The Paradigm of Complexity in Clinical Neuro-Cognitive Science

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Abstract

Neuro-cognitive science represents the modern approach to integrate the sub-disciplines aimed at a scientific study of the brain-mind system. This relatively new discipline recognizes, implicitly or explicitly, that this is a complex system whose states and processes are determined by multiple bio-psycho-social variables and order parameters. In a generic perspective, all neuro-cognitive science is complex as it is multidisciplinary but, in some studies, complexity has become a more defined scientific paradigm using its own specific empirical and theoretical tools. Some neuro-scientists consider Complexity Science as a specific and formalized paradigm. Between their contributions, we will try to highlight some current promising paths and new frontiers for neuroscience. In this perspective we will mostly focus on those contributions directly related to clinical perspectives. This is the reason why some seminal contributions more focused on physiological functioning might not be mentioned.

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...exiguum clinamen principiorum
nec regione loci certa
nec tempore certo…

Lucretius

A state of the art
The verses in the exergo are by the classical Roman poet Lucretius, about what he called *clinamen* and we now call *sensitivity to initial conditions*, later popularized in the media as the *butterfly effect*. His poem, *De Rerum Natura* (the Nature of Things) reminds how an awareness of the intrinsic complexity of natural dynamics has been present for very long times in human cultures (Lucretius 1971). It is quite recently, however, that complexity has become suitable of a scientific approach.

The meta-paradigm of Complexity Science crosses over different disciplines, from physics and mathematics to biology and the neurosciences. Complexity Science can be regarded as a scientific toolbox, containing some tools to deal, empirically and theoretically, with complex dynamical systems (i.e. many variables systems changing in time). This definition comprehends a series of sub-disciplines: Dissipative Systems, Cellular Automata, Fractals, Catastrophes, Self-Organization, Self-Organized Criticality, Quantum Chaos, Fuzzy Logic, Stochastic Resonance, Cellular Automata, Neural Networks, Genetic Algorithms, …and some others. As the history of its birth is quite long and …complex… for a summary of its development there are some now classical introductions by Gleick (1988), Waldrop (1992), Lewin (1993) and Taylor (2001).

The enterprise is crucial for the advancement of modern science but not new. Classical knowledge was called *Philosophia Naturalis*, Natural Philosophy, until it had been specialized in many sub-disciplines during the XVII and XVIII centuries, after Galilei, Descartes and Bacon launched the Scientific Revolution. Natural Philosophy, instead, had been rooted on the integration of different ways to approach a reality recognized as complex and multi-ordered. Unfortunately at that time the mathematical, physical and statistical tools were inadequate and the computation power was missing the crucial support of digital computers. Specialization was the way to focus on more defined areas of knowledge.

The gradual emergence of a set of formal and methodological tools called Dynamical Systems Theory, or Complexity Science, coupled with the huge increase of calculation power available on modern computers, has finally brought some metaphorical visions of natural philosophers in the domain of normal science. Complexity Science was then also called Nonlinear Science as a marker of the shift in scientific paradigms (Kuhn, 1996) but, as Stanislaw Ulam said: “Calling a science ‘nonlinear’ is like calling zoology ‘the study of non-human animals’ “. Almost every system is complex, dynamical and nonlinear by nature. It is the limit of our approaches or our deliberate choice that makes us see them as linear. Yet the distinction has been necessary in the natural sciences, which became so accustomed to linear systems because they were more treatable: linearization could “tame” their “wild” complexities. Complexity Science should now be considered the normal modern science.

The discovery of the possible scientific study of dynamical behaviors unrestricted by linearity is one of the greatest scientific revolutions of all times. It is becoming even a revolution in our everyday perception of reality, as trees and lightning become scientific objects under the name of fractals, just as cubes and cones have been for centuries.
It is clear that Maxwell and Boltzmann, the founders of statistical physics, were acutely aware of the property of sensitivity to initial conditions and its consequences. Not before Poincaré (1892) however, could ascertain the existence of this property in a system with few degrees of freedom, namely the reduced 3-body problem.

In any case scientific developments at the beginning of the last century prepared the conditions for John von Neumann, circa 1950, to affirm a quite proud mission: “All stable processes, we shall predict. All unstable processes, we shall control.” (Dubè, 2000). Several years after, in his 1985 Giord Lectures, Freeman Dyson (1988) expressed his quite different opinion:

“A chaotic motion is generally neither predictable nor controllable. It is unpredictable because a small disturbance will produce exponentially growing perturbation of the motion. It is uncontrollable because small disturbances lead only to other chaotic motions and not to any stable and predictable alternative.”

Was Von Neumann's a mistake to imagine that every unstable motion could be nudged into a stable motion by small pushes and pulls applied at the right places? If chaos is one of the possible marriages between order and disorder, habit and life, how much is it possible a reliable knowledge of complex systems?

Now that we have the toolbox of Complexity Science we realise that the enterprise is still at the beginning. The science of complexity, now recognized as a “mission possible”, still resembles a sea of ignorance with some small islands where results are known and applicable. There is also a wide accepted idea that there are many different ways in which reality blends order and randomness: deterministic chaos, in its similar and yet different cycles, is just one of them.

This state of the art is well represented in the sketch below that we owe to Francisco Varela (1991) and Thomas Schreiber (Schreiber, 1999).

A state of the art in Complexity Science (Varela, 1991; Schreiber, 1999)
Dynamical systems theory
The first evidence of physical chaos is associated with the name of Edward Lorenz (1963; 1994) whose discovery of the first strange attractor in a simplified meteorological model containing only 3 state variables has led to a remarkable explosion in the study of chaos and its properties.
More recent years have seen the definition of a new frontier in complexity studies: the theory and application of control and synchronization (Pecora & Carroll 1990; Ott, Grebogi & Yorke 1990). We will mention some of its interesting applications later on.

Local geometry of control: left 2D saddle dynamics and right linearization of the stable and unstable manifolds (Dubè, 2000)

Chaos theory becomes also a crucial way to understand some deep implications of Darwin’s research on biological laws. If chaos is a source of optimal variation, a flexible order capable to include some disorder, targeting desirable states within chaotic attractors is a preliminary phase of selection and co-evolution.

One of the major problems in the above process is that one can switch on the control only when the system is sufficiently close to the desired behavior. This is warranted by the periodicity of chaos regardless of the initial condition chosen for the chaotic evolution. Anyway, as any chaotic cycle is always different, it may happen that the small neighbourhood of a given attractor point (target) may be visited only infrequently, because of the locally small probability function. Thus, one of the issues in the application of synchronization to complex systems is how reducing time to target the control zone of the attractor. This is just one of the many questions now still open for research.

Another important question is related to the role of computers in the development of Complexity Science. They are regarded as crucial in its recent developments for their power of “crunching” huge quantities of data. Their capacity to visualize interactive “mathematical environments” is also considered essential. Anyway, the role of computers simulations is now under scrutiny.

David Ruelle (1994), summarized some methodological caveats: “Suppose that you have concocted a mathematical model in biology or economics; you put this model on your computer and you discover a Feigenbaum period-doubling cascade (…) is this result interesting?” He answered that it is probably not: you should care about the relation between your model and real empirical situations. Real systems are not straight equivalent to computer models: “Computer study of a model is an important method of investigation, but results can be only as good as the model”.

However, the greatest challenge will remain for some time the application to complex neuro-cognitive systems: in particular to mind and brain dynamics (Freeman, 1999; Orsucci, 2003).

The perspective of unifying the techniques of deterministic chaos control with a statistical description as a possible therapeutic strategy against dynamical diseases might be the challenge for
the next years. The balance between empirical research, modelling, simulation and metaphors is located at the core of the current debate in this field (Verhulst, 1994).

Neuroscience and Complexity
In an editorial maybe ironically entitled "Chaos in Psychiatry" in vol. 31 of Biological Psychiatry, Walter Freeman (1992), stated that psychiatrists “are no strangers to complexity, because, in the course of their daily management of mental illness, they must connect data over all levels, from genetics to disturbed behavior. What few of them know is that there are new and powerful tools available to them for the treatment of complexity.”
Freeman noted how the amount of data produced in neurosciences is now so huge that the main task might be no longer to get more data, but rather to acquire proper scientific tools to integrate the existing information into powerful and coherent theories.
In the editorial of the following edition of the same journal, Mandell (1992) took Freeman's reflection one step further. He mentioned the story of the US-NIMH project on systems’ dynamics in neuroscience (Computational, Theoretical and Mathematical Neuroscience - Koslow and Coll., 1987) which, involved several hundred scientists. He concluded confirming Freeman’s point of view that “we know quite much about what, but not enough about how.”
In the fields of cognitive science and psychoanalysis, some kind of similar attention began to be seen, bearing the metaphorical mark of the “humanities”. In some sense, this new form of dynamic neuropsychiatry might be seen as an update of the “Project for a Scientific Psychology”, the “psychology for neurologists” written by Freud in 1895. But, there has been a great deal of neurological, psychiatric and cognitive research in the meantime and certainly the scientific landscape is very different now (Kandel 1999).
In that particular Project, Freud attempted to describe relationships between hardware and software of neuro-cognitive systems, using some conceptual tools of physical and physiological determinism of the late 1800's. In any case, while neural systems apparently seemed more easily definable in mechanistic terms, he realized that linguistic and cognitive structures were too complex to be easily described in statistical-mathematical terms. On top of this, the scientific tools he had to integrate such different domains were quite poor. For this reason Freud and his followers drifted towards literary and metaphorical descriptions.
Just a few of them were aware that during the same years Poincaré, Planck and Einstein defined the theoretical tools which were later to revolutionize that same vision of nature. So, now we live in a very different scientific world and neuro-cognitive science is developing so fast also because many “hard scientists” are fast moving to this new El Dorado.
The Lorenz attractor: optimal dynamics between cycles and randomness.

**Dynamical Diseases**

Various studies in the field of physiopathology propose a new viewpoint on disease as a change in a physiologically intact system. This means that disease is starting not because it is modified by the outside, but just because, while operating within its own control parameters, they can, at times, cause it to take anomalous dynamics (Glass & Mackey 1979; Mackey & Milton 1987; Pool 1989; Schiff et al 1994).

This is a dynamical way to consider diseases as possibilities already embedded within physiological processes. The development of a disease may be associated with passages from one dynamic regime to another (Mackey & Glass 1987). These dynamical changes, called *bifurcations*, have been observed in neurology (Milton et al 1989), especially in studies on epilepsy (Babloyantz & Destexhe 1986). Using this discovery, some *in vitro* studies have shown how epileptic fits could be managed and controlled using chaos theory approach (Schiff et al 1994).

This same type of dynamic approach has already produced appreciable clinical results towards prevention and possible treatments of arrhythmias and sudden cardiac death (Goldberger & West 1987). Based on the analysis of time series in cardiac frequency (R-R space in the ECG) several studies in cardiology have shown how healthy hearts have a much more variable frequency than was previously thought. These patterns are probably organized by strange attractors, structured in fractal geometry. Hearts at risk, on the other hand, seem more ordered: the variability of their parameters is much more restricted. This implies a reduced elasticity of the system to various stressors, and a vulnerability to different kinds of disturbed dynamics, including sudden cardiac death. Ari Goldberger proposed a remarkable statement to define this finding: "Healthy systems don't want homeostasis, they want chaos". He explained that if we accept our anatomy is fractal, only a small step further is needed to recognize that the functioning of physiological systems is obviously based on fractal geometries and chaotic dynamics.
Neuro-cognitive systems are organized in a similar way, though brain architectures are fractal on a scale larger than the neural conduction system in the heart. Anyway, this model based on systemic complexity as a health factor, has been applied to the study of various degenerative and decay processes: Parkinson's, epilepsy and senescence (Lipsitz et al 1992; Glanz 1994; Garfinkel et al 1992) Results of these studies imply a serious revision of Cannon's homeostasis. A biological system is now recognized to be powerful, efficient and adaptable if it is complex, whereas disease and decay have in common a simplification of dynamics. This finding generated proposals for the experimental treatment of degenerative diseases, and the delay of systemic senescence, based on anti-control (Ditto et al 1990) strategies instead of more usual linear control, homeostatic, approaches.

Dynamics in Mood Disorders
Chrono-psychobiology has established an important trend in the dynamic study of mood disorders. This line of research started with the discovery that mood disorder often include a disorganization of psycho-biological rhythms.
Each biological rhythm may be considered, in physical terms, as an oscillator and studied as such in its couplings or de-couplings with other rhythms within the same system. Furthermore, each rhythm has its own Zeit-Geber, a pace-maker metronome that marks its tempo and may also have Zeit-Störers: psychosocial, biological or physical factors that can change its rhythm (Ehlers 1988, 1995). The chrono-biological approach has been extended by (1978; 1981; 1984) towards a neurodevelopmental perspective by identifying numerous events and psychosocial conditions acting as Zeit-Störers during infant development. Interpersonal relations and social needs are also recognized as having the capability of acting as powerful synchronizers of biological rhythms. This same area of research comprises well known applications of phototherapy and other means as restorers of correct biological rhythms in seasonal depression. Implications for attachment theory are wide (Fonagy et al 2003).
Some studies have been focused on the rhythms of mood disorders, and their fluctuations (Wehr 1984; Wehr et al 1984; Kniffki et al 1990). They have shown that time series of mood variations tend to organize according to the so called self-organized criticality, SOC, whose degree of unpredictability is lesser than chaotic systems, and it is defined to be situated "on the edge of chaos" (Bak 1990; Bak, Tang & Wiesenfeld 1984). In these kinds of complex systems, the combination of a minimal dynamic stability produce a distribution of time series according to a power-law. A relative predictability is the result.
In manic-depressive subjects, it means that transitions from one state to another (just as bouncing from depression to mania) may be triggered by minimal perturbations and, once started, a change can be just as sudden and massive as in a catastrophe theory model. In any case, within certain levels of intensity and within a defined period, this change in mental conditions might be predictable using nonlinear methods for the analysis of time series (Schiepek et al 1990). This limited predictability might be used for therapeutic purposes and biological and psychosocial treatments might be targeted against those mood loops, in the purpose to increase the “dynamic complexity” of manic-depressive subjects.

Complexity and Schizophrenia
As we mentioned, recent developments of studies on complex systems were favored by the huge increment in computation power. At the same time, computers have enabled the emergence of interactive simulations of system dynamics.
A simulation of events and processes, rather than their direct manipulation in vivo, is inherent to the maturation of every scientific discipline. In recent years, this approach has started to emerge also in neuro-cognitive science.
Historical precedents have been provided by some intuition by William James, the classic works of Alan Turing and the development of the so-called Artificial Intelligence (though it has had some difficulties to maintain its messianic promises of the beginnings).

In a seminal series of research projects, Hofman (Hofman & Dobscha 1989; Hoffman & McGlashan 1993a-b), proposed "a computer simulation for the study of the schizophrenia-mania dichotomy". His inquiry was starting from well known clinical descriptions stating that respective thought disorders sometimes overlap. Previous studies noted how manic patients disorganize their discourse projects or *Gestalten*. This might be due to jumps between too many parallel thought processes.

In schizophrenic patients, on the other hand, the ability to generate coherent thought processes would seem difficult *ab initio*. Their thought processes are incomplete and disorganized, resulting in lapses in speech and logical inadequacies.

Hofman organized an experiment based on a neural system structured according to a model of associative memory and mass action. During the experiment it became evident how “overloading” the neural network produced "parasitic states", similar to epileptic *foci*. These states generated some computational equivalents of schizophrenia’s secondary symptoms. Hoffman’s research nowadays continue to lead the simulation modeling approach to psychopathology.

On a more traditional mathematical approach Schiepeck (1990) has proposed an evolutionary profile of schizophrenia based on nonlinear differential equations, built within a bio-psycho-social framework. In doing so, he attempted to maintain a multidimensional (many degrees of freedom) approach. He included in his model: diathesis-stress dynamics (Gottesman & Shields 1976), interactive evolution (Strauss & Carpenter 1981), neural plasticity (Haracz 1984), vulnerability (Neuchterlein & Dawson 1984) and genetic (Ciompi 1989) components.

The construction of this multifactor mathematical model generated a simulation of the evolving patient-system, based on a possible manipulation of many variables.

These studies can be considered within the framework of neurodynamics, as a modern form of psychodynamics, which recognizes the "mass action" of millions of neurons and billions of connections as a necessary foundation for self-organization and plasticity (Freeman 1975; 1990).

This new approach defines “obsolete” the traditional distinction "state vs. trait" as, for example, a state transition, albeit temporary, in a psychotic condition, can leave a permanent imprint in the neural "hardware". From this assumption derives the neurodevelopmental importance of the duration of any mental state. A process as such does not imply a simple increase or decrease of neuromediators and receptors, but rather implies a disorganization and successive reorganization in a neurocognitive system (Kohonen 1988; Basar 1990).
Personality Disorders in Small Worlds.
A quite new perspective on Personality Disorders and antisocial behavior is produced by studies in the so called “small worlds” network theory.
At the first Artificial Life Workshop (Langton, 1989) Craig Reynolds presented a computer simulation of bird flocking based on 3 simple rules conditioning an otherwise unconstrained set of “boids”. Each boid was required to:
1. Maintain a minimum of distance from other objects, including other boids;
2. Match velocities with neighbouring boids;
3. Move toward the perceived centre of mass of boids in the neighbourhood.
These rules are all local, applying to individual boids, and yet their effect is that of flocking dynamics of striking realism and elegance. Flocking is here an emergent global phenomenon. It is interesting to reflect on the extent to which the three rules capture the essence of a standard 3-value set (for example Liberty, Equality, and Fraternity). It is worth noting that this value set is based just on simple contextual, local, rules about relations.
Of special interest is the way in which the component elements emerging during such self-organization are both mutually constraining and mutually sustaining. Each is a vital local part of the global pattern within the bounded space. A different pattern can be engendered within the same space and with the same values, but the significance is distributed into different clusters, whether differently located, of a different size, or of a different number.
Another basic feature of this cited experiment is that computer simulations based on Artificial Life can show how ethics and values can generate some sort of in vitro experiments. The history of humanity has shown enough about the risks of in vivo experiments in ethics and politics, and this seems a new opportunity to test ethical hypotheses before any “collateral damage”.
These experiments highlight the structuring process of value sets in a small world, by applying just local rules and not hierarchical rules. Organization of values is the emergent production of local iterated interactions. This kind of contextual organization is more flexible and adaptable to unexpected events than “top-down” organizations.
From such a perspective it is clearly far less appropriate to attempt to focus on any particular pattern of values. Of much greater relevance is to recognize the process whereby different kinds of contextual circumstances can evoke the emergence of such different patterns from the value space. Another way to look at such patterning is in terms of the “pathways” that may emerge between different value locations. Just as a pattern of mountain valleys may severely condition the nature of relationships between otherwise proximate zones, particular values may also affect (or be dependent on) each other to a greater or lesser degree.
The cultural historian William Irwin Thompson synthesizes: “Values are not objects, they are relationships. When you overlay one pattern with another, a third pattern emerges, a moiré pattern” (Thompson, 1996). As Gregory Bateson stated: “Destroy the pattern which connects and you destroy all quality” (1979). This means that values, just as qualia, are (embedded in) a complex mesh of relations. The popularized paradigm of “six degrees of separation” is certainly one of the most important contributions of complexity science (Watts & Strogatz 1998).
The Small World network is an optimal organization between regularity and randomness.

**Neuro-ethics and non-consciousness**
Around 1911 Husserl introduced the term *double intentionality* (1980) for the articulation, since there is not only retention (of the object-event) but also retention of retention (a reflective awareness of that experience).
William James (1967) had come to a similar conclusion when he described his phenomenological experience of lying in bed, telling himself to get up. He stayed in bed. He later found himself up without remembering the exact instant of transition. This is a shared experience as a full awareness of actions includes blind spots and lags.
Libet’s (1993; 1999; Freeman, 2001) experiments on the consciousness lag and the Readiness Potential, though sometimes discussed in their methodology, suggest a solution: there is a doubling between intentionality and consciousness, and it has neurobiological foundations.

Libet’s finding of a readiness potential preceding action planning (1993)
Vitiello (2001), from a quantum field point of view, suggests a different solution of these non-consciousness phenomena: “The openness of the brain to the external world (dissipation) implies the doubling of the brain system degrees of freedom. The system obtained by doubling, the Double, plays the role of the bath or environment in which the brain is permanently embedded. It is suggested that conscious as well as unconscious activity may find its root in the permanent dialogue of the brain with its Double.”. This double might be just thinking and the Language & Culture universe in which we are immersed as a second identity (Donald 2001; Orsucci 2003).

Radically “readiness-for-action is a micro-identity and its corresponding level a micro-world: we embody streams of recurrent micro-world transitions” (Varela et al 1991). These micro worlds are nested and intermingled in other worlds. There is a small time-lag somewhere, like a butterfly-wings’-flap generating, through multiple cascades, the doubling and mirroring effects we are used to call consciousness.

Time in experience is quite different from time as measured by a clock. Time in experience presents itself not only as linear but also as having a complex texture (evidence that we are not dealing with a “knife-edge” present) a texture that dominates our existence to an important degree (Varela in Petitot, 1999).

We could define three levels of temporality:
1. A first level proper to temporal objects and events in the world. This level is close to the ordinary notions of temporality in human experience, which grounds the notion of temporality currently used in physics and computation.
2. A second level, which is quickly derived from the first by reduction, the level of acts of consciousness that constitute object-events. This is the “immanent” level, the level based on the “internal time” of acts of consciousness. Their structure forms the main body of the phenomenological analysis in Husserl's Lectures (1980).
3. Finally (and this is the most subtle level of analysis), these first two levels are constituted from another level where no internal-external distinction is possible, and which Husserl calls the “absolute time constituting flow of consciousness”.

As phenomenological research itself has repeatedly emphasized, perception is based in the active interdependence of sensation and movement. Several traditions in cognitive research have, as well and in their own way, identified the link between perception and action as key. It is this active side of perception that gives temporality its roots in living itself. Within this general framework, we will concentrate more precisely on the structural basis and consequences of this sensory-motor integration for our understanding of temporality.

This overall approach to cognition is based on situated embodied agents. Varela (Varela, 1991; Thompson, 2001) has proposed the adjective enactive to designate this approach more precisely. It comprises two complementary aspects:

1. the ongoing coupling of the cognitive agent, a permanent coping that is fundamentally mediated by sensory-motor activities;
2. the autonomous activities of the agent whose identity is based on emerging, endogenous configurations (or self-organizing patterns) of neuronal activity.

Enaction implies that sensory-motor coupling modulates, but does not determine, an ongoing endogenous activity that it configures into meaningful world items in an unceasing flow.

From an enactive viewpoint, any mental act is characterized by the concurrent participation of several functionally distinct and topographically distributed regions of the brain and their sensory-motor embodiment. From the point of view of the neuroscientist, it is the complex task of relating and integrating these different components that is at the root of temporality.

These various components require a frame or window of simultaneity that corresponds to the duration of lived present. There are three scales of duration to understand the temporal horizon just introduced:

- basic or elementary events (the “1/10” scale);
• relaxation time for large-scale integration (the “1” scale);
• descriptive-narrative assessments (the “10” scale).

The first level is already evident in the so-called *fusion interval* of various sensory systems: the minimum distance needed for two stimuli to be perceived as non-simultaneous, a threshold that varies with each sensory modality. These thresholds can be grounded in the intrinsic cellular rhythms of neuronal discharges, and in the temporal summation capacities of synaptic integration. These events fall within a range of 10 ms (e.g., the rhythms of bursting inter-neurons) to 100 ms (e.g., the duration of an EPSP/IPSP sequence in a cortical pyramidal neuron). These values are the basis for the 1/10 scale.

Behaviorally, these elementary events give rise to *micro-cognitive phenomena* variously studied as perceptual moments, central oscillations, iconic memory, excitability cycles, and subjective time quanta. For instance, under minimum stationary conditions, reaction time or oculo-motor behavior displays a multimodal distribution with a 30-40 ms distance between peaks; in average daylight, apparent motion (or “psi-phenomenon”) requires 100 ms.

This leads naturally to the second scale, that of long-range integration. Component processes already have a short duration, on the order of 30-100 ms; how can such experimental psychological and neurobiological results be understood at the level of a fully constituted, normal cognitive operation? A long-standing tradition in neuroscience looks at the neuronal bases of cognitive acts (perception-action, memory, motivation, and the like) in terms of cell assemblies or, synonymously, neuronal ensembles. A cell assembly (CA) is a distributed subset of neurons with strong reciprocal connections.

Windows of time (Varela, 1991)
The diagram depicts the three main hypotheses. A cognitive activity (such as head turning) takes place within a relatively incompressible duration, a cognitive present. The basis for this emergent behavior is the recruitment of widely distributed neuronal ensembles through increased frequently, coherence in the gamma (30-80 Hz) band. Thus, the corresponding neural correlates of a cognitive act can be depicted as a synchronous neural hypergraph of brain regions undergoing bifurcations of phase transitions from one cognitive present content to another. Recently this view has been supported by widespread findings of oscillations and synchronies in the gamma range (30-80 Hz) in neuronal groups during perceptual tasks. Thus, we have neuronal-level constitutive events that have a duration on the 1/10 scale, forming aggregates that manifest as incompressible but complete cognitive acts on the 1 scale. This completion time is dynamically dependent on a number of dispersed assemblies and not on a fixed integration period; in other words it is the basis of the origin of duration without an external or internally ticking clock. Nowness, in this perspective, is therefore pre-semantic in that it does not require a remembering in order to emerge. The evidence for this important conclusion comes, again, from many sources. For instance, subjects can estimate durations of up to 2-3 seconds quite precisely, but their performance decreases considerably for longer times; spontaneous speech in many languages is organized such that utterances last 2-3 seconds; short intentional movements (such as self-initiated arm motions) are embedded within windows of this same duration. This brings to the fore the third duration, the 10 scale, proper to descriptive-narrative assessments. In fact, it is quite evident that these endogenous, dynamic horizons can be, in turn, linked together to form a broader temporal horizon. This temporal scale is inseparable from our descriptive-narrative assessments and linked to our linguistic capacities. It constitutes the “narrative center of gravity” in Dennett's metaphor (Dennett, 1991), the flow of time related to personal identity. It is the continuity of the self that breaks down under intoxication or in pathologies such as schizophrenia or Korsakoff's syndrome. As Husserl points out, commenting on similar reasoning in Brentano: “We could not speak of a temporal succession of tones if … what is earlier would have vanished without a trace and only what is momentarily sensed would be given to our apprehension” To the appearance of the just-now one correlates two modes of understanding and examination (in other words, valid forms of donation in the phenomenological sense): (I) remembrance or evocative memory and (2) mental imagery and fantasy. The Ur-impression is the proper mode of the now, or in other words, it is where the new appears; impression intends the new. Briefly: impression is always presentational, while memory or evocation is re-presentational. This behavior embodies the important role of order parameters in dynamical accounts. Order parameters can be described under two main aspects: 1. The current state of the oscillators and their coupling, or initial conditions; and 2. The boundary conditions that shape the action at the global level: the contextual setting of the task performed, and the independent modulations arising from the contextual setting where the action occurs (namely, new stimuli or endogenous changes in motivation). Recent advancements in the complex neurodynamics of time could provide seminal contributions in advancing our understanding of ethical issues on personal responsibility of actions (Gazzaniga 2005). A rather cryptic and intuitive statement by Freud sounded as: “The unconscious is extended but knows nothing about it”. Complexity Science is providing evidence about the wide territories of human knowledge extending beyond what, during the past century, we called consciousness and unconscious. New explorers are preparing new maps.
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