Consciousness, as an emergent process

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Abstract. Starting from the wave-corpuscle duality in quantum physics, we propose a model for structuring reality, based on the emergence of systems that contribute to the integration and coherence of the entire reality. Thus, the mind-brain duality, which has been dominating the representation on psyche for a few centuries, could be solved by an informational approach, describing the connection between object and subject, reality and human consciousness, between mind and brain, thus unifying the perspective on natural sciences and humanities. Physical-mathematical models based mainly on (mereo) topology can provide a mathematical formalization path, and the paradigm of information could allow the development of a pattern of emergence, that is common to all systems, including the psychic system, the difference being given only by the degree of information complexity.
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1 Introduction

Progress in neuroscience has left a central question of psyche unanswered: what is consciousness? Modelling the psyche from a computational perspective has helped to develop cognitive neurosciences, but it has also shown their limits, of which the definition, description and functioning of consciousness remain essential. From Descartes, who tackled the issue of psyche as the brain-mind dualism, to Chalmers, who defined qualia as the tough, difficult problem of research in neuroscience, many hypotheses and theories have been issued to encompass the phenomenon of consciousness. Neuroscience specialists (e.g. Tononi or Eagleman), consider consciousness as a phenomenon of emergence of all processes that take place in the brain. This hypothesis has the advantage of being supported by progress made in the study of complex systems in which the issue of emergence can be mathematically formalized and analyzed by physical-mathematical models. The current tendency to associate neural networks within the broad scope of network science also allows for a physical-mathematical formalization of phenomenology in neural networks and the construction of information-symbolic models. The extrapolation of emergence at the level of physical systems, biological systems and psychic systems can bring new models that can also be applied to the concept of consciousness. The meaning and significance that seem to structure the nature of consciousness is found as direction of evolution and teleological finality, of integration in the whole system and in any complex system at all scales.

2 Challenges of the information paradigm in neurosciences

In the field of epistemic knowledge, once modern sciences took shape, there was also the passage from the age of mechanics governed by Newtonian laws to the age of energy, marked by

Einstein's relativity theory, quantum physics and atomic energy. In the second half of the twentieth century, what we call the era of information science, has gradually emerged, which forefronts the role of information in the knowledge of reality. The identification of information in previously established theories, laws and physical-mathematical models becomes a necessity imposed by the current development of knowledge. It is imperative to establish the ontological role of information, together with substance and energy, as well as the relations between the components of the triad, which underlie the structuring of reality.

Since the beginning of the 20th century, the role of the observer in describing quantum phenomena has been highlighted for the first time. The dilemmas of physicists and philosophers, as well as contradictory discussions, have not ceased up to the present day. The principles of computer science prove that both the transmitter and the receiver, both object and subject, must be in correlation (coherence), and that a certain structure of reality can be perceived only to the extent that there is a representation, an axiomatic context in the brain of the subject on observational aspects of the object. Therefore, the axiomatic logic discussed by mathematicians since antiquity is still today, in the informational era, a way to connect the object and the subject, the observer and the reality, the brain and the mind.

Today's technology, including information technology, is based on research from the 19th and 20th centuries, related to electromagnetism laws, relativity theories and quantum physics. They have mathematically imposed the use of complex analysis. The old conception of mathematicians that this field of mathematics is an abstract domain must be revised so as to understand the dynamics of information between the a-spatial, a-temporal reality of the field and the space-time dynamics of the corpuscle. As a result, conferring a physical significance to the complex space allows the understanding of reality through the dynamics between real space and complex space via information.

A duty of the twentieth century physicists remains today a proper and complete description and description of what we call field. Theories from the last half of the 20th century related to fractal geometry, chaos theory, non-linear dynamics and topology have led to the theory of complex systems. This research imposes, on the one hand, a rewriting of Physics from this perspective, but also the possibility of building a general theory of the field, in which information, too, can be found.

The fractal structure of reality can lead to a set of principles that allow for a physic-mathematical modelling to construct a theory of the fractal field, a basal field which, depending on the scale, is built of specific particles, and which gives coherence and unity to reality at any level. Linking the subject to the object by correlation (coherence) makes it possible to know reality, because fundamentally, there is a logic common both to the subject and the object and which enables the informational link between subject and object, between the observer and the reality.

The latest discoveries by Gallant et al. [6] highlighted the semantic system of the brain. This underlines the fact that the semantic logic of language studied over the past 50 years by semiology and semiotics is the logic based on which information is processed in the human brain. The connection between the neural network and the spectral network of the brain presupposes the phenomenon of coherence, as well as an equivalent logical topology. It seems that both the brain and the mind use a semantic logic. The brain functions on the basis of the laws of physics, being the most complicated complex system. The dynamics of this system follow the laws of an emerging topology, which is, nevertheless, consistent with the semantic logic of the mind. The conclusion is that both the mind and the brain function on the basis of the same logic and topology, i.e., the emerging semantic logic. In fact, IT practitioners already operate with semantic information, algorithms and semantic webs, semantic networks and ontologies.

3 The process of emergence

Emergence plays a central role in theories of integrative levels and of complex systems. For example, the phenomenon of life studied

in biology is an emerging property of chemistry, and psychological phenomena arise from the neurobiological phenomena of living things. Through emergence, new systemic levels occur, usually leading to a jump in the functioning of systems, as well as to the emergence of new properties resulting from a new form of organization (Crumpei and Gavrilut [3]).
In philosophy, system theory, science and art, emergence occurs when "the whole is greater than the sum of the parts", i.e., the whole has properties that parties do not have. These properties are due to interactions among parties.
An emerging property of a system is a property that cannot be explained by the traits of its parts. In any system / biosystem, its parts and elements generate new properties, establishing, through interaction, new dynamic relations, either of which have not existed initially, being unpredictable prior to their systemic integration.
On the other hand, reductionism is described by several philosophical ideas connected to associations among phenomena that can be described in terms of simpler or more fundamental phenomena. Reductionism does not deny the existence of phenomena but explains them in terms of another reality.
Reductionism does not exclude the existence of what could be called an emerging phenomenon, but it involves the ability to understand these phenomena completely in terms of the processes from which they are composed. This reductionist understanding is very different from emergentism, which intends that what appears in "appearance" is more than the sum of processes from which it occurs.
Emergence can be highlighted, depending on the system approached, through a series of mechanisms:
- Processes characterized by incompatibility (algorithmic limits);
- Systems with a large number of elements;
- The emergence of nonlinearities in the evolution of systems;
- Systems with feed-back and feed-forward mechanisms;
- Presence of the non-localization principle;
- The emergence of chaotic areas in which the direction of evolution of the system is given by the competition of attractors in the basin of phases.

These processes are encountered in what is currently the complex systems theory, which includes fractal geometry, non-linearity, topology and chaos theory.
'The impossibility of reducing the whole to its parts, as well as the rejection of physical reductionism (there is also a mathematical reductionism, through which mathematics can be reduced to classical logic, as understanding), the interactions of the elements (annulling the differences - by combination), the hierarchical level (achieved sometimes by the transformation of quantity into quality), the existence of the chaotic state (deriving, in a general framework, from an initially stable state, through the emergence of bifurcations), and the estimation of its limits, the passage from the discontinuous (microscopic) form to the continuous (macroscopic) one (which, in turn, is likely to represent a certain form of discontinuity for other higher levels of knowledge and perception) generates a “causality rupture” (Baiculescu [1]).

4 The brain’s semantic system

Research from the last century has made semiology, as a field of philology that studies the significance of natural language, to be extrapolated through semiotics as a science of sign meanings, in many fields of social and human sciences, as well as in natural sciences and in information technology. Nowadays we talk about semantic web, semantic algorithms and semantic logic, whose goal is to building programs and systems that are related to artificial intelligence.
At the same time, the semantics of information is a field of research of human cognition, starting from the reality that language is the expression of thought, and studying the semantics of language is a specifically human analysis of processing. Syntax, semantics, pragmatics, as well as the hermeneutical and holistic approach, are logical mechanisms that can explain superior psychic processes, such as abstraction, conceptualization, generalization, symbolization and metaphor. They have all been used in the

narrative process since times immemorial, but they have not been analyzed in a holistic perspective, which has to do with the structuring of reality, both of the physical and psychic reality.
New approaches in cognitive psychology and neuroscience in general hold information at the forefront, together with the way in which, starting from data, information becomes a set of knowledge that can describe reality.
Beyond the quantitative aspect of the information, present in Shannon and Weaver's information theory, its qualitative component is important from a psychological point of view. This qualitative component is given by its significance. Semiology and semiotics, meaning and semantics are, therefore, notions resumed today from a different perspective, not only the philological one. This has led to the development of semiology as a way of analyzing the text. Today, semantic information is a phrase analyzed by both philosophers and IT experts (semantic information, semantic web, ontologies).
The semantic aspects of information are very important for psychologists as well because the structure and way in which the nervous system works impose this approach. Nervous structures, from the periphery to the cortex, contain over-layered nodular nuclei of increasing complexity, from the spinal cord to the bulb and the cerebral trunk, then to the diencephalon and the subcortical centers. Information undergoes completions, from simple binary data, combined in frequencies and amplitudes, to evermore complex information structures that reach the level of the cortex in order to create images by mapping, used for our representations of reality.
The meaning of language is represented in the regions of the cerebral cortex, commonly referred to as the semantic system. Until now, a small part of the semantic system has been mapped, the semantic selectivity of most regions remaining unknown. In April 2016, Gallant et al. [6] from Berkeley published in Nature a study in which they systematically mapped semantic selectivity in different regions of the cortex using “voxel-wise” in their research with functional MRI. Subjects have been subjected to narratives they listened to for several hours, and the research highlighted the organization of the semantic system in stable patterns from one

individual to another. Generative narrative models were then used to create a semantic atlas in detail. The results suggest that many areas in the semantic system represent information related to specific semantic domains or groups of related concepts that are located in cerebral areas related to the multiple meanings that notions and concepts can have.

These semantic maps give us for the first time a detailed map of how significance is represented on the entire surface of the human cortex. Instead of noticing that language is limited to just a few brain areas, we find that it activates quite large areas of the brain. We also find that these representations (Gallant et al. [6]) are bilateral: reactions from the right brain hemisphere are approximately as large and varied as reactions in the left hemisphere.

Continuing research in this field, as well as our approach connected to semantic logic (Crumpei, Gavriluţ, Crumpei Tanasa, Agop [4]) may lead to new theories connected to the functioning of the mental component of the psychic system.

5 Emergent semantic logic

We currently have two separate but complementary approaches: a semantic system of the brain, described by the modern techniques of functional MRI, statistical programs and computer processing on the one hand, and on the other hand, a study of language semantics and a semiological study of signs in general during the last century. Given that language is the basis of superior psychological processes (the logic of language expresses the logic of thought), a theory is needed to explain this connection between thought and language. If the new highlighting (Gallant et al. [6]) of the brain's semantic system describes the localization of the polysemantic meanings of words in neural structures (semantic hardware), it is necessary to focus on the program that uses this neural structure (semantic software).

In our conception, this program involves describing a special logic, the semantic logic (Crumpei and Gavrilut [3], Martin [7]). For coherence reasons, this logic is used both in structuring the brain as an emerging complex system and in structuring the semantic mind. This is the emerging semantic logic. There is, therefore, information that we call emerging semantic information. The logic on which this information is structured will be called emerging semantic logic. This is different from the bivalent logic, as well as from the multivalent or fuzzy logic, since the values that may be true cannot be assessed probabilistically but are conditioned by their semantic value.

6 Physical-mathematical argues

Research in the field of complex systems did not succeed in reaching a hypothesis which could explain the emergent properties, just as the relationship between the dynamics of the component elements of the systems and the properties of the system as a whole. Physics laws are now described by two fundamental theories: relativity theory and quantum mechanics developed in the framework of quantum field theory). Both theories are highly efficient and accurate in terms of the predictions they make. The constraints imposed by the restricted relativity were even incorporated in relativistic quantum theory. But these two theories are based on different bases, which are still complementary even if they seem to be contradictory in appearance and use different mathematical tools.

General relativity is a theory based on fundamental physical principles, namely, on the principle of general covariance and the principle of local equivalence. His mathematical tools appear as natural realizations of these principles. On the other hand, quantum mechanics is based on a mathematical formalism which, until now, was not enough depth. These findings lead to a strong dichotomy in physics: two seemingly opposed worlds cohabiting, the classical one and the quantum one. Gravity, in particular, so clearly and precisely described by Einstein’s theory of general relativity, has failed so far to describe acceptable quantum field theories. In

contrast, our understanding of electromagnetic interactions, weak and strong, made great progress in the quantum gauge theories, while all classical attempts of unification (i.e., gravity and electromagnetism) have ended in failure.
All these, as well as others, indicate that physics is still in a ”embryonic” stage, so that the big problems are still open. There is currently no theory able to make predictions on the two directions of the world of physics, namely elementariness and globality, i.e., on scales (small and large) of time and length.
At small scales, the ”standard” model of elementary particles based on quantum chromo-dynamics and on electroweak dynamics, is able to include the observed structure of elementary particles and coupling constants. However, the model is unable, at least in the moment, to predict on purely theoretical bases, both the number of elementary particles and their masses, and coupling constants values. This failure must be correlated with the failure of electrodynamics (classical and quantum) in the divergence problem.
On the other hand, the fact that on very large scales, although the current cosmological theory knew great successes, we must not forget that general relativity, being a local theory (the instrument or base, the metric element, is differential), says nothing about the global topology of the Universe. This, together with the gravity source problem (why inertia curves space), is one of the limited areas in which general relativity is an incomplete theory, as Einstein even recognizes: a proof of this incompleteness can be even its inability to include the principle of Mach, except for some particular models, while the observations seem to imply that this is made by Nature.
The intermediate level, the classical one, is not devoid of open fundamental problems. In recent years, there had been an explosion in the dynamical chaos research. Generally, chaos is ”perceived” either as a strong sensitivity to the initial conditions of the motion equations solutions, which involves a rapid divergence (i.e., exponential) of the trajectories in the phase space, or as a complete loss of predictability on large time scales etc. Furthermore, chaos could generate ”order” through specific mechanisms (e.g., self-

organization) thus basing complex sciences. But either quantum or cosmology or complex sciences, they all prove to be reducible to scale dependent physical theories, i.e., to fractal space-time type theories.

The paradoxes highlighted by quantum mechanics in the first half of the 20th century include, apart from Heisenberg's uncertainty relations, a strange involvement of the observer in developing quantum phenomena.

The Copenhagen school avoided giving significance to these observations, but today they must be researched also from a philosophical and methodological aspect. Anyway, these facts suggest that the splitting into subjective and objective information is artificial and that they should be regarded as aspects of the same phenomenon.

In order to support this idea, we must take into account another paradox of quantum mechanics, which is just as exciting and linked to the entanglement phenomenon. The latter, as a result of repeated experiments, highlighted a reality which is hard to infer, that is that all particles which interacted at a certain point remain connected.

All these paradoxes that quantum mechanics imposed, along with the wave-corpuscle duality, determined a new approach in physics, mathematics and in the scientific approach in general. If during the 20th century information was studied from the point of view of elementary particles, of the wave component, from the spectral viewpoint and materially, under the form of substance and energy, it was not treated at its true value, according to the role it has in quantum mechanics.

The information technology and the complex systems theory (with the chaotic aspects in which information has a potential character, but which explains the dynamic patterns of evolution of the system which is highlighted in the phase space), have imposed the return to the role of information at quantum level.

An analysis of the particle behavior in the wave corpuscle duality can be regarded from the perspective of the fractal space-time, with the unpredictable and nonlinear evolution, allowing that, on the basis of Shannon's information theory, we can connect it to entropy and further to informational energy in the sense of Onicescu.

There still remains an essential question: where can we search for and find information in this quantum dynamics. It must be present both in the wave structure and in the particle properties. This connection cannot be made otherwise than in the phase component of the wave, which is to be found in the spinning of the particle and which allows for the transfer of information from the spectral reality to the corpuscle one, as the Fourier transform demonstrates.
The phase is given by the magnetic component of the electromagnetic field and represents the unpredictable, potential part, described by the complex function of Schrödinger's wave formula, as these characteristics can be explained both through fractal theory and through the topological transformations supported by the phase from the electromagnetic wave, respectively by the spin from the particle description. Thus, a complex space is organized, which explains the difficulty of highlighting the informational component.
The successive passage through the Euclidean, fractal and topological dimension determines the quantitative as well as the qualitative dynamics of energy. The moment this qualitative diversity is expressed is given by the moment of topological transformations at every level. This practically unlimited diversity provides also quality along with quantity to energy in its dynamics.
From the perspective of the complex systems theory, we can find, in the above-described phenomena, the main characteristics that are specific to complex systems: non-linear dynamics, fractal geometry, with a potential latent informational energy, along with a dynamics of a practically infinite diversity, obtained through topological transformations within the complex space of the phase.

7 Emergent semantic information

The topological transformations are not dependent on scale; they have the same qualitative information, no matter what the reality level is, which makes the information ubiquitous, just as substance and energy are both at microcosmic and at macrocosmic level.

Our hypothesis concerning the emergent semantic logic, based on the general principle related to the permanent flow between corpuscular and wave structures, between the information structuring matter in space and time and the information structured in the corresponding waves, can provide new premises facilitating the elucidation of the emergence mechanism.
Basically, what we encounter on the level of the nerve structure represents a general principle on the level of matter. This is why we call this information emergent semantic information, and the logic which enables us to structure this information is an emergent semantic logic, different from bivalent logic, but also from multivalent or fuzzy logic, as the values which may be true cannot be estimated probabilistically but are conditioned by their semantic value.
Studies in the field of semiology and of philology can be useful in order to understand these emergent phenomena, as language is most useful when trying to prove the role of semantics. Semantics is sensible to minor stimuli, just as in complex systems (Radu and Agop [8], Cilliers and Nicolescu [2]), having a determinist character, following a semantic logic which oscillates between the discreet and the continuous, the digital and the analogical, the fragmentary and the holistic. For instance, the meaning of a letter in a word is related to the role of the word in a sentence, of the sentence in the complex sentence, of the complex sentence in the paragraph, of the paragraph in the chapter, of the chapter in the book and of the book as an aspect of reality in relation to reality as a whole.
The quantum agitation is the expression of the wave-corpuscle duality and a proof of the oscillation of information between the three-dimensional space and the electromagnetic field. This oscillation is at the basis of non-linear dynamics, of continuous curves and of fractal non-differentiability (Gavriluţ and Agop [5]), but also origins in quantum agitation, which is present in the dynamics of the matter up to the cosmic level. Fractal geometry of reality is a proof of the connection between the corpuscular and the spectral structure. The non-linear evolution and the determinist chaos enable the dynamics of the matter, evoking at the same time

the link between the discrete and the continuous, between the fragmentary and the holistic.

In conclusion, any corpuscular structure from the three-dimensional space and time presents an informational equivalent dispersed in the modular waves, correlated with the spatial-temporal corpuscular structure. The wave-corpuscle correlation is preserved during the constitution of corpuscular structures and participates to their achievement. This is due to the discrete, fragmentary structural information, correlated with the continuous information, dispersed in the modular wave resulting from the integration of all the waves corresponding to the respective corpuscles. Even if it is not intuitive and we cannot imagine more than three spatial dimensions, this hypothesis of a dimension reserved to the field (the electromagnetic field) could help us integrate the different aspects of the information, both in the three-dimensional reality and in the timeless, a-spatial reality of the field.

The permanent functional link between the fragmentary and the holistic, the discreet and the continuous, the digital and the analogical one, can be mathematically formalized by mereotopology, a field underdeveloped nowadays. Mereotopology is a first-class theory in philosophy and computer science. It includes topological concepts (such as connectivity, interior, border etc.) and mereological concepts, highlighting part-and-whole relationships, as well as relationships between parts and their borders.

The emergent semantic logics (the semantic emergent topology, when applied to the reality structure) can contribute to elucidating the old mind-brain dualism, while also solving other paradoxes, especially that of the emergence theory.

Conclusions

When investigating the brain using mathematics and physics, biochemistry and biology laws and theories, it could be surprising, but extremely necessary, to apply semantic logic (specific to mental processing and to the dynamics of complex systems, to the phases 'basin and the attractors' dynamics) in the non-linear dynamics and system evolution. Thus, we could understand a phenomenon which interests both physicists and philosophers – emergence. The brain-mind duality, which has been dominating the psyche representation for some centuries, now could be solved through an informational approach, describing the link between subject and object, reality and human condition, mind and brain, unifying at the same time the perspective on natural sciences and human sciences.

References

1. S. Baiculescu. The emergence. Noema, Vol. XIV, 147-170, 2015.
2. P. Cilliers, B. Nicolescu. Complexity and transdisciplinarity: Discontinuity, levels of reality and the hidden third. Futures, 44, No. 8, 711-718, 2012.
3. G. Crumpei, A. Gavriluţ. Emergence, a Universal Phenomenon which connects Reality to Consciousness, Natural Sciences to Humanities. Human and Social Studies, VII. 2, 89-106, 2018.
4. G. Crumpei, A. Gavriluţ, I. Crumpei Tanasă, M. Agop. New Paradigms on Information, Mind and Reality. A Transdisciplinary Perspective. Junimea Publishing House, Iasi, 2016.
5. A. Gavriluţ, M. Agop. A Mathematical Approach in the Dynamics of the Complex Systems (in Romanian). Ars Longa Publishing House, 2013.
6. A.G. Huth, W.A. de Heer, T.L. Griffiths, F.E. Theunissen, J.L. Gallant. Natural speech reveals the semantic maps that tile human cerebral cortex. Nature, 453–458, 2016.
7. J.N. Martin. Epistemic semantics for classical and intuitionistic logic. Notre Dame J. Formal Logic, Vol. 25, No. 2, 105-116, 1984.
8. V.R. Radu, M. Agop. Complex Systems (in Romanian). Ars Longa Publishing House, 2013.