The brain in light of Edgar Morin's paradigm of complexity

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Summary

This paper aims at pointing out the contributions of Edgar Morin´s complexity theory for the study of the brain. According to Morin, the brain is a unity of multiplicities, "Unitas multiplex," given that it works through dialog and sociocultural, genetic brain domains converge within it, from which multiple ecosystem religares emerge, which turn it into the core of the phenomenal association, shaping, and reproduction. The brain is polycentric, poly-phenomenal and multidimensional; order–chaos–organization come together as a result of a recursive, recurrent, organizational operation.

Keywords*: brain, complexity anlysis, creativity, psychophysiology, health.*

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Resumen

Este es un artículo de reflexión que tiene como objetivo señalar los aportes de la teoría de la complejidad de Edgar Morin al estudio del cerebro. Para Morin el cerebro es unidad de multiplicidades «unitas multiplex» dado que, funciona dialógicamente y en él convergen dominios genético-cerebro-socioculturales, de los cuales emergen múltiples religares ecosistémicos, los cuales lo constituyen en el centro de asociación, formación y reproducción fenoménica. El cerebro es policéntrico, polifenoménico y multidimensional, en él se reúnen orden-caos-organización a partir de un funcionamiento recursivo-recurrente-organizacional.

Palabras clave*: análisis, cerebro, complejidad, creatividad, psicofisiologia, salud.*

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Introduction

This work has a descriptive character and in it, it is recognized the importance of the principles of Edgar Morin in the complex understanding of brain functioning, connected to the authors' book The Method I [1] including similar approaches in respect to the nature, ideas, the brain and evolution, topics that were widely developed in his later writings. It should be noted that Morin performs a dual isomorphism, in which extracts concepts of physics, thermodynamics, the systems theory, the transdisciplinary, the biological sciences, and the social and human sciences, being assembled together with them articulately, in, through, and beyond its own postulates, in a integrator position that reveals the brain in its hyper-complexity, and invites us to relate to the knowledge surrounding its understanding of dialogue.

These ideas give way to other understandings that are articulated to new isomorphisms [2–4] whose contributions are possible through the dialogue of knowledge, new forms of understanding the brain's functioning. Thus, Edgar Morin's paradigm of complexity implies strong relationships between "master" concepts that direct discourses and knowledge in a context of conscious and intentional relationships [5]. This drives the rupture with a determinism whose linear causality, no longer constitutes the fundamental law of nature as an essential condition of any possibility of knowledge. Complex thinking proposes a radical change around social problems and overcomes the simplifying thinking that tends to equalize investigative knowledge and knowledge between things and people, that is, between the social and the non-social. In complexity relationships, constituent elements are not reduced, the investigative relationship occurs between subject-subject, the unification of the opposites is tended – dialogical - and the classic budget of objectivity of science is rejected among other aspects.

From a complex perspective, the human being and the brain must be understood as a "genetic sociocultural" system [5,6] that operates through the interrelations and emergencies arising from four systems: 1) the *genetic* system; 2) the *brain*; 3) the *sociocultural* system, and 4) the *ecosystem*. Through its functionality, structure, creativity, virtual work, internal relationism, endo-exogenic articulation, dialogic intention, and multidimensionality, the brain shows a base complexity, which dissipative interrelation generates the reiterative hypercomplexity. That way, it comprises a complex system that contains multiple complexities at the functional-structural level, and which operates in connection with other complex internal-external systems *per se*, with which it obtains "endo-exogenic" relationships of mutual exchange, structuring, and self-organization.

The above explains why *learning* entailed aspects such as interrelation, affectivity, communication, and strategy in the brain, as knowledge arose as something useful to resist clearly inhospitable, dangerous and resource-poor contexts that would guarantee survival [7]. Understanding the world and the interactions of other subjects has always required the introjections of the other, and the multidimensional transformation of the brain and the individuals.

In the brain (…) (it is possible to) observe the left and right hemispheres. The corpus callosum that separates both hemispheres can also be found. The brain is subdivided into main portions: the occipital and parietal lobes present in each of the hemispheres, the temporal lobe and the frontal lobe, separated by the so-called main sulci, which are responsible for separating the different parts of the brain [8].

It is worth noting that, from this conceptual perspective, the brain is exposed in search of multi-functionalities structured in brain areas, in which operations and results give shape to the brain activity [9]. Although this is true, for complexity, such operability is valid while the eco-bio (genetic)-sociocultural polycentrism

is acknowledged, that allows for the convergence between various functional, convening, operational centers, in charge of *relinking* or *integrating* the multiplicity of the stimuli/spheres/commands/folds/contexts that take place in it, and such interrelation results in senses, knowledge and ways of knowing, the reality, and the coexistence, making the human being more prone to constant progress and transformation.

Complex perspective

The paradigm of complexity is not the answer to all the epistemological gaps and drifts of knowledge, as it actually constitutes a bet for the challenge of knowledge that promotes a dialog of knowledge, the critical and relational thinking, that is to say, to establish relationship networks nesting between elements that were previously dissociated (insulated and compartmentalized) due to their uncertainty, antagonism, and unpredictability [5]. According to Morin [1], a *religare* need exists precisely in the compartmentalization of knowledge, therefore involving the transition to a transdisciplinary perspective of existence, and a dialog of knowledge that includes the subject as a cognoscente being through its reinsertion into language and the knowledge process [10].

Complex means "*complexus*," in other words, "woven together" and, as per Edgar Morin [1], this entails that no knowledge occurs by itself, as the very fact of generating knowledge involves the incubation of multiple networks of knowledge which, in line with the operating co-ordinations allowed for thinking and language. In addition, he points out the need to *ecologize thinking,* that is to say, to hold on to the environmental awareness in pedagogical–relational controls and elements of global solidarity with the ecosystems [11,12], since the mankind shows self-destructive behaviors and, paradoxically, the greater the scientific development, the higher the chances of self-destruction on a large scale. At the same time, he identifies the influence of a reductionist paradigm or a "simplicity paradigm" that differs from the relational propensity of the paradigm of complexity [1].

He further notes that *reduction* has removed uncertainty, and that is why it has been built upon epistemological certainties and a scientific-investigative method, which clearly proves to be of *Cartesian–Comtian* origin. In contrast, it proposes an *anti-method*—made up of the acknowledgment of a *base complexity*—and an interpretative-comprehensive transformation operator/device, *complex thinking*, in addition to a compendium of contributions that highlight the relevance of the dialogic, uncertainty loops; the *order–chaos–organization* relationship; the dialog across disciplines and knowledge—a transdisciplinary; a neo-humanist and anthropoetic view of the world; ecologized thinking; education; and globalization, among other elements.

The paradigm of complexity emerges from the inadequacies of the paradigm of simplicity [13], without becoming a simplicity reducer, as it accepts its contributions and values and transforms its causalist, closed, linear perspective, integrating networks of points of contact, divergences, breaks, dissipations, and associations, which result in neo-concepts, new transdisciplinary perspectives, and dialogs about the studied phenomena. In this vein, the paradigm of complexity allows for the extension of knowledge about the brain and its organizational functioning, as well as the way in which this learns and accounts for reality, all within the framework of the individual–society–species interrelationship and under a systemic view wherein the system—brain is open-closed, self-produced (*autos*) in a place (*Oikos*), preserves its identity (operational privacy), and constantly changes as it expands; that is, *dispels* its connections and interactions with other ecosystems (*eco*), generating, in turn, new states or conditions in its organization (*reorganization*) [1].

Complex thinking and brain functioning operators

Morin and Le Moigne [14] point out that there is an increasingly deep dilemma between the knowledge derived from compartmentalized disciplines, and the facts that are increasingly multidimensional, transnational, transdisciplinary and complex, in which case the production of knowledge seeks to interrelate global, multidimensional and intercultural issues, and this is where the complex thinking operators emerge as reform means, tools, and mechanisms for the way in which knowledge is built. Morin's proposal [1] covers seven logical principles or operators to outline complexity, useful to transform knowledge, which are as follows: systemic or organizational, hologrammatic, circular retroactive movement (of retroactive loop), circular recursive movement, self-eco-organization (autonomy–dependence), dialogic, and the subject reintroduction principle in any kind of knowledge. It is important to note that these principles represent a valuable contribution, as well as a useful proposal for the understanding of the multiple brain relations and functions through neural nestings and complex organizations (brain areas).

The brain operates through multiple computations (brain pulses between neurons, and neurons' pulses with other structures) or interneural mega-computations that connect the internal and internal world, besides generating reality folds that give meaning to the subject's existence[2]. The *systemic or organizational principle* denotes that the *whole* is greater than the sum of its parts and greater than the whole because it is constantly expanding and producing new properties that were inexistent in isolation (emergencies), but it is also less than the whole as it generates organized systems with its own identity, which contains the qualities of the parts [15]. In this vein, the brain is a "recurring, recursive, and organizational" complex organization, given its multiple operations, relationships, and emergencies, that go beyond the production of language and thinking, as it results in the world's symbolization and re-symbolization, and comprises generative contributions of the reality principle with which the brain gives meaning to itself (*self*) and to the other's existence (*otherness–environment*).

Thus, the brain is a system of systems inter-nested in interlinked-rhizomatic, chaotic, organizational computing relations. The *hologrammatic* principle applies to complex organizations and makes reference to the control of the presence of the object as a whole in each part of such whole [1], this way, it is possible to obtain complete images in the hologram, based on the parts of the image [16]. This principle reveals that each part contains the information of the object's meaning as a whole or in general and, as a consequence, in all organizations, the part is in the whole and the whole is in the part. The brain is hologrammatic, as each part is a whole in itself as it contains the totality of the brain. This is how genetically (*Genon*) and phenotypically (*fenom*) speaking, the brain can integrate into the *central and peripheral nervous system* to which each part belongs.

Likewise, in the *retroactive loop or feedback* principle, the cause acts upon the effect while the effect acts upon the cause [6], so they are looped—reinserting each effect in the cause and transforming it—with what is broken in the linear causality, allowing for the system's organizational update and autonomy. This principle operates in the brain through multiple brain connections, leading to changes in its structure and functioning, *plasticity*. For example, the electrochemical nervous impulse modifies the neuron and the system of neurons transforming the paths to communicate, its resistance threshold and the way by which they process such impulse [17,18], while the

2 The *fold* or group of reality levels shape *fractal commands,* or perception-level folds (54), which represent the set of realities taking place in a particular place at the quantum, biophysical, sociocultural levels.

transmitted information re-enters the system over and over again, specializing areas and generating multiple efferents, afferent, and emerging pathways of integrative, redistributive and associative intercommunication [18]. In terms of complexity, this means that mental processes are generated and transformed during the connection-information dissipation, and learning, which results from the interrelationship between eco–bio–brain self-eco-modifications, takes place.

For its part, the *recursive loop* shows the systems' self-production (autopoiesis), self-organization (self-organizational property) and self-eco-organization (endo-exogenic) processes, acting through inter-retroactive loops where the consequences, effects or results are, in turn, the cause-producers of the processes that cause and produce them [1]. According to Morin, the brain's complex processes have an inter-retroactive characteristic, in such a way that the brain is recursive, creative, and non-linear. Putting it that way, each neo-process or path to receive, recreate, and retransmit stimuli and communicate them constitutes an emerging novelty, that is to say, a product that, in the case of the human brain, involves the inter-influence and reciprocity between higher mental functions, and thinking—symbolization in language [19]. The brain complexity is akin to social complexity, although the latter requires the brain to respond to the new requirements of the environment and its various bio-eco-anthropo-ecological contexts, which involves the development of a higher-skilled dynamic and agile memory with greater associative capacity [12].

The *autonomy–dependence* or *self-eco-organizational* principle is another principle pointed out by Edgar Morin [6] on the Heraclitus premise of "*living death*, *dying life*," *and which guarantees the systems*' replacement and evolution, systems that show a relative autonomy as, despite being independent, they are subordinated to the exchanges with other ecosystems for the purposes of self-eco-organizing themselves. In the brain, this is revealed as relative brain autonomy, as it may generate the resources process that allows for its operation in various reality folds (*autopoiesis*), while it demands endo-exogenic exchanges with other systems for *self-eco-organization* purposes. Take, for instance, the brain–environment–society self-eco-organization that reveals its complex and multidimensional condition. According to Solana [3], the brain's genetic development implied the existence of a prior ecosystem-ecological development condition (an *autos)* that, at the moment of achieving characteristics at the sociocultural level, self-generated the conditions, competences, and provisions for the development of the brain complexity, so the *self-functioning* of the brain follows the *self-organization* of the *self-eco-organization* containing it.

Similarly, the *dialogic* principle "allows for the rational acceptance of the inseparability of contradictory notions to conceive the same complex phenomenon" [6], that is to say, to gather the antagonisms to make them complementary with each other, therefore exploring their ability to redefine, retrieve, and propose new phenomenal relationship, understanding generation. According to Edgar Morin [20], the brain is skilled enough to organize, define, or create reality and process the infinite amount of internal and external sensitive information, as it operates through a *dialogic bio–brain* operation. The above means that its *genetic–phenotypic* development necessarily involved antagonistic evolutionary conditions–relations–events, which found the unity of the multiple, "*unitas multiplex*" in complementarity. These changes took place at the morphogenetic and functional level, thus resulting in the complexity of its capacity to interact since the increase in the ecosystem complexity demanded evolutionary changes and greater response skills.

The brain evolution substantially emerged from the exponential increase of the endoge-

nous pressures—dissipations—of the nervous system under development, which were in line with the eco-environmental pressures—transformations and, later, anthropo-sociocultural pressures—mutations, an interrelationship that has largely reshaped the brain in a dialogical way. According to Morin [20], "we need to focus the brain's genetic development through a dialectical relationship between the complexity's pressure and primacy". Finally, the "*decomputational*" principle involves the reintroduction of everyone who knows in all knowledge, that is to say, that the presence and inter-influence of the other transform and generate knowledge in both parts (observer–subject), encouraging the frequent reconstruction of the perceived-interpreted reality. This way, in the knowledge process, both parties take charge of "renaming and reinterpreting reality from the complexity and uncertainty perspectives, questioning its certainties and making progress to a metamorphosis of the cosmic self-conscience of unity in diversity" [21].

The *computational principle* allowed for the brain's mega-computational evolution, for the purposes of processing the continuous flow of stimuli from the environment and those generated in the inside [22,23]. The *neural* brain cells compute—deliver pulses—but so do other cells and the living organism by itself, with computation as the basis of its existence, and neurons being their reason of being. These principles account for the interrelation, enlargement, and diversity of the brain, which allows us to consider new emerging dynamics in the bio-psychic and anthropo-sociocultural phenomena. The understanding of the brain functioning is facilitated by them as they reveal its hyper-complexity and inter-complex functioning, in other words, the *complexity of the complexity* that arises, inhabits and recreates it. Hyper-complexity favors the overcoming of the *restricted complexity*, which acknowledges the systems' complexity but does not go beyond acknowledgment, as it reduces it to a specific number of situations or events [24].

Complex psychic activity

Morin [24] also states that the *psychic activities* emerge from the cellular mega-computation and, to that end, implements the ecology of ideas (knowledge and culture); Noology (the organization of ideas); Noosphere (the life of ideas) and the Spirit (the emergence of the brain), which comes from the brain and shapes it, facilitating the *I* "the objectivity of multiple identities" and *Me* "the identity/individuality of each system of the subject."

Thus, the spirit guarantees the brain virtuality that gives rise to the language-thinking relationship, consciousness, the representations-cognitions, and the strategic and relational activity that shapes intelligence [21]. Morin [5] points out that "consciousness consists of 'the emergence of the reflexive thinking of the subject by themselves, over their operations, actions'", such consciousness "presupposes a suitability to reflect, in the sense of splitting, thanks to which knowledge is observed in itself and becomes an additional object of knowledge" [5]. In evolutionary terms, we can also speak of the triadic-hypercomplex *brain*, of which Morin says, "the idea of a triune brain does not lie in a tripartition but a trinity which, being complex as in the Catholic dogma, it is one and, at the same time, is triple" [25].

Additionally, he claims that the triune conception "can be seen as a scheme lacking complexity if we consider that the human brain is made up of three overlapped cerebral layers (a position opposed to MacLean's), each of which localizes global phenomena" [5]. As we already know, the brain is, in fact, a complex organization composed of multiple complex systems. Edgar Morin [25] considers that the brain activity reveals the existence of the "spirit," that is to say, of the brain virtualization and potential; however, he emphasizes that reducing the spirit to the brain or the brain to the spirit is not feasible as, under this perspective, the spirit/brain has biologically evolved from the

hominization process up to *homo sapiens*, which at the same time is homo-*pensantis*, homo-*ludens*, homo-*clausus*, etc.

Human and other ecosystem evolution arise in order with the evolution of cellular complexity, and in hominids, according to the integration of internal and external complexity in the development of thought, which, created a psychic activity increasingly Complex. Human and other ecosystem evolution arises in order with the evolution of cellular complexity, and in hominids, according to the integration of internal and external complexity in the development of thought, which, created a psychic activity increasingly Complex [5,16]. As Chris Knight [7] states, hominids did not learn about their condition in solitude, as the interactions with their environment, the confrontation of natural situations, and their relationships with other hominids favored the communication development and, as a consequence, the social ties and bonds; thus, every learning required the collectivity and the direct and indirect involvement of others. Far from implying a reiterative passivity or balance, the subjects were self-eco-changed in accordance with the external modifications, generating *computations* or biophysical pulses that allowed for the acknowledgment of such changes and the eco-systematical operation in line with them. As a consequence, the *geno-morphogenic* organization (*fenom-geno*) was restructured while its change resulted in innovations in other subjects.

Brain hyper-complexity

The brain can be understood as hypercomplex based on the complementarity of three elements: spirit-knowledge-psychism [1] Its hologrammatic condition allows for its parts/systems to be interdependent, inter-complementary, inter-influential and self/eco/organizational as each party represents and constitutes it as a whole. This way, the brain is more than a whole because its functions expand, generate relationships between learnings, and create emergencies such as thinking, language, symbolization, strategies, etc [25]. In other words, the brain is homogeneous-heterogeneous, and the complexity of the various levels of reality is composed, integrated, and interrelated therein. Such complexity invites us to understand that each process is the loop of other processes, as in the case of acting, thinking, feeling, sensing, perceiving, deciding, hesitating, conceptualizing, arranging in series, memorizing, creating, etc., which are reflexes of other loops, and of these with the socio-historical-anthropo-cultural dynamics inter-influencing one another in a reticular way [26].

All activities are recorded-relinked in the brain's *endo*(internal*)-exogenic*(external) interrelation, in such a way that the behavioral variables and external environmental situations influence the organism's internal dynamics. One example of this is the personal, social, and community experience's promotion of the *plasticity* of the brain, that is to say, its reorganization; hence, the rest-equilibrium state is inexistent, as "neuroplasticity is the property of neurons to reorganize their synaptic connections and modify the biochemical and physiological mechanisms in response to an external stimulus" [27]. The above means that the endo-exogenic relationship leads to the variability, randomization, the distinction, and the brain's evolutionary pathways, which also shape a complex thinking *per se* and increasingly emerge more reticulate, rhizomatic, and focused on social survival, the generation of knowledge, the exchange and the interaction with other beings [26].

In the human brain, the cerebral complexity is a complexity of complexities, in other words, *structural-structured-structuring* hypercomplexity. The brain is not a simple or a passive organ, and it also does not show an equilibrium state as it integrates the nested flow of stimuli and internal-external *aleas (*fortunes) [28,29], showing a relative equilibrium and the autonomy-dependence of such flow. *Ergo,* it is non-reducible to products or cognitions, as it is

set as a totality and *unitas multiplex,* through trilogies: spirit, brain, computation; individual, society, species; chaos, order, organization; organization, self-organization, self-eco-organization; thinking-language-symbolization; intelligibility, explanatory-intelligibility, understanding-intelligibility. The brain is *structural* because it has interconnected, flexible, ever-changing—neuroplastic—complex structures [30], which integrate new structural processes and changes in a dynamic and complex way [31], being able to potentially compensate flaws in the functional-structural order [32].

Similarly, it works as a *structured* organization that integrates and structures the order-disorder-organization interrelation, whenever it establishes, meets, changes the bio-psycho-cultural-anthropo-ethical stimuli and transformations [5]; also being *structuring* as it contributes to the structuring-destructuring-restructuring process of other organizations, dynamics, and operations, which allows for the integration of the *endo-exo-systemic* diversity, facilitates the brain's relative equilibrium, and paves the way toward its autopoietic self-eco-organization. In the same way, the hologrammatic principle makes it possible to explain that the brain as a hypercomplex organization requires an *imprinting* of the *whole-global* (hologram) in each part, and integrates its organizational complexity therein. That being said, each segment, area, and case, relation-interaction of the brain cannot be considered in isolation, since its existence and functionality make sense as the *organizational whole* inscribed in the *functional-cerebral-geno-phenotypic* dynamics is integrated into its existence, which does not involve the loss of its singularity or fragmentation but the re-significant interrelation of its interrelations, relations, and products.

Morin [20] states that the *brain and culture* have mutually influenced-promoted each other, in such a way that the brain has enabled and brought the culture's impulse along, while culture has arisen the brain development, favoring the evolutive transition from the hominid to the man (*homo sapiens*). As Solana explains [3,33], *cerebralization* is the evolution process of the brain, its complexity and capacities, a process associated with the cerebral juvenilization, that is to say, the property of learning and adapting to new experiences throughout the life cycle, learning and relationally integrating the developed skills, which involves the updating, change, transformation, and belonging. Thus, the social complexity and the brain complexity turn out to be interconnected, and the brain and culture's generative potentialities spring up from such inter-influence, which at the same time emerge from the polyphenomenic and sociocultural complexity.

According to Morin [20], brain hyper-complexity is related to the intelligibility principles such as the *dialogic*, the *recursive*, and the *hologrammatic*. The dialogic principle is integrated into the sociocultural world of people through the generation-establishment-interiorization-reproduction of the rules and modes of coexistence, such as, also, the inheritance-environment relationship [25], a context in which the recursive principle accounts for the capacity of interaction and hologrammatic self-eco-production of the brain [3]. For example, the memory has the power to retain the information, retrieve-code it, but this process is feasible inasmuch as it is due to a concatenation of organizations of organizations, of mutually inter-influenced relations of relations, and this is why Morin invokes the hologrammatic principle to explain the memory's representation and functioning.

Morin [25] supports part of his ideas in Karl Pribram's work [34,35] on hologrammatic brain, who concludes that the memory is computing, hologrammatic, reconstructive, and holoscopic; based on that, he establishes the brain's hologrammatic-scopic-nomic principle, "which presents a single principle with three modalities that concern the 'brain machine,' each in their own way" [36]. In that regard, Edgar Morin [11] states that the hologram serves to explain the

complexity of the memory's representation and functioning and, for this reason, it has three modes:

1. The holonomic mode by which the whole governs the partial activities and vice versa. 2. The hologrammatic mode through which the whole is somehow recorded in the part that is recorded in the whole [11]. 3. The holoscopic mode that carries out the global representations of phenomena or situations [36]

It is worth mentioning that Morin [25] does not entirely agree with Pribram as, for him, the degrees of freedom that characterize the holonomic condition may be determined mathematically, what makes reference to a linear attitude in its explanatory chart, "this way, the holonomic model of the brain functioning is also mathematically accurate and its hypotheses are also, at least in principle, experimentally verifiable" [37]. Morin agrees that the holographic state is formed by programs in such a way that the information storage and distribution are subjected to the actions and interactions between these programs, so the holonomic condition can be analyzed in accordance with the systems that produce it.

The brain and the computation-cogito inter-retro-dialogic action

The brain does not work in a mechanistic way since its complex operation is based on the dialogic function, which relates opposites and gives rise to complementarities. This way, it operates through "*biocerebral dialogics*" [20], since the brain gives meaning, represents and provides valence to the bio-socio-anthropological rules that govern knowledge. The above means that those individual and collective learning principles that the culture introduces also define the relational-complex dynamics of the human brains/spirits so that the intelligence, choices, interaction, and society become related in a sort of *imprinting* whose imprint is curiosity and the desire to learn-pass on-build knowledge in a relational way.

The brain's dialogic functions exist *in, through, and beyond* the cerebral hemispheres and, even though the thought and condition depend on them and the information of these interrelate-manage and share, each hemisphere keeps the identity of their functions and, at the same time, the plasticity to operate/cover another function when one of them does not work properly. This way, the brain function persists through a *transdialogic* condition, or a *biocerebral* dialogics between cortex-craneal nerves-Brodmann areas-limbic-sympathetic-parasympathetic system-stem, and of these with the functions-organs-processes of the entire organism, and in continued association with the environment (*eco*) and the context (*Oikos*). The dialogic function brings together what was separated, readjusts the reality levels through a scalar and successive function that reactivates the brain areas and parts while it awakens and generates constant associative pathways used by the brain to learn.

In view of the above, it is feasible to consider that both hemispheres have an antagonistic-complementary relationship in the brain, that is to say, an inter-hemispheric relationship that acts *in, through, and beyond* the corpus callosum that connects them, as products such as ideas, representations, interpretations of the experience, cognitions, strategies, emotions, affections, etc., emerge in multiple forms of the information associative processing they handle, generating new "complex-nested-organizational" associative paths whose main role is to produce interrelationships between information, instructions, associations, programs, etc.; this way, even if the left hemisphere deals with methodical thinking, calculus, strategy, objective information, abstraction, rationality, series, sequentiality, computations [38], such products are fed by the other hemisphere (the right one), which deals with the integration of

visuospatial activities, non-verbal language, as well as senses, feelings, and passions, as it involves art, culture, and speech understanding functions [39,40].

As a whole, the brain determines the complex uniduality of both hemispheres (interconnected by bundles of nerve fibers) that, at the same time, are associated with the other cerebral parts that operate out of recurrent interconnections in dialogic interrelation. The bundles "interconnect the corresponding points of almost every area of both brain hemispheres, establishing continuous communication between them"; thus, its destruction will prevent the coordinated operation between hemispheres [41]. As a complex system, this is not reduced to the operability and interconnection of the brain hemispheres and, further, it integrates the cerebral-cortical-spinal whole in the biological-anthropo-sociocultural whole, so that it is constituted in a hypercomplex system that has the property-power-tendency-propensity to self-organize itself dialogically. This means that, based on its complex multi-systemic operation, it can constantly integrate multiple stimuli, processes, mechanisms, information, etc., and the thought, language, learning, and brain functioning as a global organized entity emerges from it.

As a consequence, the brain exists relatively depending upon other organic systems, although it preserves its functional autonomy, being able to establish the self-reproduction strategies and mechanisms that make it possible for it to exist through complex uniduality or *unitas multiplex.* In this regard, the brain produces the brain system that produces it and, in turn, they produce the organism that allows it to operate and exist in a complex way through an ecosystemic interrelation in various reality folds. So, the brain shows a bio-retro-active dialogic condition, implying that it integrates, reintegrates, and disintegrates information and extracts the information required from it to account for its existence and what is real. Such multi-systemic and multidimensional integration of complementary antagonisms turns the brain into a hypercomplex dialogic system.

The brain is a multi computing organ formed by neurons or cells specialized in generating and transporting nerve impulses carrying valuable information to carry out processes, take decisions, generate language, attention, thinking, and memory, among other functions [17]. The concept of computing is taken from the computers' operation, which processes batches of information and codifies it to generate processes and results, arranging it in function of specific functions and procedures. In the human brain, computing is more complex than an electronic processor, as it cognitively organizes the complex internal (central and peripheric nervous system) and external information (derived from ecosystemic stimuli), therefore generating the informational processing, the memory activity, the symbolic and logical processes development [3]. It should be noted that the informational-cerebral makes reference to the computing exceeding the computer's *no* and *yes* to proceed to more complex information, that operates through symbolization-signification operations based on internal information and information from the environment.

These symbolic forms make reference to the codification of signs and symbols, in such a way that the brain's software associates instructions, rules, and precepts that allow for the multiple control activities of the association, calculation, reunion-separation, etc. [3,42]. In other words, the complex and hyper-computing organization operates in the brain as from cell pulses capable of generating symbols based on the randomness and the self-organizational tendency, besides producing rules, though, the language in these processes, and making up cognitive strategies and resources for problem-solving purposes. To this effect,

(…) the cellular being is a computing being in the sense that the cell «deals with molecular configurations recorded in the DNA (memory

instance), that composes a system of differences/identities (logical instance) of symbolic/informational value (informational and symbolic instances) and transforms this engram (inactive) into a program (active) that governs the molecular interactions of the cytoplasm» [25]. Cellular computation solves problems such as the survival, regeneration, reorganization, supply, defense, and reproduction of the cell [3]

According to Edgar Morin [25], the neurocerebral system has the ability to calculate the computations of the systems composing it, generating mega-computations carried out by neurons, which constitute the computation that, at the same time, guides the development of the memory, the symbolization and the informational and logical aspect [25]. As this system acts as a computing system, it generates skills-abilities-specializations that lead to strategies focused on solving problems by dialogically integrating objectivity, subjectivity, certainties, uncertainties, mechanisms, and determinisms. In this vein, the organizational complexity produces cogitations (thoughts, languages, symbolization, communication) in the brain, for which it requires the coordination of coordinations between neurocerebral computations [33]. This way, the brain turns the neural mega-computation into cogitation, a feature that accounts for the spirit's operation in the brain and the brain's operation in the spirit as cogitation, virtuality, and potentiality.

In fact, the spirit as *cogitation* is an emergence derived from the cerebral mega-computation, while it is established as an emergence of the brain development inherent to the hominization process and of the transition from the *hominid* to the *sapiens* brain [5]. It is worth mentioning that the computation-cogito or brain-spirit's is a *unidual* relationship, as they need each other to go through computation to cogitation and vice-versa, in such a way that each thought integrates the computations that, in turn, make up thoughts, and the computations of other beings in a context (*oikos*) in which interchanges, transformations, and metamorphosis are founded throughout the reality folds/levels. Although the logical functions-operations are developed through *cogitation,* the associations that make them possible are produced by *computing* and, although reasoning remains in the brain as an evolutionary proof of the order and organization, *hybris* or excess, disorder, destruction also persists therein [1]. Both tendencies are potentialities that survive through the spirit and constitute human nature. In this regard, he claims that humans:

Are beings who show intense and unstable emotions, who smile, laugh, and cry, who are anxious and distressed, selfish, blind, static, violent, raging, loving beings, overwhelmed by imagination, (…) And as we define "insanity" as the conjunction of illusion, excess, instability, the uncertainty between what is real and imaginary, confusion between what is objective and subjective, mistakes and disorders, we are compelled to consider *homo sapiens* as *homo demens* [1].

Given these two «*sapiens-demens*» characters, the human being is considered «*homo-sapiens-demens*," a complex uniduality in which insanity-sanity, hybris-excess are brought together, antagonisms that become complementary in the dialogic brain, and give meaning to the acknowledgment of destructive-constructive potentialities in human nature thanks to its functioning. Thought, language, and the world's symbolization are influenced by these two tendencies, which produce drifts or emergences as regards personal, collective, and social actions. The thought is a drift that becomes a tendency, whose cerebral functioning makes up the sapiens-demens, cogito-computing, *autos-oikos*, geno-phenotypic *unidualities,* among others. In this vein, Solana [33] believes thought is self-generated with the help of the uninterrupted dialogic dynamism which, as a recursive and self-organizational loop, moves, fluctuates, shakes, staggers, and changes direction until acquiring relative stability.

Some critical looks

A critique of the isomorphism of the concept of complexity to brain functioning is exposed by Reynoso [43], for whom, the idea of brain complexity not only does not belong to complexity, since, it has been present implicitly and implicitly in developments biology and medical sciences. The radical problem presented by this approach is also the lack of explanatory rigor about the evidence of empirical studies, so that analyses on brain and complexity may fall within the framework of speculation, an effect that called pseudo-complex irrationalism. However, researchers such as Llinas [2] identify the complexity at the base of brain operations, so that the complexity of the systems emerges from the inherent complexity of cells since these are emerging properties, where the systems do not constitute all or nothing but evolve.

In this respect, Montuori [44] indicates that the different perspectives of complexity allow for greater development of the trajectories and explanatory trends of phenomena, so that isomorphisms, theoretical walkways, and encounters can serve as a pivot for progress towards transdisciplinary positions, from which phenomena are enriched in their dialogical understanding. In this position, brain complexity would be a scientific topic that requires further development and inter- and transdisciplinary articulation.In this line of contributions Byrne and Callaghan [45] identify a problem in the idea of generating unifying concepts to globalize a series of processes, concepts, theories or epistemological positions, as the emergence of various concepts associated with complexity has led to a blur in the sense of the relational.

Thus, in understanding the brain rather than thinking of complexity as a frame of reference, or theory that unifies the multiple explanations about the central nervous system, it is necessary to move towards dialogical glances that make way for constructions transdisciplinary [46], with an ecological perspective, allowing from the biological, social and human sciences constructive encounters around the sense, operability and brain functioning [47–49]. An understanding of the brain from the paradigm of complexity invites us to embrace complex thinking as a logical operator, within the framework of Edgar Morin's theory of complexity. This entails the dialogue of knowledge between the three trajectories of complexity in social sciences: the sciences of complexity; complex thinking; and, the holist approach [50].

Consequently, rather than accusing the sciences of complexity as focused on scientific practice and proposing for the development of the cultural space, what it is all about is to bring it together with complex thinking, which highlights the critique of society and culture since a relational-dialogical stance that, together with the contributions of the holist perspectives, manage to place complexity as a worldview [51]. Gathering these contributions and focusing them on the complex understanding of brain functioning will overcome the scientificism that operates as reductionism; accept philosophical postulates that broaden the whole vision of theories; and integrate into these understandings contributions and discoveries with empirical value [52]. Finally, this dialogue of knowledge, transdisciplinary vocation and knowledge challenge is possible to call complexity.

Conclusions

The self-transforming association between brain, spirit, knowledge, and psychism from the complex anthropological perspective posed by Edgar Morin suggests that knowledge is a biological, cerebral, spiritual, logical, linguistic, cultural, social, and historical process. Such emerging knowledge establishes learning and helps to build more skills and attitudes to assume, face, integrate, and learn from uncertainty and multi-diversity. The paradigm of complexity understands the brain as a complex global unity, that is to say, as a whole or "genetic-brain-so-

ciocultural-ecosystemic" system, an organized whole, organizer of interrelationships between multiple interactions and inter-retro-actions that produce new qualities, relations, and properties. In the brain, *self-organization* implies its capacity to generate-degenerate-regenerate itself and therefore ensures its preservation, hence defining it as a particularity that allows such system to self-produce based on the principles-operators determining its structuring. However, for its structure's reproduction to take place, it needs to keep an active and dynamic relationship of exchanges and transformations with the environment what, according to Edgar Morin [24] implies that self-organization shows a relative autonomy that still depends of the environment as, the more independence and autonomy is sought, the greater the proof of belonging to a larger system, which enables and contributes to its self-eco-subsistence.

Morin's concept of *spirit* refers to the set of psychic and cognitive actions such as thoughts, cognitions, reasonings, languages, subjective ideas, and, mainly, the development of awareness, in charge of organizing and establishing relationships between all these processes. The brain creates the spirit that molds it and allows it to transform itself and evolve, so that the main product, knowledge, starts shaping human consciousness, and psychism. The spirit emerges from the brain, although not from any emergence but one that will give rise to language, socialization, and culture. The brain generates events that in turn generate new associative events, and the symbolization, language, thought, strategies, creativity, as well as the spirit, derive from it. The brain complexity is, in fact, a hyper-complexity. Computing is self-referential by itself, as each living being self-computes him/herself; however, in the inter-systemic exchange dynamics, each system integrates computations from other systems and a complex communication network that favors the updating and survival of systems is formed, in addition to its complexity as a result of the multiple interactions and emergences arising from such unions. In this connection, we can see the uniduality—*unitas multiplex*—as well as the dialogic function in its complementary antagonism that tends to integrate opposites and the recreation of *ex novo* properties in the systems; this way, the brain is updated and juvenilized with each learning. This is exactly what the cerebration involves: integration, relationism, creativity.

As the brain is formed by neurons, its complexity becomes non-linear, as it is impossible to precisely verify the impulse's initial conditions, whereas its untying implies a chaotic and organizational process that dispels the information in the structure, that is to say, in the cortex. As per Morin [1], the cell can be understood as a computing being that solves problems, and therefore each pulse constitutes an impulse, i.e., a potential transformation of various elements, and not just the communicational link between neurons. Computation is a cognitive organizer complex by itself, whose informational, memory, symbolic, and logical instances shape the brain. The complex neurocerebral system calculates the computations conducted by neurons producing mega-computations and, this way, cells are in fact complex living computers. The human neurocerebral system's organizational capacity allows for the development of cogitations (thought, ideas, language, consciousness) within a sociocultural context. The above means that, based on neurocerebral computations between (cogito) spirit and (computation), the brain exists as a complex uniduality. Cogitation develops the logical functions required by thought to order, separate, and associate information.

Likewise, computational dialogic brings antagonisms together, turns them into complementary, and makes the brain consolidate the contradictory information, takes decisions and uses the whole framework of interrelated processes and structures to give meaning to the world and the inter-eco-systemic existence. Human evolution does not take plunges;

it makes reference to neo-relations, *ex novo* properties, reticles of neural connections that give rise to new human skills, some of which are not yet relationally understood [53]. From the complexity theory, it is reasonable to consider the hypercomplex neurocerebral system (brain) to be able to learn and build new knowledge; it requires the environmental organizational existence–eco–within its own organization (integrate-acknowledge the whole in itself), what reveals the dual subjective-objective condition that every knowledge implies. In other words, the brain dialogically follows the bio-eco-anthropological rules of inheritance, the sociocultural limits that proscribe its personal and social activity, and the conditions contained by the natural environment and imposed on the ecosystems inhabiting it.

The thought is the dialogic use of cogitant skills of the human being's spirit; this way, the thinking activity makes reference to the continuous association between antagonistic-complementary processes that tend to mutually exclude and bring themselves together, therefore forming some sort of uninterrupted dialogic dynamism [25]. As we already know, the rules that compose human knowledge establish the spiritual mental and cerebral levels, as well as a complex analogic/digital, that is to say, an antagonistic, concurrent, and complementary dialogic.

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