TRANSMISSION OF MEANING IN BRAIN VIA *QUALIA*

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Rezumat. *Lucrarea evidențiază o nouă corelație a percepției la nivel cerebral, oferind o relație între înțeles și respectiv noțiunea semantică de* qualia *așa cum acestea apar în modelele cibersemiotice de transmitere a informației. În acest scop am propus un nou model cibersemiotic care descrie legătura dintre* qualia *(realitatea conștienței) și realitatea fizică a* creierului. *Acest model are două caracteristici de apreciere a conștienței, una cantitativă (mărimea), determinată de cantitatea de informație care poate fi integrată (stocată) într*-un *cluster (complex) de elemente neuronale din creier, cealaltă calitativă (*qualia*), determinate de relaţiile informaţionale cauzale care se stabilesc între aceste elemente*.

Abstract. *The paper highlights a novel brain correlate of perception, providing a relationship between meaning and respectively the semantic notion of qualia as they appear in cybersemiotic models of information transmission. In this aim we propose a new cybersemiotic model which describes the connection between qualia (the reality of consciousness) and the physical reality of the brain. This model has two characteristics of appreciation of consciousness, one quantitative (the size), determined by the amount of information that can be integrated (stored) in a cluster (complex) of neural elements in the brain, the other qualitative (qualia), determined by causal informational relationships that are established between these elements.*

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1. Introduction.

The scientific investigation of mental phenomena is still characterized by strong contradictions and controversies, despite remarkable advances in the cognitive sciences. How brain structures and neural circuits underlie symbolic meaning has recently been elucidated by neuropsychological and neurocomputational research. In this new perspective on cognition, cortical cell assemblies act as the cerebral basis for a wide range of higher cortical functions, including attention, meaning of concepts, sequences, goals, and even communicative social interaction. A special aspect in the examination of these cognitive actions is that of the way in which the meaning of an informational message is established in the brain. In other words, it is about the way in which the relationship between the concepts of information and meaning is transposed in

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the cortex. From the simple equivalence of the two, to the establishment of subordination relations, different approaches propose more or less plausible models that explain the connection between these concepts. As in the classical information theory, a causal chain is observable from data (unstructured units such as signs or signals), to information (structured data in the form of messages) and finally to knowledge (structured information that in this way acquires meaning). So, as information is closely related to communication, and meaning to signification, it is explicable that semiotics as a science dealing with the communication of signs has provided a basis for models that explain the relationship between meaning and information using semantic notions. Moreover, biosemiotics [1] has provided the framework in which these patterns can be associated with neural processes. One of the models that enjoyed appreciation was the cybersemiotic model proposed by Brier in the seminal work [2] published in 2003, in which he tries to integrate Pierce's semiotic principles with the systemic aspects of cybernetics. Brier has written numerous papers proposing to impose cybersemiotics as a transdisciplinary theory of communication and information. He argues that the cybersemiotic model incorporates the classical model of information theory based on the Transmitter-Communication Channel-Receiver (TCR) triad in the transdisciplinary program of integrating the information processing paradigm in the cognitive sciences. However, the cybersemiotic model (CM) is not a mathematical model of a physiological process, but only a conceptual model that uses a physiological carrier of the message that highlight the feeling of *qualia*. Because Brier is not at all interested in how the information is transmitted to the brain, CM cannot be used as a neurobiological model to describe semantic mechanisms that involve the transfer of information to the brain, but only offers a neural interpretation of Pierce's semiotic triad, in which *qualia* appears as a referential object.

It should be mentioned that about 10 years before R.D. Orpwood started publishing papers in which *qualia* is seen as an information-carrying physiological signal. But only in 2013 Orpwood uses the mathematical tools of information theory to explain how to transmit qualia to the cortex [3], stating that qualia is a result of information processing in local cortical networks. Later, in a most recent paper [4], he makes a distinction between informational structures (the physical embodiment of information in the brain) and informational messages (the meaning of those brain structures and the basis of qualia). And although in his works Orpwood makes no reference to semiotic issues, a simplified model of the way in which qualia transports meaning to the brain can be interpreted by rearrangement as a scheme of Peirce's semiotic triad.

The mentioned researches have in common a semiotic model, which in time has evolved towards a neurobiological model focused on the way in which the "meaning" is perceived by the human mind. Based especially on previous research ([5], [6]), we have considered the possibility of merging Brier and Orpwood models into a single model that equates the essential notions and simultaneously provides the basis for semantic interpretation and neurocognitive interpretation of the perception of meaning in the brain.

2. Cybersemiotic model of *Qualia Space*

As a result of recent research in neuroscience, it can be stated that *qualia* is a result of information processing in local cortical networks, in close connection with the state of consciousness. The information-based description of qualia distinguishes between informational structures (the physical localisation of information in the brain) and informational messages (which give brain cells the meaning of the basic *qualia* sensation). In [6] we proposed a new cybersemiotic model which describes the connection between *qualia* (the reality of consciousness) and the physical reality of the brain. This model has two characteristics of appreciation of consciousness, one quantitative (the size), determined by the amount of information that can be integrated (stored) in a cluster (complex) of neural elements in the brain, the other qualitative (*qualia*), determined by causal informational relationships that are established between these elements. We can consider that the neural elements in the cluster constitute the dimensions of a relational space hereinafter called *Qualia Space* (QS). The QS structure is determined by the values of the efficient information stored in the elements of the cluster.

Our idea was to establish a bridge between two approaches launched Pulvermuller [7] and Orpwood [4] in order to formalize by the integrated model the way in which sensory information is transformed into knowledge (more precisely meaning) in the brain, thus becoming an attribute of consciousness. From this point of view, both articles show remarkable results in information processing, which can be divided into two phases: i) the conversion from signals to *qualia* which is called perception and ii) the conversion from *qualia* to meaning which is called *comprehension*. We have admitted that, in association with the state of consciousness, *qualia* is only an emerging property of a complex information processing system. But if this explanation were valid, we should already be able to find a way to simulate software tools specific to current information technology - and of course artificial intelligence. In the same time, our proposed cybersemiotic model offers the necessary notions to discuss how *qualia* ensure the transport of meaning contained in information to the brain in the paradigm proposed by Tononi [8] on the inclusion of consciousness in integrated information theory (IIT).

Both Orpwood and Pulvermuller takes up Tononi's hypothesis that two types of information can be labeled in the brain, as can be seen in Fig.1. Fig.1a shows the reciprocal transformations between structures and messages. The physical information present in the brain is labeled as "information structure", and represent physical activities triggered at the cellular level which are guided by action potentials. The second type of information is the semantic information represented by "informational messages", which contain the meaning (significance) of all that is physical activity in the brain.

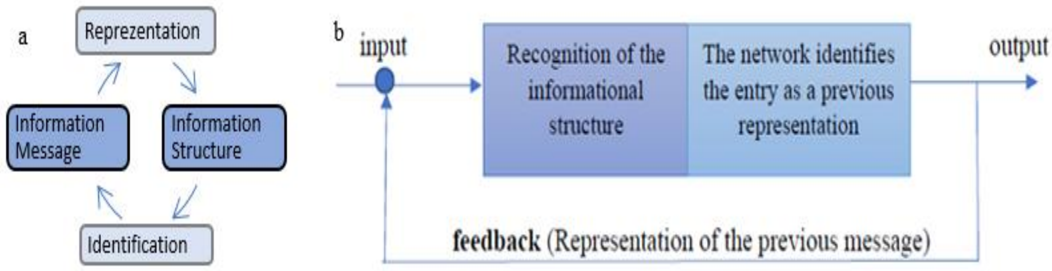

Fig.1. Correlation between the information structure and the information message.

Fig. 1b shows the response during the iterative behaviour that leads to a stable state of the neural network that behaves like an attraction pool, which we will define as an attractor state in QS. In attractor states an output structure is a representation of the identity of the same output structure. But for the network, the output is also a representation of the message. So, the result becomes the representation of the identity of a representation of the message.

In the brain, the two types of information interrelate. The first type of relationship is *representation*. Here is an example: a brain that is concerned with the perception of the color (say blue) of an object receives a pattern of inputs in a specific zone of its visual cortex. This pattern is an informational structure. The meaning for the brain, "blue", is an informational message. The second type of relationship is *identification*. At the individual element level, any neuron that receives an input pattern that it has previously learned can produce a trigger, a binary decision by which it communicates externally that an identification has occurred.

If we consider the minimal structure of the information transmission system with a single neuron, the transmitter is configured to initiate the generation of an information structure following internal state changes. For a receiver of this information, the information structure can represent an infinite number of different messages. But whatever the response to the input information, the receiver can only recognize the informational structure, not the informational messages. Of course, the problem of transmitting information to the brain is complicated if we consider sets of neurons, which we will further define as neural networks. Such networks are able to recognize input patterns but can also generate their own output patterns in response to recognition. We can say that for a neural network, in which the message is what the output represents, an iterative process is initiated in which a "representation" output represents an "identification" type input, and the process continues until it stabilizes in QS in an attractor state. The appearance of the feedback loop in the model of information transmission to the brain justifies the definition of this model as cybersemiotic. In other words, for the transmission of informational structures the linear triadic model TCR (without reaction) is sufficient, but for the transmission of the meaning of the informational message feedback is necessary. To resume, let say that the model takes into account a dual representation of information: i) a physical one, defined as the informational structure that corresponds to the *qualia* signal and constitutes the input to the recurrent neural network; ii) a semantic one, defined as an informational message that is interpreted in QS as a result of an iterative process of stabilization between an attractor pool, according to the feedback loop.

3. Representing information in brain

We discuss in the following how the cybersemiotic model can serve to represent the dynamics of activation and control actions for representing information in brain.

In the basic structure of an information transmission system with a single neuron, the transmitter generates an information structure based on internal state changes. The receiver of this information can interpret the structure in various ways, potentially representing countless messages. A receiver capable of recognizing the input structure will respond with specific activities, such as altering the depolarization level or firing a pyramid cell, or even triggering a pattern in a neural network. However, the receiver can only recognize the informational structure itself, not the specific informational messages it carries. The complex nature of transmitting information to the brain is evident when considering neural networks composed of pyramidal cells and interneurons. These cortical networks exhibit coordinated behavior, allowing them to recognize input patterns and generate output patterns in response. An intriguing example of information transmission in biological systems is observed in alarm calls, where signals convey the state of a variable through specific strategies. The transmitter's strategy involves transitioning from a state to a signal, while the receiver employs a strategy that maps signals to corresponding actions. This interplay between signaling and action highlights the intricate dynamics of information processing in neural networks.

The neurobiological model of communication through local cortical networks can be simulated in a software environment by the mentioned technique based on artificial neural networks, but only in terms of the transmission of information structures. The artificial neural network, in essence, is an attempt to simulate the brain. Such networks are able to recognize input patterns, but can also generate their own output patterns in response to recognition. We can say that for a neural network, in which the message is what the output represents, this output must represent a representation, and as such to further transmit the message "representation". The output information structure represents the information message identified from the input information structure. Information goes from a structure, to a message, to a structure again (see Fig.2). The network can recognize its input structure and generates an output structure that represents the identity of the network input.

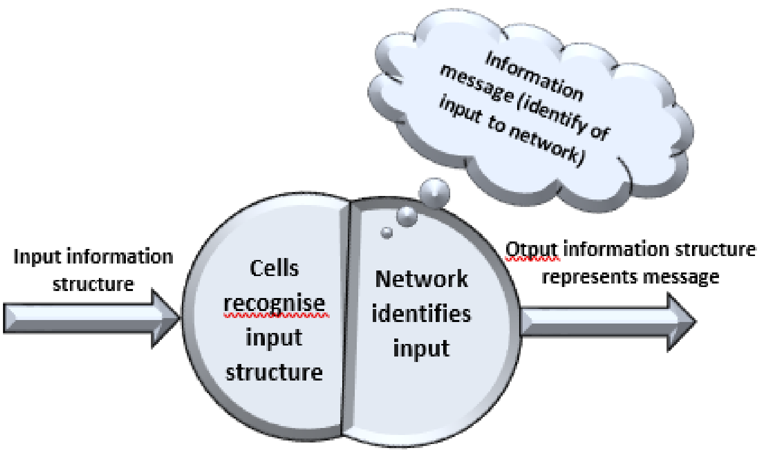

Fig. 2 Normal network response

We found that a cortical network can be both a sender of information (sender) and a receiver of information (receiver). What the sender transmits to the receiver is an informational structure, but not an informational message. Sender can only inform that the transmitted informational structure has the identity "representation". The ability to identify representations underlies the problem of the origin of *qualia*, because the informational messages we call *qualia* are internal representations. Forcing things, we can tautologically say that for a neural network, where the message is what represents the output, this output must represent a representation, and as such it must continue to transmit the "representation" message.

After reaching an attractor state, the process of transmitting information through the network takes place cyclically. The network initially receives an input structure that it recognizes as having some network identity with the "message" tag. Then the network generates an output structure that represents the message to the network. If that output structure is presented again to the network, it will identify the feedback as "Previous Message Representation". The original message is "message" and the second message is "representation of this message". If the cyclic process continues, the third message will continue to be "the representation of the previous message", in other words "The representation of the original message", and so on, as we can see in Fig. 3.

Figure 3 shows an example of connecting a chain of simple networks. Entering Network 1 can to be identified by the respective network, and the output representation of this identity to be transmitted feedforward to network 2 and so on. This feedforward activity becomes input to Network 2, which can again identify the input and feedback to Network 1 the output representation of the identity. This iterative activity can continue until an agreement is reached, whereby the outputs of the networks stabilize at structures that no longer change.

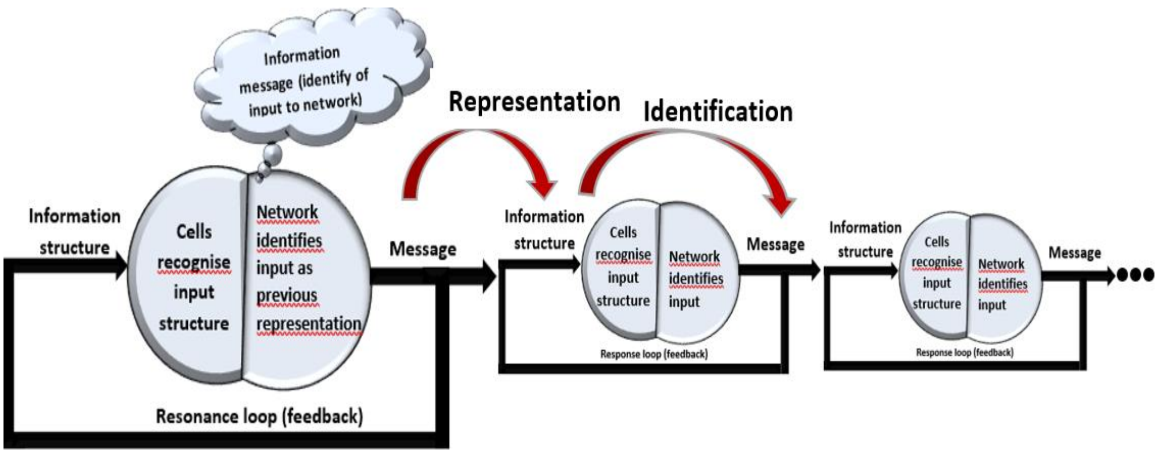

Fig. 3 Resonance loop in attractor behaviour

The development of attractor states depends on how the feedback stimulates the behavior of networks, allowing the development of some and respectively inhibiting others. Such control would lead to a kind of brain-wide constraint satisfaction of the set of activities that includes all existing networks maintained in an attractor state. The set of qualia generated at that time could constitute the brain's conscious state at that time.

The formation of synapses requires long-range interactions and the interacting cells first create a dynamic system with its own attractor, that is, a fragment of time and space in which dynamic processes occur. Thus, each input to the network will result in a stream of collective node configurations (also called an "attractor") that represents the network's response.

4. Assessment of meaning in neural networks

Information and meaning are important part of the world surrounding us, as well as part of ourselves. The main problem is that the interpretation of the meaning of the information is subjective, it depends on the person which analyses the information. Our problem is to identify if the process of identification in QS is also subjective, the subjectivity due to qualia transmission way.

Let consider that information can be transmitted only carried by a signal. By associating information to a signal, we define information as the content of the energy variations of the signal. Consequences are that a given signal can carry several different information, and that a signal always carries an information. By the same way, a meaningful information that has been produced by a system will continue to exist even if the system that has originated it does not exist anymore. The meaningful information exists as a component of the signal carrying the information. More specifically, a meaningful information as we have defined it will still be meaningful in the absence of the constraint of the system that has produced it. In other words, the meaningful information exists with the signal that carries it, and this even if the system that has created the meaningful information disappears.

We can now consider a systemic description of the process of knowledge (or information) transmission. Note that “information” and “knowledge” are both a kind of “family concepts” in the sense that they can have different meanings depending on the context where they are used, and thereby the ontological level they are related to. It is a classical triadic model composed from the prerequisite (input), the process of being informed, and finally the output of the process. By acting and using the knowledge the receiver will gain new experiences, which through reflection will add to the total knowledge base of the person. One additional difference is that we cannot really talk about knowledge as an object independent of any subjective holder. That is a characteristic that is only valid when we talk about information as an object. In other words, the process and the result of the informing process always involve someone, i.e. those meanings of the word “information” are subject-dependent. In order to clarify these points, we need to introduce the notion of "efficiency of a meaning" that characterizes the possibility for the meaningful information to participate to the determination of an action aimed at satisfying the constraint of the system. We define the efficiency of a meaning as being the aptitude of the meaningful information to participate to the determination of an action aimed at the satisfaction of the constraint of the system. We will note "efficiency (S)" the efficiency of a meaning relatively to the constraint S of the system and also, we will define "domain of efficiency (S)" the domain of efficiency of a meaning relatively to the constraint S of a system. And we will state that the domain of efficiency (S) is the location where the constraint S of the system exists.

Without any other arguments, we can consider that in brain, the Qualia Space is the “domain of efficiency (S) of a qualia signal". In other words, the meaningful (S) information is efficient (S) in the domain of efficiency (S). In it’s domain of efficiency, a meaningful information can participate to the determination of an action aimed at the system's constraint satisfaction. Outside of it's domain of efficiency, the meaningful information will still be meaningful but this meaning will not be usable for determining an action related to the satisfaction of the system's constraint. The information is meaningful, but the meaning is not efficient.

5. Conclusions

In this paper we mainly discussed the relationship between the notions of meaning and respectively the semantic notions as they appear in information transfer models. We believe that the concept of control information provides a new tool for analyzing cybernetic processes and informational processes. From an examination of the information processing capabilities of local neural networks it has been shown that interesting properties emerged if the local networks were encouraged to establish attractor dynamics. We can say that a new cybersemiotic model of information transmission approach has succeeded, highlighting the connection between *qualia* (the reality of consciousness) and the physical reality of the brain. It is shown also that the measurement of meaning allows in the same time to determine the capability to change the cognitive information and to measure the uncertainty of an experimental outcome. The importance of the feedback introduced on the appearance of the conscious perceives the sensory cortex synthetically was also highlighted.

Specifically, we analyzed the extent to which models of information transfer can be framed within a "theory of meaning" and demonstrate the ways to quantify information between the variables in the model to find the relationship between meaning and the semantic notions defined in cybersemiotic models. That is why future research will aim to demonstrate that the measurement of meaning allows, at the same time, to determine the ability to modify cognitive information and to measure the uncertainty of an experimental result.

R E F E R E N C E S

[1]. *A. Sharov*, Mind, Agency, and Biosemiotics, Journal of Cognitive Science, 19(2), pp. 195-228, 2018

[2] *S. Brier*, The Cybersemiotic Model of Communication: An Evolutionary View on the Threshold between Semiosis and Informational Exchange, tripleC, 1(1), pp. 71-94, 2003

[3] *R. D. Orpwood*, Qualia could arise from information processing in local cortical networks. Front. Psychol. 4:121, 2013

[4] *R.D. Orpwood*, Information and the Origin of Qualia, Frontiers in Systems Neuroscience, vol.11, art.22, pp. 1-16, 2017

[5] *R. Dobrescu, & D. Merezeanu*, From information to knowledge transmission of meaning. Rev. Roum. des Sci. Tech. Ser. Electrotech. Energ, 62(1), 115-118, 2017

[6] *I. Riciu, R. Dobrescu*, Semantic Perception of Meaning in Brain, U.P.B. Sci. Bull., Series C, Vol. 85, Iss. 3, pp. 37-48, 2023

[7] *F. Pulvermüller*, Neurobiological Mechanisms for Semantic Feature Extraction and Conceptual Flexibility. Topics in Cognitive Science, 10, pp. 590–620, 2018

[8] *G. Tononi, et al.*, Integrated information theory: from consciousness to its physical substrate. Nature Reviews Neuroscience, vol.17, pp. 450–461, 2016