SEMANTIC PERCEPTION OF MEANING IN BRAIN

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This paper highlights the relationship between the notions of meaning and respectively the semantic notion of qualia as they appear in cybersemiotic models of information transmission. The research work proposes a new way to model the perception of meaning in brain, based on an original cybernetic aproach of the relation between information structures and information messages at the level of brain's neuronal networks.

Keywords: Perception, Meaning, Qualia, Information, Cybersemiotic, Transdisciplinary.

1. Introduction

The scientific investigation of mental phenomena is still characterized by strong contradictions and controversies, despite the remarkable advances of the cognitive sciences. A discussion of great interest is that of the relationship between the concepts of information and meaning. From the simple equivalence of the two, to the establishment of subordinate relationships, different approaches propose more or less plausible models that explain the connection between these concepts. Because in classical theory information is closely related to communication, and the meaning to signification, it is explicable that semiotics as a science that deals with communication of signs has provided a basis for models that explain the relationship between meaning and information using semantic notions. Moreover, biosemiotics [1] provided the framework in which these models can be associated with neural processes.

It is understandable that when referring to (bio) semiotics, a scientist begins by discussing the semiotic triad proposed by Peirce. Brier does the same when introducing the concept of the cybersemiotic model [2], in which he tries to integrate Pierce's semiotic principles with the systemic aspects of cybernetics. Brier takes an important step in this direction, appealing to an essential concept of biosemiotics, namely the notion of qualia, as it was defined by Peirce in relation to the functional aspects of feelings, i.e in relation to their cause and goal.

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Brier has written numerous papers proposing to impose cybersemiotics as a transdisciplinary theory of communication, knowledge, and information. To this end, he proposes a model to describe the semantic mediation of the content of a message from a producer to a user, including also the phenomenological and cognitive aspects. 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. Unfortunately, the cybersemiotic model is not a mathematical model of a physiological process, but only a speculative model that shows whether the system of interpersonal communication indicates another level of significance in experiences that highlight the feeling of qualia as a carrier of the message. Moreover, Brier is not at all interested in how the information is transmitted to the brain.

Around the same time, starting in the 1990s, R.D. Orpwood publishes several papers in which qualia is seen as an information-carrying physiological signal. With a bachelor's degree in physiology and a second bachelor's degree in engineering, Orpwood uses without reticence the mathematical tools of information theory to explain how to transmit qualia to the cortex. He states [3] that qualia is a result of information processing in local cortical networks and distinguishes 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). Although concerned with the meaning of the informational message conveyed by qualia, Orpwod makes no reference to semiotic issues. But in more recent work (e.g. [4]), discussing how qualia transports meaning in the information to the brain in the paradigm proposed by Tononi [5] on the inclusion of consciousness in Integrated Information Theory (IIT), Orpwood presented a simplified model from which by rearrangement Peirce's semiotic triad can be found. He states: “All that constitutes our inner conscious world are aspects of semantic information, related to the physical processing of information that takes place in the triggers of our neurons”.

Tononi's ideas are taken over most of the works that Pulvermuller dedicates to the processing of meaning in the mind and brain. Specialized in neurology and linguistics, Pulvermuller is concerned with the neurobiological models used to describe semantic mechanisms that involve the transfer of information to the brain (he states "semantic information is the meaning associated with physical information" [6]) and implicitly refers to the semiotic triad, which he describes after the triadic model proposed by Ogden and Richards in 1923 [7]. This model makes no reference to the Peirce triad, nor implicitly to the term qualia, which does not appear in Pulvermuller's.

The mentioned research studies 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. Because this issue has been addressed by the authors of this paper (see [8]), we have considered the possibility of merging the models into a single model that equates the essential notions and provides the basis for semantic interpretation and neurocognitive interpretation of the perception of meaning in the brain. Intuitively, we appreciate that a cybersemiotic model could provide the frame of reference for this integrated model.

2. Proposal for a triadic cybersemiotic model

By proposing as a central objective, a comprehensive science of information, cognition and communication, cybersemiotics is assumed as a transdisciplinary vision that integrates different frameworks at a meta-theoretical level that gives rise to a different vision, not only of life and cognitive processes, but of its communication and epistemological construction. Therefore, a general transdisciplinary theory can be developed from each of the concepts, including, of course, communication.

In cybersemiotics we integrate Peircean biosemiotics with cybernetic view of information into a new transdisciplinary framework based on triadic semiotics. Peirce’s radically new way of thinking, and it has made a great impression on what became the Copenhagen School of biosemiotics and its members Jesper Hoffmeyer, Claus Emmeche, Frederik Stjernfelt and Søren Brier. The proposed framework is developing an integrative multi- and transdisciplinary theory of the complex area of cybernetics information science for nature plus the semiotics of all living systems cognition, communication, and culture, with meaning as the overarching topic. It is an integrated transdisciplinary, philosophy of science, and semiotics meta-level from where to monitor our multidisciplinary research endeavor. What is still the problem for the sciences is the phenomenon of meaning and how that can develop from an informational world.

In Peirce's triadic biosemiotic model, qualia is one of the basic ontological elements of reality, along with feelings, habit formation, and meaning. By extension, and as a result of 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). The qualia study explains how the transmitted messages are represented by the informational structures and how the informational messages can be identified from the structures.

Fig. 1 shows 4 triadic models, which reflect three essential semantic notions: representation, referencing and interpretation, which are associated with defining terms for physical support (sign, object, meaning), as shown in Pierce's original model Fig.1 a). Note that the term of interest for this article ("meaning") is passed as a support, because it appears as a final product of interpretation, usually in the form of a pattern. Depending on the author, other terms were used for the supporting elements (symbol for sign, concept for object, sense for meaning). The second term of interest is qualia. It appears implicitly in three models (Fig. 1 a, b and c), associated with the referencing operation (equivalent to concept). In the Pulvermuller model qualia does not appear but can be associated (see the comment in Fig. 1d).

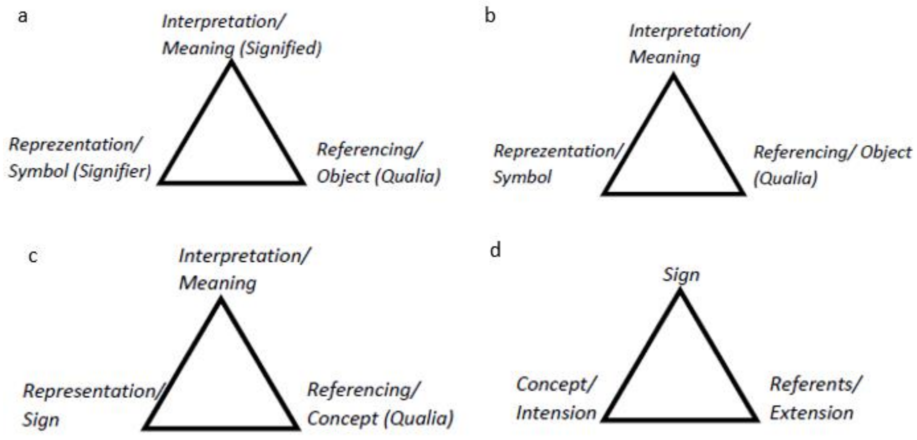

Fig. 1. Representation of different models of the semantic triangle - all based on Peirce 's semiotics: Representamen, Object and Interpretant
a. Peirce's Semiotic Model; b. Brier Model; c. Orpwood Model; d. Pulvermuller Model.

As shown in Peirce's Semiotic Model (Fig.1 a), the relationship between a representation and the referent (that sometimes results in meaning making), involves an interaction between the sign or representation (what is created), the referent (what is being represented) and the meaning made (personal interpretation). The development of semiotics to a transdisciplinary scientific field is mostly based on Peirce's triadic evolutionary and pragmaticistic semiotics. A symbol in Peircean semiotics is a sign where the code is conventionally and arbitrarily defined. It can be a word in common language, but gestures and things. Brier Model (Fig.1 b), proposes the concept of propositional content of a signal, which can be read from an "informational content vector" and wants to show the system of inter-human communications and control indicates another level of significance in experiences with the feeling of qualia (carrying agent) and wants to see if it is possible to couple systems theory with Peirce's triadic and pragmatic semiotics.

Orpwood does not exactly represent Peirce (Fig.1c), but we can easily translate his ideas into this model. He says in his work as an important set of ideas about the locus of conscious perceptions it revolves around the concept of re-entered feedback. The information message is a more abstract concept and the content of consciousness comprises information messages,not their structure. However, the conclusion after a few cycles feedback is that the network is recognizing its input structure as how its original input "seems" to it. This outcome is identical to the concept of qualia. Given these, Peirce's model can be represented from Orpwood's perspective. The cybersemiotic model could be the transformation of the Orpwood model. The output becomes a representation of the identity of itself (which is interpretation).

Pulvermuller Model (Fig.1d) shows the relationship between a sign and its meaning, using an intermediate form of referencing, called Concept (associated with the term Intension). This term can be equivalent to Qualia. Instead, the term Referents (associated with Extension) appears to be inappropriate for the Interpretation action. In fact, in the original model of Ogden & Richards the term used is Tought or Reference, which can be very well associated with Meaning. According to Faggin [9], three main terms are essential for understanding qualia:

- Comprehension: “indicates the integration of all our understandings and provides the context for any new understanding to occur.”

- Understanding: “requires to intuitively “get” how the elements of a body of knowledge are linked together within the context of comprehension, thus capturing the deepest possible meaning.”

- Knowing: “refers to the process that constantly increases comprehension by the integration of new understandings.”

Knowing is a difficult process to explain, because it requires a sophisticated combination of differentiation and integration. Differentiation is based on the ability to discriminate the subtle differences and similarities between the elements we try to join in a new cognitive structure to give rise to a new understanding. Integration involves the ability to synthesize a new set of semantic relationships between lower-level cognitive elements by "connecting" them into a new structure that will ultimately characterize the new understanding. In other words, a new comprehension occurs when a provisional understanding (a local component, a part), trying to integrate with the previous comprehension (a global component, the whole), reaches the point where “the whole integrates the part”, forming a new whole in the instantiation of knowing.

Firstly, let note that a theory of meaning can by understood in two senses. In a large sense, it is obvious that the classic triadic sender-channel-receiver communication system can give pertinent answers to all three questions. But there is also a "Theory of Meaning" in the narrow sense, (closer to naturalistic communication), which aims to answer only one question: what does it mean for a state S to mean M? The question also contains the causal hypothesis, because only for the information associated with state S there is the meaning of M. In our research we decided to adopt the narrow sense, because it directly represents the relationship with semantics. Moreover, we will assume that the meaning of a message is independent of the observer.

To summarize, let's specify that the conversion from signals to qualia is called perception and the conversion from qualia to meaning is called comprehension. We now have the necessary notions to discuss how qualia ensures the transport of meaning contained in information to the brain in the paradigm proposed by Tononi [10] on the inclusion of consciousness in integrated information theory (IIT).

3. A cybersemiotic approach to the transmission of meaning

A special point of view is the application of information theory to the relationships between states, signals and actions. It is often said that information theory refers to the evaluation of quantities of information and not to informational content, but in this paper, we focus on highlighting the semantic content of biological signals. In [11] the concept of propositional content of a signal is proposed, which can be read from an “informational content vector”. The authors claim that this content is highlighted only in models of information transfer in contexts of common interest through which the semantic part of "meaning" is separated from the pragmatics of the transfer of information structures.

Conceptually, the cybersemiotic approach to the transmission of meaning highlights the connection between qualia (the reality of consciousness) and the physical reality of the brain. But this intimate connection is very complex; in fact, forcing things a little, we can say that the nature of qualia cannot be explained scientifically, because no phenomenon can be associated with it exactly - be it nervous, informational, chemical or physical. 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. So far, however, a robot with feelings has not been designed, which suggests that consciousness belongs to a different order of reality, something beyond a purely mechanistic approach.

Obviously, the integrated model aims to formalize 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 Pulvermuller's articles and Orpwood's 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. On the other hand, there are 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. The cybersemiotic approach should be a bridge between Pulvermuller and Orpwood research to the transmission of meaning, highlighting the connection between qualia (the reality of consciousness) and the physical reality of the brain.

Both Orpwood and Pulvermuller takes up Tononi's hypothesis that two types of information can be labeled in the brain (Fig.2).

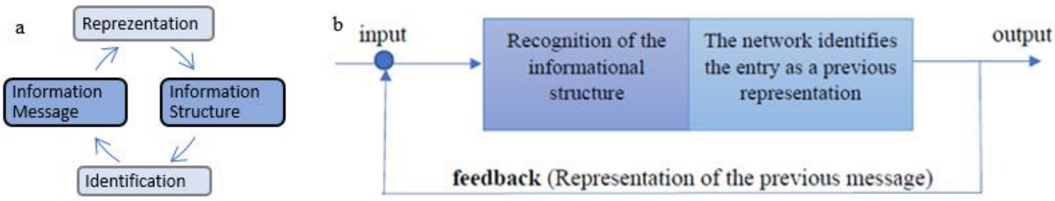

Fig.2. Correlate between the information structure and the information message. a - Reciprocal transformations between structures and messages; b - Response during attractor behaviour.

Thus, the physical information present in the brain is labeled as "information structure", and represent physical activities triggered at the cellular level 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.2a).

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 (Fig.2b). The presence 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 (qualia) feedback is necessary.

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.

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 a state which is called by Orpwood “attractor states” (Fig.2b).

4. A cybersemiotic model for perception of meaning in brain

Messages can be transformed into structures through a process of representation. Structures can be transformed into messages through an identification process.

Informational structures can be transmitted through a classic sender->channel->receiver type structure. In summary, we can say that:

• Information can be in the form of structures or messages.

• The physical activity of the brain deals with informational structures.

• Our inner conscious world is fed with informational messages from qualia space.

• Structures represent messages, and messages can be identified from structures.

• Only structures, not messages, can be transmitted from a sender to a receiver.

If we consider the basic (minimal) structure of the information transmission system with a single neuron, the transmitter is configured to initiate the generation of an informational structure following internal state changes. The emitter can be a simple timer, an internal clock configured to send a signal when it reaches a predetermined time marker. The signal is the transmitter's output informational structure through which the transmitter reports the event represents the "reached landmark of time" event. The emitter does not phenomenologically participate in experiencing the events, it only reacts to the event by generating an informational structure. The signal it generates is the information structure, and the "reached landmark of time" is the information message. The information structure represents the information message, but only for that sender.

For a receiver of this information, the information structure can represent an infinite number of different messages. A receptor capable of recognizing an input pattern will only react with a specific activity, for example changing the level of depolarization of a pyramidal cell, firing of a pyramidal cell, or even a more complex activity such as a firing pattern of a neural network, by generating another informational structure in itself. But whatever the response reaction to the input information, the receiver can only recognize the informational structure, not the informational messages.

Of course, the problem of transmitting information in the brain becomes more complicated if we consider ensembles of neurons, which we will further define as neural networks. These cortical networks consist of large numbers of pyramidal cells and supporting interneurons, which act in a coordinated manner in response to an input informational structure. Such networks are capable of recognizing input patterns, but they can also generate their own output patterns in response to recognition.

A local cortical network can be part of a chain of networks, possibly structured on several hierarchical levels. For each network in the chain, the basic dual process (recognition/identification) occurs. The network recognizes an input informational structure and generates an output informational structure that represents the identity of the input to the network. This structure will be communicated to the next network in the chain. This process can be repeated along the entire chain of networks.

A key assumption in this article is that the basic information-processing entities in the brain are not individual neurons, but ensembles of neurons or networks. There is a growing belief that ensembles of neurons, rather than individual cells, are the key to linking neuronal dynamics and their function in information processing. Such networks are able to recognize patterns in their inputs and can generate their own output patterns of firing activity in response to such recognitions. 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 (Fig.3).

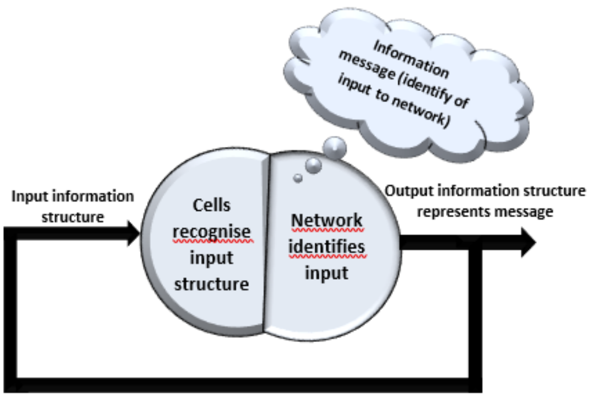

Fig. 3 Normal network response

The network can recognize its input structure and generates an output structure that represents the identity of the network input. 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, and so reaching the attractor state defined in Fig. 2b.

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 (Fig.4).

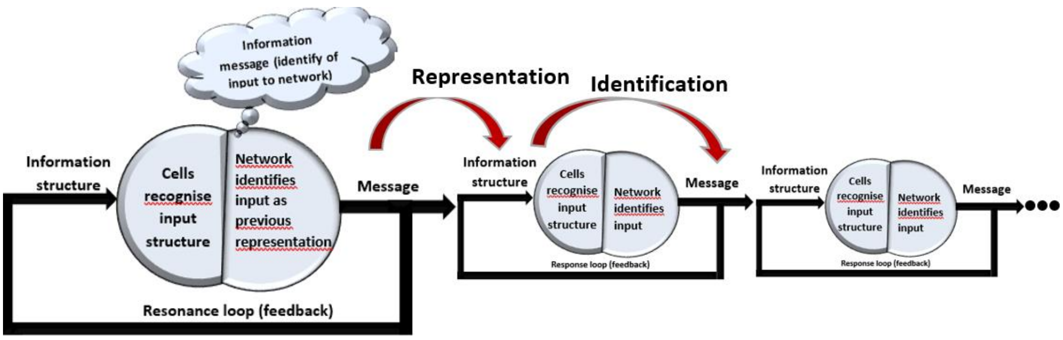

Fig.4 Resonace loop in attractor behaviour and the representation of the original message

Fig.4 shows an example of connecting a chain of simple networks. Entering Network 1 can 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.

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. According to the above and the summary, a cybersemiotic model of the qualia space was created to exemplify the transmission of informational structures. The problem is that in terms of neuro-modelling, the feedback that leads to the attractors and the mathematical representation of their behavior is very complicated. To solve this problem, future research will aim to translate this model into a simulation neuro-modelling environment (LabView or Matlab).

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 *qualia* provides a new tool for analyzing cybernetic processes and informational processes. It provides a measure of informational unity in a given context and it is the role of great scientists to boldly invent new ways of looking at reality and gain knowledge.

From an examination of the information processing capabilities of local 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 models of information transmission approach has succeeded, highlighting the connection between qualia (the reality of consciousness) and the physical reality of the brain.

The importance of the feedback introduced on the appearance of the conscious perceives the sensory cortex synthetically was shown. The actions implemented will depend upon the constraint of the systems receiving the information. 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. Specifically, we analyzed the extent to which models of information transfer can be framed within a 'theory of meaning'.

Current research has shown ways to quantify information between the variables in the model to find the relationship between meaning and the semantic notions defined in cybersemiotic models. Also, we managed to merge all the models from the specialized literature into a single model that equates the essential notions and provides the basis for the semantic interpretation and the neurocognitive interpretation of the perception of meaning in the brain, which constitutes the reference base for the development of an integrated model.

On the other hand, this integrated model can be a starting point for a new basic research of fractal geometry on the functions of neurons as self-organization guided by information and the novelty element would be: "self-organization of fractal systems in qualia space".

We can conclude the relationship between meaning and the semantic notions defined in cybersemiotic models extend the traditional framework of Information Transmission, and it can be a fruitful way of research in the future (being in fact the subject of the doctoral thesis of the first author, which is in the elaboration phase).

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