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Triple-aspect monism: Physiological, mental unconscious and conscious aspects of brain activity

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Brain activity contains three fundamental aspects: (a) The physiological aspect, covering all kinds of processes that involve matter and/or energy; (b) the mental unconscious aspect, consisting of dynamical patterns (i.e., frequency, amplitude and phase-modulated waves) embodied in neural activity. These patterns are variously operated (transmitted, stored, combined, matched, amplified, erased, etc), forming cognitive and emotional unconscious processes and (c) the mental conscious aspect, consisting of feelings experienced in the first-person perspective and cognitive functions grounded in feelings, as memory formation, selection of the focus of attention, voluntary behavior, aesthetical appraisal and ethical judgment. Triple-aspect monism (TAM) is a philosophical theory that provides a model of the relation of the three aspects. Spatially distributed neuronal dendritic potentials generate amplitude-modulated waveforms transmitted to the extracellular medium and adjacent astrocytes, prompting the formation of large waves in the astrocyte network, which are claimed to both integrate distributed information and instantiate feelings. According to the valence of the feeling, the large wave feeds back on neuronal synapses, modulating (reinforcing or depressing) cognitive and behavioral functions.

Keywords: Brain activity; neurophysiology; information; unconscious activity; conscious activity.

1. Introduction

The project of a science of consciousness poses several conceptual challenges. These can be identified by taking into consideration current knowledge of the typical example of a conscious system, the human brain.

The brain is part of the body of a living individual that interacts with the environment. Conscious episodes experienced by the living individual contain information patterns originated from the outside of the brain, transmitted to the central nervous system (CNS) by means of nerve pulses, as well as endogenously generated patterns. For the sake of methodological simplification, when focusing on the intrinsic activities of the brain it is convenient to refer to patterns embodied in brain activity without tracing their origin, but it should be made clear from the start that

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interaction with the environment is essential for the survival and proper cognitive/affective functioning of living systems.

A scientific description (and possibly an explanation) of brain activity should make reference to three aspects:

(a) *Physiological* processes covering structures and functions that involve *matter* and/or *energy*, including metabolism, catabolism, the release of transmitters, their binding with protein receptors, ionic fluxes, inter-cellular signal transduction pathways, diffusion of hormones in blood flow, etc. These processes are studied by scientific disciplines as biophysics, molecular biology, biochemistry and neurobiology;
(b) *Mental Unconscious* processes, composed of dynamical *patterns* (more precisely, frequency, amplitude and/or phase-modulated ionic patterns, detected and registered with the use of electromagnetic devices) embodied in neural activity and transmitted between brain systems, forming *cognitive and emotional unconscious processes*, including the "Unconscious" studied by Sigmund Freud in the beginning of the 20th century. These processes involve pattern transmission, recognition, storage, combination, interference, fusion, amplification, erasure, distortion, filtering and cancelation, in processes such as: transmission of sensory messages by means of a population frequency encoding, spike timing codes, feature detection by means of receptive fields with amplitude modulation, formation of representations by means of inter-cellular patterns of connectivity, network adaptive matching of "bottom-up" and "top-down" patterns and neuronal assembly encoding by oscillatory synchrony. These processes cannot be explained in terms of matter and energy changes only; an adequate explanation requires the tools of information and computation sciences. The scientific study of these processes is made in areas as information theory applied to electroencephalographic analysis, applied dynamic systems theory, computational neuroscience, cognitive computation and cognitive neuroscience;
(c) *Conscious* processes, consisting of *feelings* and related cognitive processes experienced in the first-person perspective, and indirectly accessible to the scientific researcher by means of verbal or non-verbal reports. These processes have been referred by philosophers as concerning a "what is it like to be" (Nagel, 1974), or "phenomenal" experience (Chalmers, 1996). The qualitative appearances in conscious experience have been called "qualia" (Crane, 2000). Conscious functions are *cognitive functions grounded on feelings*, such as: the perception of integrated scenes or episodes, selection of the focus of attention, voluntary behavior, selective memory formation, aesthetical appraisal and ethical judgment. These phenomena cannot be explained by means of information processing and computational mechanisms only. The structure of consciousness was described by Husserl (1913) as containing two domains, the subjective (the conscious "I") and the objective ones (the contents of conscious experience, or

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conscious episodes). The "Conscious I" or "Self" has been approached by means of philosophical methods as existential phenomenology (Merleau-Ponty, 1958) and mind–body practices as meditation (Walach *et al.*, 2012; Schmidt & Walach, 2014). The contents of conscious experiences can be described by means of the conceptual space analytical tool (Pereira Jr. & Almada, 2011).

The first two aspects have been studied in a variety of ways by brain scientists, using tools as the electroencephalogram (EEG), single cell electrode recordings and functional magnetic resonance imaging. The "hard problem" identified by Chalmers (1996) refers to the difficulty (or, maybe, the impossibility) of explaining the first-person conscious aspect from our third-person knowledge of the other two (physiological and mental unconscious) aspects. One clue to a possible solution (Chalmers, 1995) was the distinction of two aspects of information, but until today — 20 years later — this move did not lead to a tangible bridge principle able to logically connect the physiological with the conscious aspect.

In this paper, I do not try to solve Chalmers' problem, but attempt to show that it can be bypassed when taking into consideration an alternative approach, triple-aspect monism (TAM) (Pereira Jr., 2013), a theoretical approach to conscious systems as the human brain. For TAM conscious systems are integrated units in which the three aspects are complementary to each other. These relations can be conceived as a hetararchy of structures and respective functions, as shown in the next section.

2. An Analogical Model for TAM

TAM intends to cover the diversity of brain activity with three fundamental aspects. In a broader ontological picture, the evolution of the cosmos (or the evolution of a subsystem like Planet Earth) corresponds to trajectories in the state space of Nature (Pereira Jr., 2013). TAM requires a multi-dimensional state space, containing all possible states of Nature, both those that we know to have been actualized and those that remain in a potential state. In this paper, I concentrate on the state space of the human brain.

The representation of the first aspect, brain physiology, includes four dimensions for the physical space-time occupied by the brain, with physical and chemical properties (mass, movement, temperature, pressure, electrical currents, etc) represented in additional dimensions.

The second aspect, unconscious mental processes, requires additional dimensions to represent informational patterns and computational processes. In the language of electroencephalography (EEG; see Lehmann, 2013) and computational neuroscience, the new coordinates would include frequency, amplitude and phase dimensions embedded in the four-dimensional space-time of brain physiology. In psychoanalysis, a very different language is used, as the symbolic topological notation developed by Freudian disciple Jacques Lacan for the description of unconscious processes.

According to the new approach of Neuropsychoanalysis (see Solms, 2014, this journal issue), unconscious operations of the human brain could be translated to neurobiological language.

The third aspect, conscious feelings, requires new coordinates to represent qualitative dimensions (referred by philosophers of mind with the term "qualia"); e.g., three dimensions for color, four dimensions for taste, and additional ones for sound, smell, emotional feelings, etc (Pereira Jr. & Almada, 2011).

The resulting structure of TAM is represented in a very simplified version in Fig. 1. This is, of course, a sketchy representation of a hugely complex structure, without the respective functions and transformations undergone in time. The box stands for the totality of reality, called "Nature". The three aspects are partially superposed, forming the "three-layered cake" inside the box.

The picture displays a central principle of TAM, stating that for every conscious experience there must be corresponding mental unconscious and physiological processes, but not vice-versa, since there are many physiological processes without mental activity, and many mental processes without consciousness. This principle derives from the logical order of actualization of Nature's potentialities: the actualization of mental processes requires the previous actualization of physiological conditions, and the actualization of conscious processes requires the previous actualization of unconscious mental operations.

The above framework leads to questions about what kind of physiological process qualify as being mental, and what kind of mental process qualify as being a conscious experience. In the next sections I address the above and related issues, beginning with the concepts of Monism, Evolution and Emergence, and then Mental

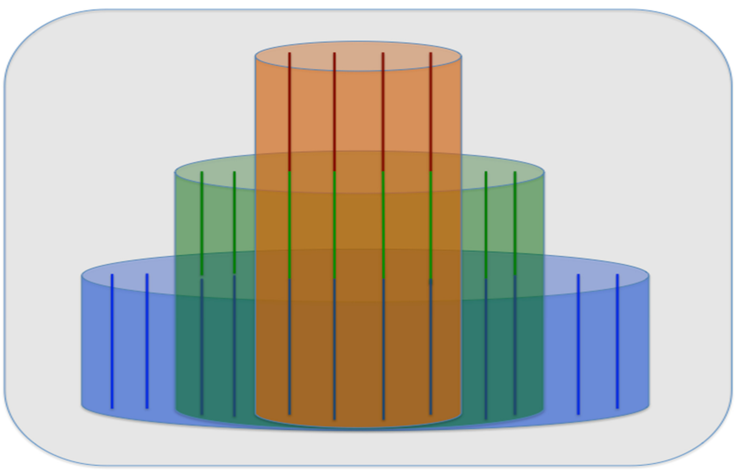

Fig. 1. The three-layered cake in nature's box. Legend: The whole box: Nature; first layer (blue): Physiological; second layer (green): Mental Unconscious; third layer (orange): Mental Conscious; blue lines: Physiological Processes; blue–green lines: Mental Unconscious Processes; blue–green–red lines: Conscious Experiences. Conscious experience requires the participation of the three aspects in a continuous and complementary fashion, as discussed in the next sections.

Unconscious activity and Feeling. For now, I advance the two main thesis of TAM (Pereira Jr., 2013):

(a) The Mental Unconscious aspect emerges when biophysical systems communicate, *transmitting* the form of one to another, as in Aristotle's *formal causation* (e.g., the form of a statue is transmitted — by means of human work — from the mind of the sculptor to a material). In this example, the form of the statue is probably conscious for the sculptor, but in the contemporary technological context the same kind of process can be instantiated in machines without consciousness, as e.g., the transfer of Beethoven's 5th symphony from a vinyl record to the hard disk of a computer, and then to a pen-drive, or the performance of mathematical operations by a computer — in both cases, there is a mental process without consciousness. Considering the existence of brain sub-threshold activities, both in sleep and awake epochs, it is possible to scientifically argue — with Freud and other psychoanalysts — that a large part of brain activity is unconscious;

(b) The Mental Conscious aspect emerges when the result of information processing feeds back on physiological processes, in a (literally) *affective* process, characterized by the instantiation of a *feeling*. For instance, the brain receives information about an increase of sodium in the blood; this information elicits the formation of a specific waveform that feeds back on metabolic processes, instantiating a conscious sensation of thirst.

3. Varieties of Monism

Speculative philosophers tend to assume dogmatic positions and defend them with *a priori* arguments. Idealist and Materialist doctrines, as well as Cartesian Substance Dualism (which, in this context, can be taken as a solution of compromise), are well suited to speculative discussions. Neutral Monism, although being still a sketchy philosophical program, is an attempt to overcome those limited positions (Stubenberg, 2010), accounting for possible contributions of scientific and technological progress for a better understanding of reality. Interdisciplinary approaches to consciousness should "take monism seriously" (Nunn, 2013).

There are two ways to interpret the "neutrality" of Neutral Monism. The first one, compatible with reductive strategies, is to postulate the existence of a substance and/or primitive mode of activity from which both the physiological and conscious aspects are derived. From pre-Socratic philosopher Anaximander's concept of "*apeiron*" (a qualitatively indeterminate and quantitatively infinite substance) to contemporary String Theory (postulating modes of sub-atomic activity underlying both matter/energy and informational processes; see Greene, 2001), researchers have attempted to find a primitive substance or mode of being that could explain the diversity of phenomena found in reality.

The concept of "*apeiron*" is not adequate to play the role of the primitive substrate in TAM, for two reasons: first, the second and third aspects require a source of

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qualitative determination, which is apparently lacking in Anaximander's philosophy; second, there is no reason to conceive Nature's state space as being spatially infinite (without prejudice to the idea of a continuum within Nature, allowing the use of real numbers to describe physical functions). The concept of tiny sub-microscopic vibrating strings is more adequate to be the primitive element of Nature's state space, since these strings can be conceived as finite and able to instantiate qualitative states (Greene, 2001). However, it should be noted that TAM's state space is not limited to physical phenomena (first aspect). The second and third aspects depend on physical conditions, but lead to the emergence of additional dimensions, as explained below.

Reductionism — in the sense of Nagel (1961) — or Eliminativism — in the sense of Churchland (1986) — can build on Monistic approaches. If there is a substance or mode of activity from which everything is derived, then it is possible to explain the current state of affairs as modifications of this substance or mode of activity. The properties of the primitive entity would constitute the initial state of the universe, as well as the ground for the laws and principles that explain the present state of affairs.

Although Reductionist and Eliminativist strategies, as well as the causal approach of Searle (1999) are close to the Materialist field, they can be considered as an advance, when taking into consideration *the existence of cognitive and conscious domains* to be explained (deductively and/or causally) by the physiological aspect, or eliminated at the time when a physicalist language becomes able to account for that domain.

The second interpretation of Neutral Monism postulates two (or three) fundamental aspects of reality, without identification of a primitive substance from which they could be derived. In Dual-Aspect Monism (Velmans, 2008, 2009) these aspects are related to *modes of knowing*: the physiological aspect is the one that appears in the third-person perspective, while the conscious aspect is the one that appears in the first-person perspective. Non-Reductive Physicalism (holding that everything that exists is physical, but with different types of existence that cannot be scientifically reduced to each other) is another philosophical position that recognizes the non-existence of a deductive connection between concepts that describe physiological and conscious properties, but still believes that the conscious aspect is somehow derived from and/or embedded in physical stuff.

Dual-Aspect Monism and Chalmers' Property Dualism (1996) could be distinguished by a subtle difference. Chalmers defends Substance Monism together with Property Dualism. The implication of this philosophical mix is that a system capable of conscious processing possesses both types of properties (physiological and conscious), but each property cannot be physiological and conscious at the same time. For instance, the characteristics of neuronal action potentials in a neural network would be predicated only as physiological — such as electrical and magnetic properties. The experience of "qualia" instantiated in the same network would be predicated only as a conscious — e.g., visual, auditory, somatosensory — feature. An "explanatory gap" (Levine, 1983) remains between the two kinds of property, which are predicated of the same system.

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In the above TAM's diagram (Fig. 1), conscious episodes were represented as continuous lines containing physiological, mental unconscious and conscious segments. This representation suggests a complementarity of aspects that is not the main focus of Chalmers' Property Dualism, but may be compatible with it.

For Dual-Aspect Monism, the properties of a conscious system are considered as being physiological and conscious at the same time, *depending on the perspective* in which the system is conceived; e.g., action potentials have both physiological (in the third person perspective), and conscious properties (from the first-person perspective of the owner of the brain). Although being an advance for the epistemology of cognitive neuroscience, Velmans' Dual-Aspect Monism seems to have two limitations:

(a) The lack of distinction between conscious and unconscious mental processes, and
(b) A purely epistemological basis that leads to a dead end, because all scientific knowledge ultimately derives from first-person conscious experiences.

The limitations of Velmans' Dual-Aspect Monism are addressed by TAM, as follows:

(a) TAM expands the fundamental aspects of Nature to three, thus distinguishing between non-conscious cognitive/emotional processes and conscious processes (conceived as those characterized by the presence of a *feeling* about the information being processed);
(b) TAM is grounded in interdisciplinary scientific concepts, overcoming the purely epistemological duality by considering the third-person perspective as the inter-subjective, instrumental and experimental perspective of the scientific enterprise. Scientific practice extends individual first-person perspectives into a social construction. For example, the scientific observer that analyzes the EEG record is more than the individual with his/her first-person perspective. This scientific subject is shaped by cognitive, educational and technological constraints that confer "objectivity" to his/her observations. In the analysis of EEG recordings of someone's brain performing cognitive tasks, the first-person perspective is the perspective of the subject that experiences the feelings corresponding to the brain events being measured, i.e., it is the perspective of the person whose brain activity is being recorded, while the third-person perspective is the perspective of the socially constrained subject who is looking at the register.

4. Evolution and Emergence

TAM is based on the idea that all possible states of systems are contained in Nature. These states occupy two classes: potential or actual. As originally proposed by Aristotle (2012) in his *Physics* (Book 1, Sec. 1), potential states are considered to be as real as actual states that we can methodically observe. Potential states can be scientifically treated by means of the state space theoretical tool used in the theory of

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dynamic systems, because the state space of a system contains all its possible states, potential and actual.

Each fundamental aspect of brain activity needs its own structure, a set of dimensions defining a state space region. Recapitulating, the description of physical systems require three dimensions for space and one for time, as well as additional dimensions for physical properties such as mass and movement; the representation of informational or computational processes requires additional dimensions to specify the patterns that emerge from the interactions between two or more sub-systems; and representing conscious states requires additional dimensions to specify their qualitative states (Pereira Jr. & Almada, 2011). How to explain the emergence of the mental unconscious and conscious aspects of brain activity?

According to the First Law of Thermodynamics (the Law of Conservation of Energy), in all transformations in Nature there is no absolute gain or loss of energy. However, it does not imply that all possible physical trajectories are equally likely. The Second Law of Thermodynamics (about the spontaneous increase of entropy in closed systems) sets certain conditions to be met in the evolutionary process for each combination of possibilities, indicating *restrictions* on their process of actualization.

Quantum theory allows us to understand the possibilities of Nature as *co-existing superposed states*, one of which — at each time of interaction with a macroscopic system, as the scientific observer — is macroscopically actualized (Vimal, 2013). This process, also called "decoherence" (for an introduction to this topic, see Zurek, 1991), is possibly related to the effects of the Second Law in far from equilibrium open systems. In these systems, there is a "fluctuation" of possible states (Nicolis & Prigogine, 1989), from which a resulting pattern emerges.

Central to this approach to evolution and emergence is the idea of *self-organization*. In open systems, existing structures support functions that modify these same structures. This modification can lead to the emergence of new structures. The "order from fluctuation" principle expresses the natural mechanism underlying the emergence of new structures when the functions carried by the older structures amplify fluctuations that change themselves, thus making possible the emergence of new structures. Potential states, possibly inhabiting the quantum superposed microworld, appear at the mesoscopic and macroscopic scales as very small fluctuations that do not alter the dominant organization of the system. However, in critical epochs, when these fluctuations are amplified and take the whole system, a new order parameter is established, forming a new structural arrangement.

The main principle underlying the emergence of new structures is therefore the following: interactions of statistically independent subsystems extend the universe of study because the resulting state space is not the sum, but the *product* of the state spaces of the interacting sub-systems, *while the entropy of the whole system does not increase in the same proportion.*

The actualization of natural possibilities may occur in different *combinations*. The temporal sequence of actualizations in a spatial region is called *evolutionary process* (in regions of the universe where there is life, the evolutionary process naturally

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includes *biological evolution*). The actualization of combinations of possible states that cannot be deduced from a previous state of affairs is called *strong emergence*. Alternatively, when newness can be traced back to a previously observed state or combination of states, the process that leads to it is called *weak emergence* (corresponding to the use of these terms by Stephan, 1999).

Strong emergence is possible in open non-equilibrium self-organizing systems, even when taking into consideration that the repertory of natural possibilities is finite. The number of possible combinations is so large and the system is so sensitive to small variations in the computation of the initial or boundary conditions that — for practical purposes — the outcome of such processes cannot be calculated (i.e., deduced) with precision.

The concept of strong and diachronic emergence (Stephan, 1999; Vimal, 2013) in open and interacting self-organizing dynamic systems is basic for an understanding of the becoming process of reality. These issues were previously discussed, in different conceptual frameworks, by philosophers Whitehead (1929) and Bergson (1907). Strong emergence means that the actualization of subsets of possibilities of Nature does not occur in a Laplacian deterministic process, but in a contingent fashion, as advanced by the French mathematician Antoine-Augustin Cournot and formalized by Lungarzo & Pereira Jr. (2009). In Laplacian deterministic processes, all causal lines of the universe are previously coordinated by physical laws in such a way that the result of their meeting can be predicted with precision, once the initial states of the sub-processes are known with precision. The concept of "Cournotian processes" (Lungarzo & Pereira Jr., 2009) refers to processes in which statistically independent causal lines meet, generating a new system or driving an existing system to a new region of its space state. One interpretation of Cournot's idea is that human knowledge of the laws of Nature and/or the initial state of sub-processes is incomplete and/or not sufficiently precise. In this case, Laplacian determinism would still be ontologically possible. A second interpretation is that causal lines are really not previously coordinated, and therefore statistical independence expresses an ontological condition, possibly originating from the quantum micro-world.

There is an important caveat to be mentioned concerning the predictability of strongly emerging states. This type of prediction can occur in an approximated or probabilistic manner, but this possibility does not imply that the case of emergence is a weak one. Weak emergence has to be strictly deductive, as sought by Nagel (1961), in his well-accepted theory of scientific explanation. In Cournotian processes, the interaction of statistically independent subsystems, driving the global dynamics of a given complex system, amounts to a *combinatorial explosion* similar to what happens in Henri Poincaré's three-body problem in classical physics, and to other complexity issues currently discussed in theory of Chaotic Dynamical Systems. Small variations in the computation of the initial state of the interacting sub-systems, and/or in the existing boundary conditions, can generate large variations in the possible results. Although the emergency of evolutionary newness could be in principle exactly calculable, the limitations of computational processes and the intrinsic complexity of

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combinatorial processes in systems with many degrees of freedom lead to the result that — for practical purposes — the emerging properties of such phenomena are indeed unpredictable, and even irreducible *a posteriori* to properties of the interacting parts.

5. Mental Unconscious Activity

A concept of information processing and computation, adequate to the understanding of the unconscious activity of the human brain, can be found in Aristotelian philosophy and in Shannon–Weaver's Information Theory, the latter being related to the statistical formulation of the Second Law of Thermodynamics.

Aristotle conceived Platonic Ideas as *Forms* embodied in material systems; he proposed that matter and form are the fundamental constituents of natural systems, called "substances". For instance, what distinguishes natural species — such as the dog, the cat, the rat, etc is the Form, and what distinguishes individuals of the same species — for instance, in the cartoon world: the Felix cat, the Garfield cat, etc — is matter. Aristotle also identified four kinds of natural causation: Efficient, Material, Formal and Final. For him, knowing these kinds would afford an explanation of any natural phenomenon. The Efficient cause is the factor that acts on a substance to change its state of being, as in the example of a sculptor who works on a piece of granite to make a statue. In modern science, the efficient cause has been related to four fundamental forces, two atomic (weak and strong), the gravitational and the electromagnetic ones. The Material cause refers to determination that comes from the matter composing the system that undergoes changes, for instance, the hardness of the granite statue.

The Formal cause is the most interesting one for our purposes. It refers to a transmission of forms from one material system to another, as in the case of sculpting: the form of the statue is initially in the mind of the sculptor, and is transferred to the granite by means of working with tools that shape the matter. In Information theory, information transmission is conceived as a transmission of a message between a source and a receiver, much like Aristotelian formal causation. The issue with the Aristotelian example is that the form of the statue in the mind of the sculptor is most likely to be conscious; only many centuries later, with the concepts of Freudian unconscious and Turing machines, the possibility of unconscious information processing was fully accepted.

The Final cause refers to the goal of actions and was important in Aristotelian Cosmology. He related God to the concept of Final Cause; God was conceived as the first mover that drives the world by means of a kind of attraction (Aubenque, 1960). Several attempts to criticize modern science from the Aristotelian perspective have relied on a revival of final causation, but for the purposes of this paper a discussion of the final cause is not needed.

In the contemporary context, Aristotelian forms can be conceived as transmittable *patterns* distributed in space and time. An approach to these patterns became

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necessary in the enterprise of translating the Second Law of Thermodynamics to Statistical Mechanics, beginning with the Kinetic Theory of Gases in the 19th century. The conception of patterns of organization in a physical system appeared in Boltzmann's attempt to explain the Second Law. He used Probability Theory to approach the dynamics of a many-body system, using the model of a gas isolated in a recipient (Boltzmann, 1896, 1964). The entropy of a macroscopic pattern was conceived as the measure of permutability of all possible underlying microstates; a *macrostate* that can be produced by a larger number of *microstates* was assigned a larger entropy value than others produced by a smaller number of microstates.

Information Theory can be regarded as an elaboration on the Aristotelian Formal Cause, although this reference does not seem to have been relevant for the authors of the theory. When Weaver & Shannon (1949) formulated their mathematical theory of information, they used an analogue of Boltzmann's statistical concepts to refer to the information generated in the source system. When the receptor achieves the same pattern of the source, a transmission of information has occurred. Therefore, the transmission of information implies a law-like probabilistic structure (Dretske, 1981) between the source and the receiver. An important development of the theory pointed toward the conclusion that too random or too redundant systems process less information; an optimal range for information processing is between the two extremes (Atlan, 1979, 1981).

Contemporary science and philosophy have conceived informational processes mostly as *computations*. Based on Turing's Theory of Computation, we design and construct machines that operate with a set of programmed rules (instantiated in their electronic circuits), receive external patterns (inputs), perform computations (information processing) and generate results provided at the output of the machine. With the concept of turing machines and its physical implementation in digital computers — i.e., using a binary code inspired by neuronal axonal activity, as originally proposed by McCulloch & Pitts (1943) — there was a demonstration of the possibility of information processing/computation without consciousness. However, it may be that interactionism (Cacha & Poznanski, 2014, this journal issue) and not information processing underlies unconscious mental processes. While computationalism is the special characteristic of the second aspect and also the characteristic of so many machines that process information without consciousness, for the integrative view interactionism is more realistic than computationalism. If aspect 2 is changed to *local interactionism* then we are talking about a different system all together that does not rely on information processing and is not necessarily computational, but can still remain within the TAM framework (as proposed by Cacha & Poznanski, 2014, this journal issue).

The origin of information transmission — as we conceive it in the contemporary technological context — would be closely related to the origin of life. Life is basically a physical–chemical phenomenon (the *nucleo-proteic binding,* by which the DNA, the RNA and proteins form a self-replicating cycle; see Guimarães, 2012) that makes possible the emergence of a functional form (the form of the living system).

Information transmission at the macro level is possibly a phenomenon that occurs in the context of the co-evolution of living systems and their environments. It possibly begins with signal exchanges between the living cell and the environment. In the evolution of life in our planet, this signaling made use of available ions, such as calcium, sodium, chloride and potassium ions. In the evolution of the brain, these signaling ions became the main computing medium that instantiates unconscious and conscious cognitive patterns. Dynamical processes in this medium are controlled by protein mechanisms, but cognitive and emotional information is not carried by protein configuration changes; it is carried by amplitude, frequency and phase modulation of ionic populations (Pereira Jr., 2012).

Unconscious brain activity is very complex and not opposed to conscious activity; on the contrary, it supports conscious activity. Both unconscious and conscious activities use the same physiological mechanisms. Brain representations are constructed by means of the combination of glutamatergic excitation and GABAergic inhibition, modulated by serotonergic, dopaminergic, noradrenergic, cholinergic and neuropeptide systems. Sensory information, the basis of all information processing in the brain, is registered and processed by means of a combination of excited and inhibited microcircuits, in a process that can be compared to the formation of an image in a black-and-white computer screen. The "differences that make a difference" between the pixels correspond to the differences of excitation/inhibition. If all neurons were excited, the screen would appear completely white; if all neurons were inhibited, the screen would appear completely black. In both cases, there would be no figure represented in the screen, corresponding to the near absence of information in the brain.

Continuing the analogy, neuromodulation would be responsible for the addition of colors to the image on the screen, corresponding to emotional processes in the brain. Emotion can be unconscious or conscious; when it is conscious, the emotional physiological process is accompanied by feelings (Pereira Jr., 2013). Emotion reinforces or depresses neural activity, driving both conscious and unconscious processes. The Freudian unconscious can be conceived as an emotion-driven information processing/computational system, where patterns are processed, reinforced or depressed, according to their emotional valence.

An important part of unconscious processing occurs during sleep. In the awake brain, rhythmic activity is dominated by medium to faster synchronized waves, in the theta, alpha, beta and gamma ranges (Buszáki, 2006). In slow wave sleep, delta waves take the whole system, in such a way (alternating long hyperpolarized "down" states with long depolarizing "up" states) that the "differences that make a difference" (i.e., information patterns) registered during the awake circadian period tend to be erased, resetting the system for another day full of new experiences. Without this resetting during sleep, the system would probably become saturated of information and incapable of enjoying new adaptive experiences. The erasure is not complete, since the "up" states possibly retain traces of learned information (Destexhe *et al.*, 2007).

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Sleep is necessary for the healthy functioning of the human brain, but some emotionally charged patterns resist to be erased, thus making their appearance in dreams. The Freudian insight that dreams and involuntary linguistic utterances are windows to the unconscious is possibly true. In dreams, the brain recovers part of the fast rhythms, making possible the operation of part of the mechanisms of cognitive and emotional representation characteristics of the waking state, while the brain is functionally disconnected of sensory receptors and motor effectors. This functional disconnection make possible for the emotionally charged patterns to recombine autonomously, forming conscious dream episodes — i.e., expressing feelings — that reveal the valence of the patterns for the person.

While a person is awake the unconscious continues to function supporting conscious activity, influencing somatic processes and behavior. In human individuals, language makes connections between the unconscious and the conscious aspects of mental activity. Syntactic processing is largely unconscious, and part of semantic processing is also unconscious. The results of these processes burst in consciousness and behavior, offering an opportunity to the observing psychoanalyst to interpret the person's unconscious.

6. Feelings and the Two-Sided Structure of Consciousness

Considering the powers of informational explanations, many authors have attempted to explain consciousness as a computational process. The most convincing argument against an informational/computational theory of consciousness would be that conscious systems, while conscious (in awake states or dreaming), besides processing information and attributing meaning also experience *feelings* about the contents of the information patterns being processed (Pereira Jr., 2013).

An answer to the issue of what makes informational/computational processes conscious is not easy to find. At first, it should be noted that most kinds of information processes we know — as the working of a digital computer or the processes involving electrostatic couplings and changes in configuration of biological macromolecules in the living cell — are not conscious. Even in the cognitive domain, there are many unconscious processes, as exemplified in Freudian studies. The formation of symbolic or distributed representations — respectively, in artificial intelligence computer simulations or artificial neural networks — does not imply that they are conscious.

Important philosophers assume that what makes cognitive representations conscious is *thought*, linguistic or not. However, if thought is also composed of representations, it is hard to conceive how more of the same unconscious stuff, even forming complicated loops, could afford a basic conscious experience as the feeling. The alternative solution (Pereira Jr., 2013) is that what makes information conscious is *the emergence of a feeling about the meaning of the information*. For instance, John receives the notice that a relative died, interprets the information as meaning that he will not be able to be with her again, and feels sad.

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In this view, unconscious meaning (the biological "proper function" triggered by the recognition of a stimulus, as proposed by Millikan, 1984) is conceived as a cognitive process that antecedes and conditions conscious feeling, such as the processing of syntax and the matching of the forms of stimuli with mnemonic patterns. Our brains receive information from the body and environment, process this information unconsciously, attributes meaning to it and only after the meaning is attributed the corresponding conscious feeling is formed.

Linguistic meaning (in the sense of the *feeling* attributed to a sentence in human language) is a conscious process. Although a large part of these operations occur unconsciously, the attribution of linguistic meaning to sentences involves feeling-based conscious processes. For this reason, Millikan's approach is better for the understanding of unconscious meaning — as in the case of the immune system distinguishing what belongs to the system and what does not — than for linguistic meaning, since so many semantic categories of the human mind involve the relation of sentences with feelings.

Assuming that essential to consciousness is *the feeling of the meaning* of information/computation (eventually leading to a "psychosomatic" effect on the body), scientific investigation would be directed toward finding mechanisms that underlie conscious feelings. In this regard, considering that the feeling experience is similar to a wave that crosses the body, the physical substrate of feelings would be a medium that behaves in a *wavelike* manner (Pereira Jr., 2012).

For TAM, the existence of consciousness depends essentially on the existence of feelings, which can be conceived as *affective states*, in the sense that the meaning attributed to processed information *affects* the physical body. In other words, consciousness (the third aspect) occurs when the product of conscious mental activity (the second aspect) affects physiological processes (the first aspect). The existence of a first-person perspective can be therefore explained by identifying the conscious "I" with *the system that is affected by the feeling*. As Merleau-Ponty (1958) proposed, the "I" would be the *whole living body* of the person who feels.

Living individuals are possibly conscious by means of an *endogenous feedback* (Carrara-Augustenborg & Pereira Jr., 2011). This feedback adds to a previous condition for being alive: the *external feedback* between brain, the whole body and the environment, forming the "functional cycle" (Uexkull, 1934). Calcium waves (Pereira Jr. & Furlan, 2009, 2010; Pereira Jr., 2012, 2013; Pereira Jr. *et al.*, 2013) were proposed to instantiate the feelings that make the whole cycle appear as a conscious episode for the living individual; without them, the information processing would also exist, but in the unconscious mode.

The concept of feeling used by TAM encompasses all kinds of conscious lived experiences. "Qualia" (Crane, 2000) and experiences of "what it is like to be" (Nagel, 1974) are considered to be feelings. Both cognitive and properly affective feelings compose conscious experiences. Cognitive feelings are egocentric *representations* (also called *maps*, and in some cases *symbols*, to refer to forms that *stand for* other forms) while affective feelings are presentations (*lived* experiences, with a *wavelike* dynamics), always having a valence (basically, they are good or bad).

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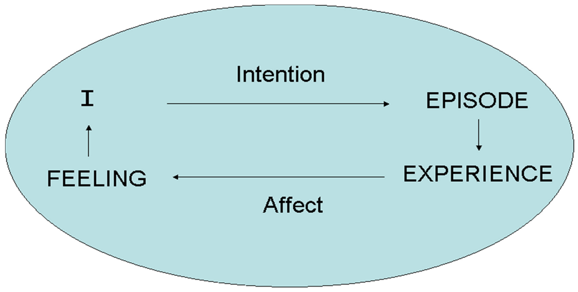

Fig. 2. Formation of feeling habits: The conscious "I" intentionally focuses a conscious episode and is affected by the experience of the episode, producing what Damásio called "the feeling of what happens" (Damásio, 2000).

The thesis that consciousness has a dual structure, composed of one subjective and one objective components, was originally proposed by Husserl (1913). Considering the property of consciousness called "intentionality", for Husserl the conscious subject (the "I" or "Self") is always focusing on an intentional object. In an embodied version of the Husserlian theory, the subjective pole is the living individual who has conscious experiences, and the objective pole is the conscious episode, consisting of informational patterns processed in the brain (for a brain-embodied version of the Husserlian theory, see Mitterauer, 2013).

In addition to the intentional structure of consciousness in Husserl's model, TAM includes a reverse mental action: the conscious "I" being affected by the sequence of conscious experiences, resulting in a "feeling habit" that constitutes the conscious subject's *personality*. Each experience of a particular content — a conscious episode — affects the conscious "I", eliciting a feeling (Fig. 2). TAM and the above concept of personality are possibly compatible with the Freudian psychoanalytic theory, but this relation needs further clarifications that cannot be done here.

A feeling is therefore the state of the subjective pole (the conscious "I"), resulting from conscious experience of an intentional objective episode. In this sense, feelings always have a degree of consciousness (Pereira Jr., 2013). The existence of unconscious feelings, as proposed by Damásio (2000), would constitute an ontological impossibility. In TAM, feeling is the mark of consciousness.

Feeling habits constructed during a person's life history constitute his/her personal identity that contains a value system that serves as a basis for ethical behavior. When a person has a purely reactive attitude, reproducing habits already established in culture, his/she action is not property *ethical*, but just a morally framed one. An ethical attitude includes more than morality, since the person may decide not to follow well-established habits, and alternatively do what he/she considers to be an ethical duty. In the case of moral behavior, action reproduces the current state of affairs, but in the case of ethical action the search for goals that fulfill the person's values may contradict the current state of affairs.

The ethical operations of consciousness, with an additional aesthetical component, are illustrated in Fig. 3. Again, the concept of intentionality is being used; in the

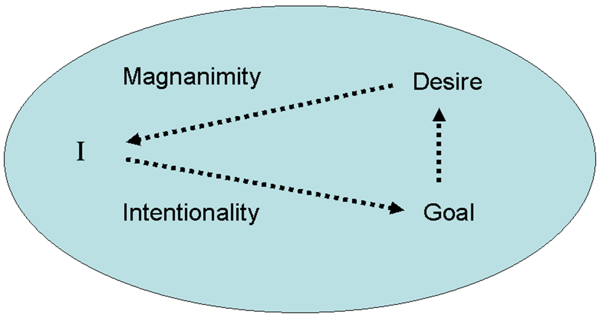

Fig. 3. Ethical and aesthetical operations of consciousness: The conscious "I" or "Self" projects a goal according to his/her previously formed value system. The aesthetic appeal of the goal elicits a feeling of desire, which empowers the Self to struggle for the actualization of the goal, even in adverse conditions. This kind of attitude was named "magnanimity" by Aristotle, implying virtues like authenticity, wisdom and moderation. The ethical consciousness results from philo- and ontogenetic processes, and feeds back on these processes, thus influencing the pathways of the evolutionary process. Such a feedback is not a causal process, as argued by Baldwin (1896). According to TAM, it is an affective process.

context of the ethical and aesthetical consciousness, "intentional" is used in the sense of a goal-directed action.

7. Neuro-Astroglial Interactions

For a century, progress in neuroscience was based on the Neuronal Doctrine advanced by Ramon Y Cajal (Bullock *et al.*, 2005; Douglas Fields, 2009). Neurons were considered to be the structural and functional units of the mind. Within this doctrine, the understanding of brain functions that support mental functions was equivalent to understanding the structure and activity of *neurons*.

With the successful application of principles of neuron communication to the construction of computers, the part of neuron activity assumed to carry cognitive operations was the action potential. Most attempts into understanding inter-cellular mechanisms generating collective behavior of cells in the brain also have assumed that the main kind of signaling supporting mental functions is the action potential (Buszáki, 2006). Action potentials operate on a population frequency and phase encoding. As all action potentials have approximately the same amplitude, the message transmitted from neuron to neuron is encoded in the frequency and phase of the firings in a spatially distributed population. Therefore, the salient property of sequences of action potentials is that the message is encoded in a binary fashion (a neuron is firing or not firing) in the frequency and timing of the pulses. The apparently sound conclusion seemed to be that the mind operates on a binary code similar to digital computers, which in turn were inspired by the "modus operandi" of neuron axonal signaling.

The analytic method of modern science has further pushed researchers toward the study of single neurons, focusing on molecular processes involving their

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membrane receptors, transmitters that bind with them, intra-cellular signaling pathways, as well as the genome and its expression in epigenetic processes. These features of neurons are related to their activities, dendritic graded potentials and axonal action potentials, but only the latter were fully accounted in computational models. There is no doubt that axonal activity is the key to understanding voluntary behavior, since motor actions are triggered by axon potentials of pyramidal neurons in the motor cortex, which descend the spinal cord and contact with muscles. However, scientists did not find a logical connection between the encoding of information patterns in these digital-like pulses and conscious states. Feelings in particular do not seem to be a digital-like phenomenon, but a continuous wave-like temporal experience.

A popular strategy toward finding correlations between conscious mental functions and brain activity is *localizationism* (Betchtel, 2014). This strategy has led to progress, but a very limited one. Although there is localization of brain functions, there is no reason to assume that *conscious* mental functions (and related feelings) are localized in separate parts of the brain. Some parts and respective circuits are known to process signals related to emotions (such as the insula, the amygdala, etc.), but there is no evidence that subjective feelings are instantiated in these regions. In order to account for the brain basis of conscious mental functions, it is necessary to postulate an integrative mechanism able to explain how different kinds of conscious processes and contents are made available to the same outputs, as the control of skeletal muscles that initiate voluntary action (Morsella, 2005), the endocrine system, as well as the brain system involved in memory formation. In other words, how do the activation of specific molecular mechanisms and signaling pathways in the brain reach a global domain, supporting the execution of conscious mental functions?

An attractive hypothesis is that the astroglial network, having a hub structure, provides multidirectional and long-range inter-cellular communication, mediating global effects of locally released transmitters, modulators and neuropeptides/hormones. Calcium waves in the astroglial network have a wavelike nature compatible with the instantiation of feelings, and a spatio-temporal dynamics that relates well with data about conscious processing (Pereira Jr., 2012; Pereira Jr. *et al.*, 2013). As an important consequence for the research in brain sciences, conscious mental functions would be experimentally correlated with neuro-astroglial processes, not neuronal activities alone.

Historically, the idea of Camillo Golgi — that the nervous system is a lattice where electrical and chemical signals travel continuously — preceded the "Neuron Doctrine". The doctrine of Cajal remained fully hegemonic until the 1990s, when calcium waves were observed *in vitro*; a decade later, other information processing functions of astrocytes were discovered, leading to a new view of brain function (Pereira Jr. & Furlan, 2010). The recent debate has focused on the possible roles of these calcium waves *in vivo*, and functions of electrical synapses between neurons, which also use "gap junctions". Making use of multi-photon microscopy, some laboratories have conducted experiments with a variety of kinds of brain stimulation to observe how astrocyte calcium waves occur. Two findings of the Nedergaard lab in Rochester-USA are remarkable in this regard. The first was an important discovery that common use anesthetics selectively disrupt astroglial calcium waves (Thrane *et al.*, 2012). The second was that the insertion of human astrocytes in mice improved their cognitive capabilities (Han *et al.*, 2013).

Another line of research concerns astroglial activity induced by binding with GABA. Failure of GABAergic mechanisms in major depression may have an effect on astrocytes; for instance, depressive feelings may relate to a decrease in astrocyte activity. These mechanisms also point to a possible role of astroglial dysfunction in Autism and ADHD. The role of astrocytes in brain death is becoming increasing clear, with the discovery of their role in the disruption of K+ homeostasis (Wang *et al.*, 2012), leading to the failure of neuron repolarization.

According to TAM, consciousness requires — besides an information processing system — *a feeling system*. In a series of publications (Freitas-da-Rocha *et al.*, 2001; Pereira Jr. & Johnson, 2003; Rocha *et al.*, 2005; Pereira Jr. & Furlan, 2007, 2009, 2010; Pereira Jr. & Almada, 2011; Pereira Jr., 2012; Carrara-Augustenborg & Pereira Jr., 2012; Almada *et al.*, 2013; Pereira Jr., 2013; Pereira Jr. *et al.*, 2013), it has been argued that such a system is basically composed of ionic currents and waves (especially calcium ions, which plays essential functions in living systems).

The brain waves more compatible with the instantiation of feelings are those located in the astrocytic network. These waves are induced chemically by neural transmitters and electromagnetically by neural dendritic fields (Ingber *et al.*, 2014). According to the author of "astrocentric hypothesis" (Robertson, 2002), astrocytes are the end point of conscious processing, but not the only system involved with the processing. Correlates of consciousness should be identified in the domain of neuro-astroglial interactions, including neuronal activities. Neuronal activities alone would not be conscious, but insofar as the cognitive representations instantiated in neurons are associated with feelings instantiated in the astrocytic network, conscious episodes are completed (see Pereira Jr. & Furlan, 2010; Pereira Jr., 2013).

The current objection to the calcium wave hypothesis of conscious processing is that inositol pathway (IP3) knocked-out mice seem to preserve global mental functions, as far as an analysis of their behavior permits to infer (Smith, 2010). This objection deserves discussion, but the data is still insufficient to reach a solid conclusion. Theoretically, it is possible to argue for alternative mechanisms of generation of calcium waves in the astroglial network, such as the ryanodine pathway (Ruiz *et al.*, 2009) and glial electrical synapses (Fróes *et al.*, 1999).

8. The Endogenous Feedback Model of Conscious Processing

There are three ways of interaction of a conscious system with the environment (Pereira Jr. *et al.*, 2013). The first one is purely physical, corresponding to the idea of

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the "reflex arc", whereby environmental stimuli initiate a physical causal process that results in a motor or endocrine response. A second way is by means of unconscious information processing, a "feed-forward" serial process in which environmental stimuli are detected by specialized neurons ("feature detectors"), generating a signal that is associated with previously stored patterns and then interpreted according to their functional significance for the system.

The attribution of biological meaning corresponds to the formation of an amplitude modulated (AM) spatially distributed waveform in a population of neurons (Freeman, 2003). This activity corresponds to an ensemble of neuronal dendritic fields, which generate further processes of signal transduction that can be bioelectrical (action potentials) or biochemical (release of neurotransmitters or neuromodulators), both converging to a behavioral response. All these processes can occur unconsciously.

The third kind of perception-action cycle includes a conscious step in the processing of information. After the attribution of meaning, dendritic fields generate calcium waves in astrocytes that instantiate feelings. What makes the process conscious is the formation of feelings and the "endogenous feedback" of these feelings and related physiological processes on neuronal activity, thus influencing behavior, memory formation and psychosomatic responses (Carrara-Augustenborg & Pereira Jr., 2012).

Neurons process information forming cognitive representations, while astrocytes react to the information being processed, forming affective feelings that modulate the cognitive processing. According to TAM, the feeling component is essential to consciousness. Evidence from brain sciences is that only the astrocyte network has a wavelike kind of activity that corresponds to the nature of feelings.

Of course, conscious experiences are not made only of feelings; they are made of feelings associated with perceptions, representations, conceptualizations, images, etc. All these have their features instantiated in distributed neuronal dendritic fields.

The integration of cognitive and affective in conscious episodes require:

(a) The existence of cognitive content (information patterns from sensory, ideomotor, mnemonic origin) instantiated in neurons and interpreted according to their biological (functional) meaning;
(b) The information patterns being transmitted to astrocytes (by means of transmitters, neuropeptides and possibly by electromagnetically transferring neuronal patterns to the momentum of astroglial calcium waves — Ingber *et al.*, 2014);
(c) The result of astroglial processes impacting back on neurons, thus modulating neuronal activity (reinforcing patterns if they feel good; depressing the activity that supports the patterns if they feel bad).

In Pereira Jr. & Furlan (2010) we argued that there are two different kinds of calcium waves, the smaller ones — that occur limited to astroglial microdomains — not directly related to consciousness, and the larger ones — that encompass the whole

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brain and generate quantum-like effects. The latter are the waveforms that instantiate feelings. The smaller calcium waves in astrocytes contain information that may or may not become conscious; because of the limited capacity of consciousness (a feature of Bernard Baars' *Global Workspace Theory* that is preserved in the astroglial model presented in Pereira Jr. & Furlan, 2010 and Pereira Jr., 2013), only the patterns that enter the larger wave become fully conscious. Therefore, it is not the astrocyte itself that is essential for consciousness, but the waveform that is instantiated in the neuro-astroglial network. This network putatively shapes brain waves like the hands of a guitar player shaping the strings' dynamic patterns.

9. Identifying and Registering Conscious Events in the Living Brain

Current brain science does not tell us if conscious information patterns are encoded by the frequency of spikes in a neural population, and/or by amplitude-modulated waves that involve extra-cellular processes and glial cells. Are there experimental evidences that astroglial calcium waves are involved with conscious processing in the brain?

A good line of argumentation in favor of a positive answer begins with studies of event-related potentials (ERP; see Coull, 1998). Several kinds of ERP correspond to conscious events reported by the subjects. Some patterns of activity detected by BOLD FMRI also display a degree of correspondence with conscious events. What is the kind of brain activity measured by these techniques? If they are more related to neuronal dendritic fields than to action potentials, then astroglial calcium waves should be involved, at least as a consequence of a physical electromagnetic causal process (as argued by Ingber *et al.*, 2014).

Recalling the main steps of information processing in perceptual processes, the following brain activities are involved:

(a) The transmission of sensory information (from the retina and peripheral receptors) to the CNS occurs by means of axonal pulses. As nerves are composed of bundles of axons, the message is encoded in a population frequency code (Connor & Johnson, 1992).
(b) Upon reception of the sensory message in the CNS, graded dendritic potentials (postsynaptic potentials, excitatory and inhibitory, i.e., EPSPs and IPSPs) are generated, in which information is embodied in AM oscillations and their resulting brain waves.
(c) These dendritic fields activate extracellular ion movements and astroglial calcium waves, forming the local field potential (LFP), which is the main source of the scalp EEG register (Buszáki, 2006), as well as the main physiological feature correlated with fMRI activations. He & Raichle (2009) relate fMRI activations that correspond to conscious states and processes with the "*slow cortical potential*" that is generated by the same sources of scalp EEG.

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(d) Despite the above observation, Buszáki and a majority of neuroscientists analyze the scalp EEG recording *as consisting of action potentials*. The power spectrum of the EEG (the area under the curve) is thought to denote the *number of neurons* firing their almost-the-same-amplitude action potentials at the region captured by the electrode. As a consequence, the encoding of mental patterns by the brain is believed to be in frequency and phase modulation only. In this view, there is no room for amplitude modulation. Buszáki (2006, p. 124) suggests that "qualia" could be encoded by combinations of frequency-modulated synchronous oscillations. This proposal needs to be detailed to explain how "qualia" are generated by combinations of frequencies of action potentials. The other possibility is to consider dendritic oscillations, but in this case there is a problem of inter-neuronal communication: how does the AM pattern instantiated in the dendrite of one neuron communicates with the AM pattern instantiated in the dendrite of the other neurons? This problem was first formulated by Edwards (2005), in his defense of single-cell consciousness. It brings us back to the second and more realistic alternative: the brain waves that instantiate conscious states are generated by neuronal dendritic oscillations that induce ionic waves, mostly calcium waves inside the astrocyte network. These ionic waves instantiate the feelings (including the "qualia") essential to consciousness.

(e) Freeman (2003), using concepts from physical acoustics, distinguishes the *carrier* wave, characterized by a frequency modulated wave — corresponding to the synchronized activity of neurons — and the amplitude modulation of this wave, which encodes meaning (Freeman, 2003). For Freeman (and also for the author of this paper), synchronized neuronal oscillations are merely "carrier waves", i.e., energy waves that carry, but do not encode the message in its frequency or mix of frequencies. Buszáki (2006) suggests that the cognitive message could be encoded in the interference patterns of different superposed frequencies; this is another possibility. Freeman's criticism of the hypothesis of cognitive information integration by means of frequency-synchronized brain waves can be compared to radio transmission. The tuning frequency of an FM radio station has nothing to do with the music or other information being transmitted by radio; it is just the operating frequency of the station. For Freeman, the assignment of meaning to stimuli, by the brain, is instantiated in spatial AM patterns carried by the frequency-synchronized waves.

(f) In Freeman's theory, *meaning* is on the plane of spatially distributed neuronal configurations. According to TAM, to become conscious, this activity would have to elicit a *feeling*. Physiologically, this event would require the generation of a large calcium wave in the astrocyte network.

(g) Another approach to conscious states is Microstate Theory (Lehmann, 2013), considering that EEG microstates — i.e., transient brain states identified from EEG waveforms with an adequate analytic tool — are "atoms of thought and emotion". TAM's "calcium wave" model of conscious processing is compatible with Microstate Theory, since calcium currents generate bioelectric fields

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included in the source of the scalp EEG signal. Neuronal AM dendritic oscillations produce AM LFPs that impact the astrocytic network, producing calcium waves. The transfer of patterns from neurons to astrocytes can occur both chemically (by means of transmitters and other macromolecules in tripartite synapses; see Pereira Jr. & Furlan, 2010) or electromagnetically (as demonstrated by Ingber *et al.*, 2014).

(h) While Freeman and Lehmann independently focused on *spatial* configurations of brain activity, *temporal* patterns are relevant for the formation of feelings. A feeling is a wave-like process with a temporal dynamics that is slower than cognitive processes like perception and thinking. The relation of time with consciousness is a classical issue since Kant, and was recently discussed by Nunn (2013). The *temporal waveform* of the astroglial calcium waves is proposed to correspond with the form of the feeling, in a way that can be compared to the graphical representation of sounds from different musical instruments in sound synthesizer. There are some basic types of temporal waveforms, such as: Sine, "Sawtooth", Square, Triangle, Pulse/Rectangle, etc waveforms (see http://news.beatport.com/blog/2007/10/25/oscillators-essential-waveforms/), each one related to a kind of sound. The correspondence of brain waveforms and feelings would be similar: each kind of feeling would have a corresponding kind of AM waveform. This is a testable hypothesis that requires the development of adequate tools to analyze images made with fluorescent multi-photon microscopy. Possibly, the "box counting" method used to identify the fractal dimension of a complex system could be used to localize the larger waves in the imaging, and further methods could be developed to analyze the *form* of the AM astroglial calcium waves.

(i) The above reasoning suggests that temporal slow waves traveling through the brain are the major source of ERPs. These waves display peaks whereby there is an increase of amplitude in a cerebral location, around 300, 600, etc milliseconds after the presentation of a stimulus. If these events result from a sequence of action potentials only, how to explain their temporal latency, considering that each action potential has the duration of a few milliseconds? They can be alternatively explained by the formation of AM slow waves (including astrocytic calcium waves). A sketchy model of how neuro-astroglial interactions generate ERP peaks is the mechanism called "carousel effect" by Pereira Jr. & Furlan (2010). Oscillatory neuronal synchrony induces, by electromagnetic and chemical means, calcium waves in the astrocyte network, which in turn feedback on neuronal activity. Both activations (neuron to astrocyte, and astrocyte to neuron) would contribute to the "slow cortical potential" (He & Raichle, 2009).

(j) In sum, conscious processing is proposed to correspond to a neuro-astroglial oscillatory mechanism that produces AM ionic waves. The AM patterns are chemically and electromagnetically transferred from neuronal dendritic fields to astroglial calcium ions, composing brain-wide waveforms that instantiate

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feelings. These waveforms feedback on neurons, modulating (reinforcing or depressing) synaptic activities involved in cognitive and behavioral functions, and producing psychosomatic effects (as discussed in Pereira Jr. & Furlan, 2010).

Making a balance of all conditions identified as necessary for the formation of conscious processes, we have:

(1) Existence of neuronal synchrony, because these are necessary to induce a large ionic wave;
(2) Existence of synchrony in frequencies above delta, because slow waves erase information, while in faster rhythms Glu-GABA combinations encode information and the action of neuromodulators enrich this information processing;
(3) Existence of large amplitude-modulated ionic waves that feed back on synapses, corresponding to the conscious experience of feeling.

10. Concluding Remarks: Overcoming the Hard Problem

In TAM, the study of brain physiology alone does not afford an understanding of mental activity, but the study of mental activity cannot be properly made without taking into consideration brain physiology.

When studying mental activity, TAM distinguishes unconscious and conscious activities. Although information processing and computation are essential tools for the study of mental cognitive processes, information and computation by themselves are not considered to be a conscious activity. TAM entails a three-layered structure and respective functions, where conscious activity depends on matter/energy and informational/computational processes, but requires an additional dimension, the feeling.

Recapitulating, TAM's first aspect is composed of processes that can be explained by matter/energy exchanges; the second aspect is composed by processes that can be explained in terms of transmission and processing of information patterns, but without consciousness (unconscious processes); and the third aspect is composed by conscious processes that can be explained by a combination of energy, information and feeling processes. Without feeling, these processes would remain unconscious.

Feeling is a case of supra-threshold information integration affecting the material substrate of a system. In a digital computer, the patterns being processed do not affect the hardware. In living systems, there is an endogenous feedback that produces an effect, conceived as a resonance or dissonance of the informational/computational patterns with the matter/energy structure. According to TAM, this affect is the root of the first-person perspective. The conscious experiencer (the "I" or "Self") is therefore conceived as the system that is affected by the patterns being processed.

The "Hard Problem of Consciousness" (Chalmers, 1995, 1996) can be summarized in two statements:

(a) Consciousness supervenes from natural processes, but

(b) Properties of conscious states ("qualia") cannot be reduced (in the sense of being deduced) from physical properties.

From the perspective of TAM's framework, to consider the conjunction of the statements a "hard problem" is an artifact of frustrated reductionism. In a Monist perspective, the statements are true and not contradictory. Consciousness supervenes from Nature, but not from the physical aspect of Nature alone (Pereira Jr., 2013).

According to TAM, a science of consciousness should address, in addition to the intrinsic structure and dynamics of conscious processes, also the physiological and mental unconscious aspects underlying conscious phenomena. Putting all these aspects together is a challenge for interdisciplinary research. TAM is a candidate to provide a better understanding of consciousness, formulating clear theoretical concepts and testable hypotheses about brain activities and informational processes supporting conscious phenomena.

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