

DOI <https://doi.org/10.30929/2307-9770.2019.07.02.01>  
UDC 159.91:004:330

## Human brain and computer: the fundamental causal differences in neuronal networks and electrical networks

Soloviov O.\*

Kremenchuk Mikhailo Ostrogradskyi National University, Kremenchuk, Ukraine

*Received:* 20.03.2019

*Accepted:* 10.04.2019

**Abstract** Paper describes fundamental differences between informational processes taking place in human brain and computer system. It is pointed out that even though both human brain and a computer generate new information by integrating data which is already fixed in the memory (i.e. 'old' information) they use different forms of determinism to obtain this new information. In the electrical networks of a computer classical (Newtonian) physic determinism takes place. Whereas in the neuronal networks of the brain a causal form of psychic (subjective) determinism occurs. This causal form described as 'self-determination', which is accomplished by means of mental processes. The structural and functional features of psychic (subjective) causality are characterized. There is discussion and arguments for impossibility of mental processes in the context of objective informational systems and for hierarchies of neuronal network. It is mentioned that the evolutionally formed neuronal networks carry out mental processes only when so-called phenomenon of 'physical causal gap' is present in the plastically changeable form.

**Keywords:** information, determinism, computer system, neuronal networks, self-determination, 'physical causal gap'

## Мозок людини і комп'ютер: фундаментальні причино-наслідкові (каузальні) відмінності в нейронних та електричних мережах

Соловійов О. В.

Кременчуцький національний університет імені Михайла Остроградського, Кременчук, Україна

**Анотація** У статті описані фундаментальні відмінності між інформаційними процесами, що відбуваються в людському мозку та комп'ютерній системі. Вказується, що, незважаючи на те, що і людський мозок і комп'ютер генерують нову інформацію шляхом інтеграції даних, які вже зафіксовані в пам'яті (тобто "старої" інформації), вони використовують різні форми детермінізму для отримання цієї нової інформації. У електричних мережах комп'ютера має місце класичний (ньютонівський) фізичний детермінізм. Тоді як у нейронних мережах мозку відбувається каузальна форма психічного (суб'єктивного) детермінізму, пов'язаного з причино-наслідковими можливостями інформації. Ця каузальна форма описується як «самодетермінація», що здійснюється за допомогою психічних процесів. Охарактеризовано структурно-функціональні особливості психічної (суб'єктивної) причинності. Здійснюється дискусія і наводяться аргументи про неможливість психічних процесів в контексті об'єктивних інформаційних систем. Зазначено, що еволюційно сформовані нейронні мережі здійснюють психічні процеси тільки тоді, коли в пластично змінній формі нейронних мереж мозку присутній так званий феномен «фізичного причинного розриву».

**Ключові слова:** інформація, детермінізм, комп'ютерна система, нейронні мережі, самодетермінація, «фізичний причинний розрив».

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**Corresponding Author:** Soloviov Oleh Volodymyrovych. Phone: +38(050) 425-99-24. E-mail: oleg@iws.com.ua  
Kremenchuk Mykhailo Ostrohradskyi National University,  
vul. Pershotravneva, 20, Kremenchuk, Poltava Region, Ukraine, 39600.

**Відповідальний автор:** Соловійов Олег Володимирович. Тел. +38(050) 425-99-24. E-mail: oleg@iws.com.ua  
Кременчуцький національний університет імені Михайла Остроградського,  
вул. Першотравнева, 20, м. Кременчук Полтавської обл., Україна, 39600.

# Мозг человека и компьютер: фундаментальные причинно-следственные (каузальные) различия в нейронных и электрических сетях

Соловьев О. В.

Кременчугский национальный университет имени Михаила Остроградского, Кременчуг, Украина

**Аннотация.** В статье описаны фундаментальные различия между информационными процессами, происходящими в человеческом мозге и компьютерной системе. Указывается, что, несмотря на то, что и человеческий мозг и компьютер генерируют новую информацию путем интеграции данных, которые уже зафиксированы в памяти (то есть "старой" информации), они используют различные формы детерминизма для получения этой новой информации. В электрических сетях компьютера имеет место классический (ньютоновский) физический детерминизм. Тогда как в нейронных сетях мозга происходит каузальная форма психического (субъективного) детерминизма, связанного с причинно-следственными возможностями информации. Эта каузальная форма описывается как «самодетерминация», осуществляемая с помощью психических процессов. Охарактеризованы структурно-функциональные особенности психической (субъективной) причинности. Осуществляется дискуссия и приводятся аргументы о невозможности психических процессов в контексте объективных информационных систем. Отмечено, что эволюционно сложившиеся нейронные сети осуществляют психические процессы только тогда, когда в пластически переменной форме нейронных сетей мозга присутствует так называемый феномен «физического причинной разрыва».

**Ключевые слова:** информация, детерминизм, компьютерная система, нейронные сети, самодетерминация, «физический причинная разрыв».

## I Introduction

Despite significant progress in understanding of human brain function in recent decades, the fundamental principles of the information processing in its neuronal networks remain poorly elucidated [4,12,15,16]. In this study the structural analysis of causality implemented in neuronal networks of a human brain will be elaborated. We investigate the principles which demonstrate information processing in two systems — in the evolutionally formed human brain and in an artificially created computer, compare these two systems performing informational operations. In our opinion, fundamentally different forms of cause-and-effect relations take place in these 'computing' networks. It is important to take into consideration mental (subjectively provided) processes realized by the neuronal networks of the human brain, because it is these mental processes that carry out informational operations, which are theoretically not feasible in the context of only objectively active neuronal networks. We mean first of all such informational operations as subjective evaluation information, subjective comparison of information and subjective choice of information which are proceeded in active human brain.

Hence, **the purpose** of this paper consists in showing a way of functional including of mental processes in operating of information in the brain as a needed factor. Particularly, we make an attempt to show that the neural networks of the human brain which are caring out mental processes, function only in order to carry out, at each certain moment of a person's interaction with his/her environment, when a shortage of information is found in the person, mental processes urged to eliminate this shortage. Achievement of this purpose allows us to indicate significant structural characteristic of neuronal networks of the brain which is connected with their information operation function and using mental processes. In addition, a clear functional boundary between functional opportunities of a human brain and the modern computer will be found. It, in turn, will allow outlining the border of a complementarity of human intelligence and "intellectual" opportunities of modern computers.

Eleven years ago one of the authors of this work have done an attempt to find the way to show the need to include mental (subjectively carried out) processes in objective activity of neuronal networks which produce these mental processes as a factor of operating information. But now the situation obviously changed to the best thanks to some works indicating this function [3,8]. So, we seek to show that information network

researchers lose much when ignoring the specificity of mental processes carried out by the neural networks of the human brain as specific informational processes.

## **II Materials and Methods**

***Obvious differences and similarities of informational processing in the brain and computer.*** We need to point out the external, i.e. given to us explicitly (phenomenologically), characteristics of information processes in the brain and a computer. There are next certain differences of these processes.

While the human brain principally may carry out behaviors independently from the environmental factors, the goals for a computer are set principally from outside, i.e. by the human brain. But it means that the directivity (intentionality) of the information processes proceeding in the electrical nets of a computer is formed in neural networks of a human brain, but not in electrical networks of a computer itself. According to this statement we may assume that the structure of electrical activity proceeding in a computer is formed or determined by the networks of a human brain.

The information processes in the brain accompanied by mental phenomena (sensations, psychic images, emotions, thoughts, ideas etc.) [1,2,5,11] realized by specialized neural networks, whereas a computer realizes its information 'activity' only by means of purely physical electric phenomena. It is for this reason we may say that the information processes in the brain can display contents of the past and the future, i.e. 'pictures' of the past and probable future can be displayed via mental images of the human brain. Whereas the information processes taking place in a computer are 'simple' physical electric processes reflecting the present moment, they principally cannot carry out any mental processes, which may reflect the past and the probable future. The first of these two points will help us to find functional specificity of acting of informational networks in the brain and a computer. The second one will allow revealing structure of causality in active neuronal nets by means of which events of the past and probable future may determine the present activity of live systems.

One of the essential similarities of information processing in the brain and a computer is the presence of numerous relays (switching devices) of the streams of electricity (in networks of a computer) and bioelectricity (in the brain). In the computer networks (in the processor and memory) as well as in the neural networks of the brain (literally in its every functionally significant structure), there are huge quantity of switching devices (relays) regulating streams of electricity (in a computer) and bioelectricity (in the brain). In the computer, it is transistors, thyristors, etc. In the brain, it is synapses located between the neurons and their nets. This structural similarity is necessary for clarifying how the information processes in the networks of the brain are self-regulating, and in the electrical networks of a computer are not.

***The function of activity mental processes in the framework of objective informational systems.*** Classical (Laplace, Newtonian) physics only knows one form of causality where 'cause' and 'effect' are confined to the present moment. Hence, there is no intermediate informational variable that could somehow interfere with the transfer of energy and its vector from the physical cause to the physical effect. However, it is well accepted by numerous humanitarian sciences including psychology that human interaction with the environment is characterized by freedom. Human physical (objective) actions are determined not so much by physical inputs but by the information about past fixated in the human brain. And human behavior is determined by the goals formulated in the context of a probabilistic future.

Indeed, the human body, being, undoubtedly, a physical body, does not behave as a 'simple' physical (or, even biological) body. For example, a boxer who takes a heavy blow in the chest does not simply drop to the surface of the ring having received sufficient amount of kinetic energy. On the contrary, being guided by his socially formed will to win the fight and by anticipation of the effect of the blow, the boxer executes maneuvers unpredictable for the opponent and the audience. In other words, his physically, objectively functioning body is governed by laws that are different from those determined by classical physical determinism.

'Being guided by his goal', 'anticipating' and 'having felt a possibility' mean that something which we call a psychic phenomenon, a subjective factor is wedged into the process of causation of objective physical

movements of the human body. We cannot refer to the human body as 'a simple physical body' because it may be controlled by mental phenomena carried out in the human brain [1,2,7,13,17,18]. And if the human body really had been 'a mere physical body', it would have simply taken the shape imposed on it at a given moment by external and internal physical conditions but not human social aims and wishes. We can tell the same about the programmer and the computer user: their actions with the keyboard are the result of their mental activity by means of which their social purposes and desires are fulfilled.

There are fundamental features of self-regulated human movement, and method of introspection is the most appropriate for this purpose. By 'looking inward', i.e. directing attention towards the contents of one's mentation, one examines his/her sensations, emotions, images, thoughts, their structure and dynamics, and their functional relationship to the objective behaviors. For example, analyzing the contents of our own mentality at one point of solving our practical problems, we discover the following fact: in order for our body to change space coordinates it is necessary that we desire of this changing and this desire in the sphere of our mentality be embodied in a certain mental image reflecting the purpose of this movement. It is the information fixed in this mental image that will set the vector of our body movement in the environment coordinate grid. For instance, individual to get certain place in town, by means of mentality 'construct' an imaginative model of trajectory to the destination and this imaginative model determines the trajectory of real movement. In other words, something and what we call a mentality, subjectively realized phenomenon, determines, and systematizes physical processes in our neurons and muscles in a way which is still unclear. Here, we have necessity of identifying the structure of causality which allows the human brain to carry out free human behavior. This causality is realized by mental phenomena with "built-in" future goal and information about the past, used for executing a purposeful behavior [6]. At the same time, we are unable to explain the phenomenon of goal-directed behavior in terms of classical determinism. This new representation of determinism must include both the information factor (mental images contain the information about the past), and the subjectivity factor (prejudgment) — qualitative assessment of objects in terms of 'good' or 'bad', 'pleasure or displeasure' [18]. Emotions, for example, are a concrete form of assessment of information in the brain [8].

Indeed, only informational operations justified by the properties of mental processes can conceptually occur in our mentality sphere and cannot occur in neuronal networks themselves without 'their' mentality. There are several of these information operations which proceed only in the mentality sphere. First, subjective assessment of information, i.e. qualitative assessment of information in terms of 'good or bad', 'pleasure or displeasure' occurs. This subjective (prejudiced) assessment of objects (information about them) determines the purposefulness of information processing by selecting only biologically or socially relevant information from the memory bank stored in the networks of the brain and directing the process of perception (restoring information for the future) and information integration for forming behavioral acts. In this case the sphere of mentality becomes a subjective epicenter of information processing that is carried out by the objectively active networks of the brain. However, it appears that objectively acting neuronal networks, by themselves, without mental phenomena generated within them, are unable to integrate information giving a specific behavior directed by a goal. Second, mental processes carry out a function of subjective comparing the information that is fundamentally different from that of computer systems (the latter can only operate information processes by quantitative computing). Such subjective informational operation of comparing principally cannot be carried out in the context of objective processing. Third, only in the context of mental processes it is possible to make a subjective choice of the future (because a subjective choice cannot be made without subjective assessment and subjective comparison).

So, when we model our future, objectively active neuronal networks, without mental processes carried out by them, cannot be utilized because they do not possess a capacity to subjectively evaluate information. Thus, neuronal networks generating mental processes may function 'with a sole purpose' of forming these mental processes. Indeed, human subject (as an evolutionary highest form of subjective evaluation of information and, thus, as the highest operator of information in the sphere of mentality) may 'see' the information about the past in the form of mental images [8]. Using this information about the past, human

subject may carry out three subjective information operations — evaluation of information fixed in networks of the brain, comparing and choice the most adequate information for solving problem in a situation of its deficiency. So, in our opinion, human on the basis of these three subjective information operations may create his own mental models of the future for causing objective environment by means of muscle movements.

Based on the fact that the subjective events may determine objective events the question arises: how in neural networks of a brain such cause-and-effect relations between mental and objective phenomena can occur? (Because we see that our plans for the future, anyway, have property to be embodied in structure of our movements by means of the bioelectric streams created in a brain going to muscles). In this case it is quite reasonable to assume that in the brain such functional relations which carry out determination of objective activity operated neural networks (for example, motor networks) by operating (more "competent") neural networks are formed. Further it will be shown that such hierarchical neuronal causal relationships are really provided on the basis of 'information competence' of higher organized networks in the human brain and that such hierarchical relationships may be realized only by the mental phenomena.

### III Results

**Processing of information in the neuronal networks of a human brain by means of mental processes.** The person exists in essentially probabilistic world where novelty is one of its main attributes. Human society represents such an environment perpetually filled with novelty, where each individual with his/her inherent freedoms represents a source of uncertainty for every other person. But the boundaries of free choice of every person are based on the continuum of personal memory. For instance, when a programmer create a new program and appropriate 'text' to describe it, he 'extracts' from his personal memory the data regarding a multitude of his past interactions with the social environment (the rules of creating programs, meanings of words of a programming language, acquisition of factual knowledge from books and lectures, etc.). Whenever we are exposed to new stimuli requiring new and yet adequate to this novelty behavioral response, we need to accumulate new information in order to use it in solving problem. Thus, the objective motor acts of the programmer, which, include the final version of the program into a computer partially are determined by a multitude of past events fixed in his brain. Apparently, this act of determination of objective motor actions of the programmer by his personal experience can't be realized by classical physical way because within a classical physical paradigm for the past 'it is forbidden' to cause the present.

Person is a being who capable to answer from the first time in new situations by principally new motor acts (structurally or from the point of view of their semantic context). We also know that the human brain is the extremely complex neural network which process information in the direction from sensory structures to motor structures (see Fig.1).

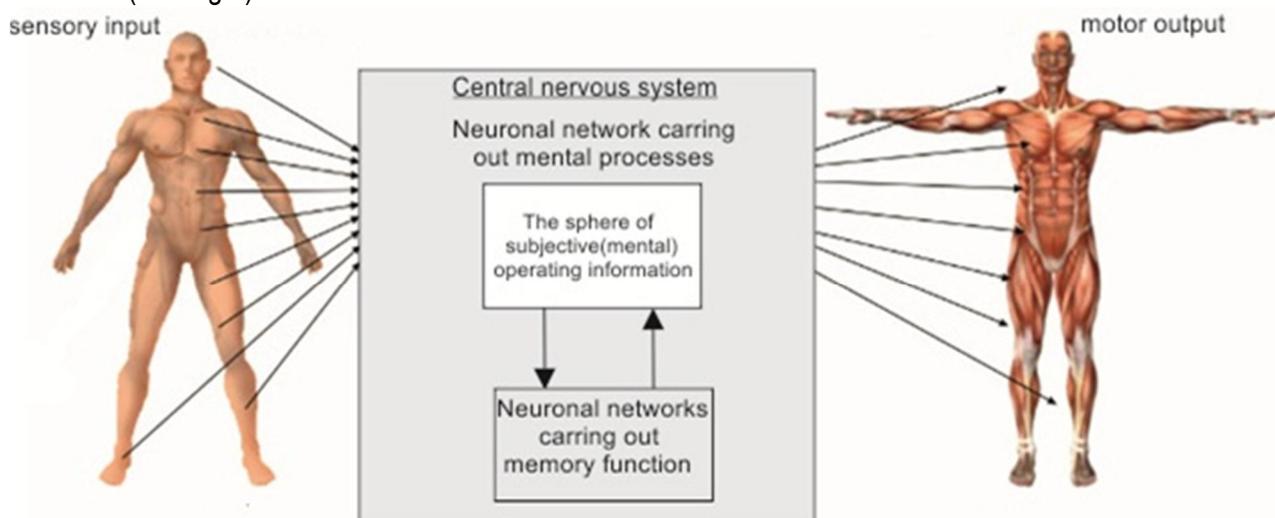


Fig. 1. Scheme of processing of information in the neuronal networks of a human brain by means of mental processes

In this case we need answer the question: how in the case when a person answers a new irritant for the first time by new and, nevertheless, by the adequate behavioral act, we can explain how the bioelectric impulses being operating signals, can find neural pathways corresponding to this adequacy from a sensory input to a motor output? For these pathways couldn't be created because of novelty of an irritant or of a motor act.

Thus, any act of determination of objective motor actions of the programmer by his personal experience can't be realized by classical physical way (in general, any act of determination of objective motor actions of any human can't be realized by classical physical way). It becomes possible only when the information factor is included in the classical causal chain of neuronal events in human brain. And we already have seen that in the real networks of a human brain this information factor is generated by means of mental phenomena (see Fig1). The neuronal networks that carry out mental processes of accumulation, storage of information and modeling of the future interactions with environment on the basis of this integrated information function under the conditions of impossibility of conducting direct physical (bioelectrical) control signals from the sensory structures to the corresponding motor structures (see Fig.1). We call this phenomenon '*the classical physical causality gap*' ('*Causal Gap*'). And mental phenomena act as a specific deterministic informational factor that allows bridging this 'Gap' in the neuronal networks because of 'their ability' to be 'the instrument' of storage and use information accumulated during life-span.

#### **IV Discussion**

**Causality in the neuronal networks, which generate mental processes.** Human mentality represents functional epicenter of information processing in the brain, where all information processed subjectively. Such structures of the human brain as the limbic system and its satellites carry out the function of subjectivity, i.e. qualitative assessment (in terms of 'good or bad', 'pleasure or displeasure') of information fixed in networks of the brain specialized in restoring information for future. This subjective assessment of information in the brain gives rise to the specific informational processes that we treat here as mental phenomena. These mental phenomena are characterized by subjectivity that provides the vector and the purpose of further information processing. The phenomenon of subjectivity gives human perception, human thinking, human memory a goal-directed quality: only probabilistically relevant information is perceived, fixed, and processed in the brain in order to form an adequate response for the given problem posed by the novel environment. For example, when a human mind is engaged in solving a problem posed by the social realm, it is guided by human desires, inclinations, motives, and values, which guide not only our thoughts, but also our objective behaviors determined by these thoughts.

In order to explain how the remote past determines future objective behavior of a person, it is necessary to assume that an important quality of this subjective system of causality in the human brain is its self-determination. At any given moment two types of neuronal networks can be functionally distinguished in the brain — on the one hand hierarchically higher controlling networks and on the other hand lower subordinate networks [18]. Furthermore, operating neuronal networks execute their control over operated neuronal networks via mental phenomena, which enable operation networks purposeful integration of information fixated in subordinate networks and thus ensure purposeful behavior. Such hierarchic functional connections between 'more informed' neural networks and the networks subordinated to them we call here self-determination. The activity of the subordinate neuronal networks of the brain enables the controlling networks to develop the most appropriate integration of experience fixed in memory (operated networks) to answer to environmental novelty. Such response is a result of integration of experiences fixed in memory, which can only be integrated via mental processes/phenomena. We can call such form of activity of hierarchies of neuronal networks by self-determination, for on the basis of the information fixed in all the subordinate subnetworks of the brain the controlling subnetwork comes up with one, most adequate solution. Thus, neuronal networks which at this moment carry out operating function start controlling the subordinate networks by the same solution resulted from the integration of the experience fixed in the brain. Such information mutual influences in neural hierarchies can proceed only by mental processes owing to existence in these networks of the classical

physical causal gap postulated above. The essential principle of this neural networks' activity comes to light – "more competent" neural systems operate "less competent". Such functional including of mental processes in mutual information influence of neural networks at each other concretizes realization mechanisms of what B.J. Baars called *global access* [3]. Indeed, controlling neuronal networks in our explanation scheme 'need' to have global access to information fixed in brain memory networks for forming new information in response to environmental novelty.

Such explanatory scheme of the informational activity of neuronal networks of the brain means that between networks storing fragments of memory divorced on the continuum of the time there are physical causal gaps. And such physical causal gaps are the physical (classical) condition of impossibility to integrate memory divorced on the continuum of the time. Such physical causal gaps have to be overcome by mental processes realized within the hierarchical operating-operated relations in neural networks of the brain generating the phenomenon of self-determination.

Mechanism of self-determination can be described with G. Haken's concept of *order parameter*. Haken's synergetic theory [9,10] explains self-determination as the phenomenon of the formation of the so called *order parameter*, i.e. synergistic and coordinated activity of a large number of primarily chaotically acting elements. This *order parameter* secondarily determines the activity of the individual elements of a system. So, *the order parameter* appears as a factor that enables a system to control its individual elements. In the sphere of human mentality, *the order parameter* corresponds to the phenomenon of subjectivity (qualitative evaluation of information, fixed in operated networks), which integrate the activity of neuronal networks that give rise to these mental phenomena. And any human goal formulated by human subjectivity. So, subjectivity appears as a goal-oriented factor, giving direction and trajectory to the informational processes taking place in the human brain. Any informational process in the human brain is guided by goals formulated in terms of human subjectivity which may be explained as one of the forms of phenomenon of *the order parameter*. Turning the focus on how mental phenomena are formed and take on their causal function in the human brain we should first validate hypothetical assertion that in the human brain the classical physical chain of causation is interrupted resulting in a 'causative gap' and mental phenomena appear to bridge this 'gap'. Thus, we should point out how mental phenomena realized by the human brain are formed and acquire their causative function. For this purpose we need to examine if there is any sense in our hypothetical assertion that in the human brain the classical physical chain of causation 'is torn'. And such a way forms a 'causative gap', which is the condition of appearing of mental processes specifically processing information.

If a living system is 'pressured' by the novel environmental factors that are not fixed in its genetic memory or neuronal structure, it needs to respond to new stimuli by motor response which is adequate to this novelty (to this deficit of information). In this situation the living system does not have any created neuronal networks which could easily conduct impulses from the sensory structures to the corresponding motor neurons. But in order to survive and be self-organized in such an ever changing environment, a living system is forced to accumulate and integrate experience (information) for adequate respond to novelty. And it is this process of information accumulation, storage and response that is carried out by means of mental phenomena in the human brain. As Damasio wrote: "Good actions need good images" [8].

We have already mentioned that the subjectivity factor (our motivations, emotions, feelings, value system) is forming by the mutually coordinated activity of the structures of the limbic complex [18,19,20] and sets a directional vector and a course for the informational processes in the whole human brain, i.e. subjectivity determine biologically adequate purposefulness in the human brain. We suggest that the subjectivity factor (how it is formed in the brain is still no clear) realizes not only the fixation of information in the brain but also its integration, and, finally, determines the objective human motor actions on the basis of this integrated information. For example, we mainly memorize information that is emotionally (subjectively) significant for us. Also we recall (extract from our memory) information that we require to solve a certain practical problems, i.e. we recall information because in most cases we evaluate it as necessary, relevant, and subjectively significant. Besides, in the mental sphere the information about various past events can become integrated to form new information adequate to a given novel situation only because of acting of factor of

subjectivity in the brain. For example, a physicist devising a new law uses a multitude of observations and facts obtained from the books, lectures, and experiments over the years. It is clear that in the context of objectively active processes such integration of memory contents is impossible. It can be explained to that objective classical physical causality 'does not allow' any interruption in its functional continuity by any other factors, including informational ones. And mental phenomena is that factor by which information about the past fixed in the brain may appear in the present for 'breaking' classical physical causal chains in neuronal networks by mental models of the future formed on the basis of integration, summation of information about the past. Using Damasio's terminology, information fixed in mental images acts as "the pathbreaking novelty" [8, p.24].

Large numbers of neuronal elements of the brain which store information about various past facts and transmit bioelectrical impulses, transform this information into another form common to all these elements, i.e. into the mental form. This occurs by means of the phenomenon of subjectivity, which allows integration of all this information about the past into new informational complexes (into information about new mathematical formulas, new dancing moves, new design solutions etc.). This is possible only in the sphere of mental phenomena, a sphere of specific informational processes in the human brain. And we see that the probabilistic models of the future generating a specific purpose for objective activity of human organism cannot exist within objective processes of the present activity of neuronal networks. They can only exist in the context of information fixed in the brain neuronal networks and appears only in the form of mental phenomena.

Only by mental images the human subject has opportunity "to see" information about his past fixed in his brain to include it in regulation of the behavior as a causal factor. Thus only by means of mental images human subject is capable to extract from ranks of similar in something past events, regularities which can be used later for formation of adequate mental models of future behavior. But factor of subjectivity just also is operator aspect of processing of information in mental sphere (workspace [3]) solving which events of the past and "fixed in them" regularities are biologically or socially significant for the subject in the future.

## V Conclusion

So, we can assume the mental phenomena in adequate structuring of movements implicitly includes the stored life experience of a person. Further, we need to specify how this inclusion of the mental (subjective) phenomena into neural objective (physical, physiological) activity of brain networks is accomplished and what functional structure such brain networks have.

In part 2 of the investigation we should point out how mental phenomena realized by the human brain are formed and acquire their causative function. For this purpose we need to examine if there is any sense in our hypothetical assertion that in the human brain the classical physical chain of causation 'is torn'. And such a way forms a 'causative gap', which is the condition of appearing of mental processes specifically processing information.

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**Соловйов Олег Володимирович,**

доктор психол. н., доцент, професор,  
Кременчуцький національний університет імені Михайла Остроградського,  
вул. Першотравнева, 20, м. Кременчук Полтавської обл., Україна, 39600.  
Тел. +38(050) 425-99-24. E-mail: oleg@iws.com.ua

**Soloviov Oleh Volodymyrovych,**

D.Sc. (Psychol.), Associate Professor, Professor  
Kremenchuk Mykhailo Ostrohradskiy National University,  
vul. Pershotravneva, 20, Kremenchuk, Poltava Region, Ukraine, 39600.  
Phone: +38(050) 425-99-24. E-mail: oleg@iws.com.ua

**Citation (APA):**

Soloviov, O. (2019). Human brain and computer: the fundamental causal differences in neuronal networks and electrical networks. *Engineering and Educational Technologies*, 7 (2), 10–18. doi: <https://doi.org/10.30929/2307-9770.2019.07.02.01>

**Цитування (ДСТУ 8302:2015):**

Соловйов О. В. Мозок людини і комп'ютер: фундаментальні причино-наслідкові (каузальні) відмінності в нейронних та електричних мережах / Інженерні та освітні технології. 2019. Т. 7. № 2. С. 10–18. doi: <https://doi.org/10.30929/2307-9770.2019.07.02.01>

**Обсяг статті:** сторінок – 9 ; умовних друк. аркушів – 1,304.