is a very responsible matter.

Observe that in view of the presumable nonlinearity of the system, the map $\{\omega_A, \omega_B\} \to \omega_C$ can include $\omega_A + \omega_B$ (as for multiplication of sinuses), which shows that the thinking can include very quick components.

5. The inputs of a system (or a subsystem) and the system's nonlinearity

The general advantage of the system approach is [5] that one can pay more attention to the definition of a system, which includes definition of its inputs (more generally, its *ports*). This gives a somewhat unexpected flexibility in the transfer from LTV to nonlinear systems and back, so that one can even speak about different linear and nonlinear "versions" of a possible brain model. This transfer from an LTV to a nonlinear version of a system (or a subsystem) has to be understood, first of all, as regards the equations.

Thus, for instance, the equation for the unknown function $y(t)$:

$$(\hat{L}y)(t) + g(t)\,y(t) = g_{in}(t) \qquad (2)$$

in which: $\hat{L}[\cdot]$ is any linear operator, $g(t)$ is a prescribed time function, and $g_{in}(t)$ is the input function, -- is a linear (LTV) equation, since the (just for brevity, consider only the scaling) test of linearity:

$$g_{in}(t) \to k g_{in}(t)\,,$$

with a constant k, obviously leads in (2) to

$$y(t) \to k y(t)$$

i.e. successfully passes. However, the equation with differently applied input:

$$(\hat{L}y)(t) + g_{in}(t)\,y(t) = g(t)\,,$$

and its important particular case:

$$(\hat{L}y)(t) + g_{in}(t)\,y(t) = 0$$

are *nonlinear*, because now $g_{in}(t) \to k g_{in}(t)$ does *not* yield $y(t) \to k y(t)$. See also the discussion in [5] relevant to axiomatization of systems' definitions.

By the same reason, the more general equation

$$(\hat{L}y)(t) + F(t, g_{in}(t))\,y(t) = g_{in}(t)$$

in which

$$F: \ \frac{\partial F(z_1, z_2)}{\partial z_2} \neq 0$$

is nonlinear.

This shows the flexibility in passing from LTV to nonlinear systems and conversely, when subsystems of a complicated real system with numerous

connections are considered, and we have different possibilities to regard the real physical (biological) connections as "inputs".

That the frequency spectra of $g_{in}(t)$ and $y(t)$ are very different is clear for any such equation, LTV or nonlinear, and, -- as the point, -- since an LTV model suggests that some internal frequency generator (here, of $g(t)$) must be present for the frequency transform at brain operation (thinking), -- this conclusion remains also for a structurally close nonlinear model that one can find more realistic.

We see the argument that the frequency conditions for thinking require some internal auxiliary generation be so important that it will be now supported by discussing the specific, but presumably relevant, nonlinearity of switching systems that also can be either LTV or nonlinear. This time, it is not a frequency, but a time-intervals' analysis, and the auxiliary generation appears not via frequency "mixing", but via some level comparators.

5.1. The "switching nonlinearity": alternative argument for the need in the auxiliary generation

Works [5,6], especially [6], and the references there introduce the possibility of creating nonlinearity using principles of switching systems, which might be relevant to modeling brain operation. We mean the *nonlinearity of some level-crossings, seen as functionals* (i.e. numerical values defined by functions).

Consider some signal/process $y(t)$ to be found in a modeling of thinking. The time-instants of the *level-crossings* $\{t_k\}$ by the $y(t)$-wave (the unknown function) of *any given time function/wave* (that may be, in principle, a constant level, but in the present case we should prefer a known inconstant function generated in the brain) are seen as constructive parameters. Since $\{t_k\}$ obviously depend on $y(t)$, any expression of the type $f(t-t_{k'})$, where f is not identically constant, and $t_{k'} \subset \{t_k\}$, is nonlinear by $y(t)$. Thus, any equation for $y(t)$, which includes a term $f(t-t_{k'})$ will be nonlinear. For instance, equation

$$(\hat{L}y)(t) + g(\{t - t_k\})\, y(t) = 0 \qquad (3)$$

in which, as was said,

$$t_k : \; y(t_k) = p(t) \quad (\text{i.e. } \; y(t) \to t_k \,, \text{ the nonlinearity})$$

where both $g(\cdot)$ and $p(\cdot)$ are known functions, is *nonlinear* just because $\{t_k\}$ in (3) depend on $y(t)$.

The necessity in the auxiliary internal generator(s) (as the generator of $p(\cdot)$ that influences (3)) is thus expressed here in the use of the level-crossings in the functions' arguments. Though we did not come this time to nonlinearity via an LTV case (which would be obtained in (3) for prescribed $\{t_k\}$), this necessity is well seen here also.

6. On the behavioral problem when the right hemisphere is overloaded, -- a system argument important also for biologists

Having different kind of inputs, we can have them to be of different intensiveness, and one of the hemispheres can be, as a rule, overdeveloped (be under overburden), when compared with the other hemisphere. Actually, the problem exists when the more "inertial" *right* hemisphere is overloaded with respect to the left one. That is, there is an unbalance in the development of the brain, which must be associated, in particular, with the information held in the memory.

Thus, in the notations of Section 4.1, i.e. in terms of the smoothed potentials $f_l(B+\hat{T}A)$ and $f_l(B+\hat{T}A)$, we can have unhealthy "thinking mode", which is expressed as

$$f_r(A) \text{ and } f_l(B+\hat{T}A)$$

where $A >> B$ (the disbalance) was used in $f_r(A+\hat{T}B)$, and we have in $f_l(B+\hat{T}A)$ that

$$|\hat{T}A| \geq B\,.$$

When using the term "asymmetry" not in the (classical) sense of the informational distinction between the hemispheres, relevant, in particular, to absolutely psychically healthy human, but in the sense of such a *disbalance*, we can speak about *asymmetry of the brain* caused by the inputs that are improper for the person under consideration.

We touch here on a very important sociological point, because such an asymmetric overburden, associated with an (intellectual) over-stress of the right hemisphere, can be caused by making some *per se* respectable, but *difficult*, e.g. scientific, ideals as the main society ideals. Even if a nation has many such people of genius as Gauss and Riemann, -- this is far from being the whole population, and making the intellectual ideals universal in a country can cause, in many, the unbalance (that is denoted in [9] as '*R*+', i.e. the *right* hemisphere is overloaded).

Assuming that this unbalance (or the associated electrical activity) are an unpleasant neurological problem felt by the human, we have the necessity in stopping further development of the right hemisphere responsible for one's creativity. Unfortunately, the solution, -- a kind of "medicine", -- may simply be the cruelty.

Work [7] thus explains some regretful events of the period of WWII, and [8,9] thus explain the (absolutely unexplained either, by any other way) relatively recent "days of violence" accompanied by the strange propaganda of the violence seen as a "need for us, the society, and the whole humanity".

The point of [8,9] is that the means of information (radio TV, internet), presenting intellectualism as the main society ideal, cause in many simple people depression, and violence makes the difficult for one intellectual situation *simpler*. That is, the "days of violence" are needed for the defined hooligans (perhaps, just some simple people with the intellectual overburden that bothers them to live) as some days of an intellectual (informational) rest.

Observe that both [7] and [8,9] *categorically reject* explanation of terrible things/behavior by usual reasons, associated with "common sense" and "natural

interests". The latter is just escaping a serious scientific analysis necessary for preventing, via understanding the causes, such terrible things in future.

This phenomenological point of view has some (still weak) correlation with the pioneering biological works [10-12] that connect brain's asymmetry with human non-satisfaction (angry faces in [10] and violence in [12]).

Figures 2, (**a**) and (**b**), illustrate schematically the distinction that can be missed by biology focused on the brain per se, but are very natural for (electrical or mechanical) system theory in which an input function is required to be proper for the system.

Remark 3: Thus, the standard course "Signals and Systems" even teaches us that though both signals and systems are *defined* independently, -- we simply do not need one without the other – so important is their interaction expressed in testing, generation, etc.. Similarly to what is, in the sense of its significance, a signal, which is defined by its action on a system, *what is* for us this world is also defined by the brain response.

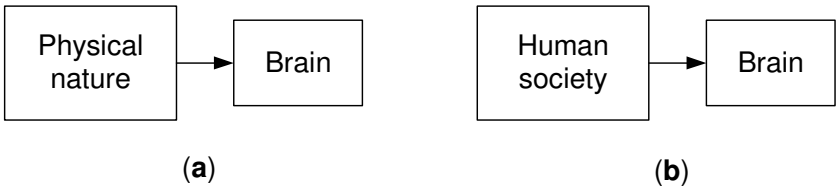

Fig. 2 (**a**) and (**b**): The signal and the system. Two cases of the informational input sources. In each case, signal should be proper, in the sense of the "inputs" *A* and *B*, in order to cause a healthy information treatment ("digestion", using the terminology of [9]). In this sense, case (**b**) is much more problematic than case (**a**), and this should be a point of our concern.

Hardly can the differences in the "signals" of the physical world and human society become a focus of academic biology, but system theory can introduce warning, as re the overburden of the right hemisphere, as was discussed. We should study the brain just as we study our child, -- that is, study while realizing on line the warnings and seeing these warnings as instructive, simply because there are some urgent behavioral problems that cannot be resolved without understanding human mind. In other words, we have to study not only the biological processes (or the algorithms of operation, etc.) in the brain, but also understand the very important *limitations of our mind*, associated with the unbalanced loading of the hemispheres.

Thus, the system approach with its phenomenological degrees of freedom allows one to see some "macroscopic" aspects of the brain activity, which are not easily seen on the thorough empirical way that academic biology passes. Even such applicative works as [10-12] are insufficiently straightforward for revealing the points that the system outlook easily notices. We thus hope that the present line of thought may be of some guiding and pedagogical values.

7. Conclusions

1. The closeness of the averaged electrical potential of the hemispheres, together with the condition for the main logical functions of the hemispheres to be strongly distinct (independent), yields the requirement of the informational and operational connection between the hemispheres. The same conclusion more phenomenologically follows

from the necessity of making decisions and from the inevitable use of memory by both hemispheres. Incidentally, the central role of memory in thinking is well seen along the argument.

2. The necessity of frequency transforms for the thinking that is based on the operation of the hemispheres, suggestes that the brain must have some internal generator(s) of real (electrical) processes with some proper frequencies.

3. It is argued that the principles of switched systems allow one to perform nonlinear modeling, by means of a use of *the level-crossings of the functions that have to be found, with some given functions*. Then, the purpose of the internal generation of time-function(s), mentioned in the previous item, is creation of the level-crossings. Since also in this scheme, some internal auxiliary generation of a time function is needed, we conclude that thinking cannot be just a direct logical treatment of the input informational signals, but also a *comparison* of such a signal or a process with the internally generated signals or processes.

4. Since human society behaves according to the action of human mind, the possibility of applying the system outlook to the logical operations of the brain, can explain some important social phenomena. Specifically, it was argued that the "days of violence" are a result *not* of the usual non-satisfaction by the welfare (the latter can just *trigger* the violence), but from intellectual overburden that the public means of information (radio, TV, Internet) impose on the population. Looking at the point deeper, one even sees that the system outlook, warning against overburden of the right hemisphere, is important not only for the sociology, also for the associated basic *philosophy* of the human society. Indeed, all the means of public information are given very significant democratic freedoms. However simple people did not vote for anyone intended to make intellect the main society ideal. In fact, the actual making, by the informational means, intellectualism a kind of dictator of the whole world, -- the one who causes psychologically-difficult life of simple people who just want to conduct with clear mind their traditional life *and be thus respected*, -- is a kind of violence in itself, causing the more prosaic violence. *That is, contrary to the physical nature, human society gives improper input for the system of the brain*. This basically simple, but not trivial and fundamental argument (observation), touching upon sociology, also demonstrates the power of the system outlook. In particular, it becomes obvious that the means of information have to revisit the principles of their work. See [8,9] for the associated discussion.

5. "*System approach to biology*" should not be limited by such problems as electrical modeling of a cell, that is, it should not be totally subordinated to biology needs *as these needs are formulated by biologists*. The system approach is also a source of instructive observations. In particular, it shows that the actually occurring long-term biological study of the brain has to be followed on line by the warnings re the spiritual health of society and the societal problems, and biologists also have to see these problems. One, comparing the quick rate of the occurrence of the social events and problems to be urgently solved, to the slow advance in the extremely difficult detailed biological investigation of brain would agree with this position.

6. I am informed (see the acknowledgements) that not all researchers share the opinion of [2-4] about the functional separation between the hemispheres. However, to *surely* say "*no*" is as important as to surely say "*yes*", and only careful logical development of a position, and analyzing its consequences, can finally say whether or

not this position is correct. It may be, however, that the uncertainty is caused by the interactions of the hemispheres. If so, then the *distinction* here between the "pure" features of the hemispheres (our "inputs" *A* and *B*) and their common action during the usual thinking, is methodologically very important.

Acknowledgements

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