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# PREFACE

In the last two decades two paradigms are emerging with great emphasis in scientific inquiry in the context of both pure and applied sciences.

One is quantum mechanics, the other concerns the sector advanced and articulated of scientific knowledge that is framed as chaos theory, complexity theory, self-organization and emergence, fractality.

The advent of quantum mechanics is usually signed about 1927 by founding father as Bohr, Heisenberg, Jordan, Pauli, Schrodinger, Born , Dirac, von Neumann , just to name only a few authors and unjustly ignoring for brevity other fundamental contributions.

A theory disruptive, able to crush the cornerstones of our traditional view of reality and yet always confirmed by experiments and constant controls that science must constantly pursue in its attempt to achieve a fundamental approach to our ultimate reality.

Starting with the preliminary contributions of Bordley and myself, an application field of quantum mechanics has become of great interest in recent years, namely the application of this theory in neuroscience and psychology. It is a new field of interest that has benefited from the important contributions of Khrennikov, Aerts, Busemeyer, Atmanspacher, Blutner, Bruza , Huping Hu ,and myself and still other important contributions that I do not mention here again for the sake of brevity but are widely referenced in the relevant literature.

The question, from the ontological, epistemological and methodological point of view the problem is a long time ago. Classical science, as articulated by Newtonian mechanics, is essentially reductionist: it reduces all complex phenomena to their simplest components, and then tries to describe these components in a complete, objective and deterministic manner. In recent year's neuroscience have made enormous strides thanks in particular to the use of advanced imaging technologies. Brain areas have been identified having specific functions as learning, memory, and still more. Here is a prevailing tendency. It is often believed that by following this path and day to day adding pieces of knowledge, in the end we will come to understand what are the mental entities, the mind and the way it is interfaced with the brain. On the other hand there are the empirical results of psychology, important but still very distant from the possibility to be able to interface with those of neuroscince. Indeed, a huge gap persists between the two disciplines. Consequently I have profound reservations. My opinion is that the existing gap is due to a missing model and such model is represented from quantum mechanics. There is the first important result that we have obtained. We have shown about the logical origins of quantum mechanics. The logic is related closely with cognition that it is a fundamental mental function of living being. We have given theoretical and experimental evidence that the basic features of quantum mechanics as the so called quantum interference has a basic role at perceptive and cognitive level in humans. By using Clifford algebra we have given mathematical proof of the existing mechanism of the collapse of the wave function giving demonstration of the basic von Neumann postulates on quantum measurement and thus restoring internal coherence to quantum mechanics and highlighting the importance of the mechanism of transition potentiality- actualization which is the core of the theory. Finally, according to Orlov, we have given evidence that Reality may be very distant from the restricted model of reality that we are accustomed to accept every day considering the matter on one side and the thinking being that is set in a separate and independent localization. We have fond that there are stages of our reality in which matter no more may be admitted per se, independently from the cognition that we have about it.

I retain this as a fundamental question. It is a new advance that is able to shake your wrists to each of us because of its implications.

In conclusion we have here new important advances that are now in progress in the filed of the basic and applied sciences.

Chaos Theory

"A horse gait from walking to trotting to galloping". We have here sudden transitions resulting from dramatic reorganization. [1]

Chaos theory, started initially as a branch of mathematics, is currently included also in the competence of theoretical physics and mathematical physics. The prevailing interest is the research in applied sciences. One basic feature of chaos theory is that it studies the behavior of dynamical systems that are highly sensitive to initial conditions. Small differences in initial conditions (also so contained as rounding errors in numerical computation) yield widely diverging outcomes for such dynamical systems, rendering long-term prediction impossible in general. This happens even though these systems are deterministic, meaning that their future behavior is fully determined by their initial conditions, with no random elements involved. The deterministic nature of these systems does not make them predictable. This behavior is known as deterministic chaos, or simply *chaos* as Edward Lorenz just outlined in 1963 [2].

There is no generally accepted definition of complexity. A feature of complex systems, such as organisms, is that they have properties (emergent properties ) that cannot be reduced to the mere properties of their parts. Moreover, the behavior of these systems has aspects that are intrinsically unpredictable and uncontrollable, and cannot be described in any complete manner. At best, we can find certain statistical regularities in their quantitative features, or understand their qualitative behavior through models and computer simulations. Complex systems lose some traditional qualities but have also a number of surprisingly positive features, such as flexibility, autonomy and robustness, which are instead missing in traditional mechanistic systems.

We have here all features of self-organization that typifies complex systems: these systems spontaneously organize themselves so as to better cope with various internal and external perturbations and conflicts. This allows them to evolve and adapt to a constantly changing environment. Processes of self-organization literally create order out of disorder . Finally, another basic concept is that one of non linearity.

Processes in complex systems are often *non-linear* , and this is to sat that their effects are not proportional to their causes. When the effects are larger than the causes, we may say that there is an amplification or *positive feedback* initially small perturbations reinforce. The non-linearity is the antechamber of chaos. Roughly speaking, in fractals the parts resemble the whole across several levels of resolution.

A fractal dimension is a ratio providing a statistical index of complexity. It may be stimated comparing how detail in a pattern (strictly speaking, a fractal pattern) changes with the scale at which it is measured. It has also been defined trough the measure of the space-filling capacity of a pattern that evidences how a fractal scales differently than the space it is embedded in. A fractal dimension does not have to be an integer The term itself was brought by Benoit Mandelbrot based on his 1967 paper on self-similarity in which he discussed *fractional dimensions* [3] In that paper, Mandelbrot cited previous work by Lewis Fry Richardson describing the counter-intuitive notion that a coastline's measured length changes with the length of the measuring stick. Scaling relationships can be defined mathematically by the general scaling rule in the following equation, where the variable $N$ stands for the number of new sticks, $\varepsilon$ for the scaling factor, and $D$ for the fractal dimension

$$N \infty \varepsilon^{-D}$$

Also time series , especially those recorded in biosignals, may exhibit fractal behaviour of self-similarity in time.

In probability theory, a normalized fractional Brownian motion (fBm**)**, is also called a fractal Brownian motion. It is important to observe that it is a generalization of Brownian motion without independent increments.

Usually $H$ is a real number in (0, 1), called the Hurst index or Hurst parameter associated with the fractional Brownian motion. The Hurst exponent describes the raggedness of the resultant motion, with a higher value leading to a smoother motion.

The value of *H* determines what kind of process the *fBm* is:

if $H = 1/2$ then the process is in fact a Brownian motion or a Wiener process;

if $H > 1/2$ then the increments of the process are positively correlated;

if $H < 1/2$ then the increments of the process are negatively correlated.

In conclusion. Quantum mechanics from one hand and the use of Chaos and Complexity theories are receiving increasing consideration in the field of basic and applied sciences . Costantly, we have evidence of an increasing large body of applied science by using non linear methodologies. In the last decade we have had also increased interest in analysis of time series data and image analysis in astronomical and astrophysical data. A very promising new field. The reason is easy to find. A body of increasing advanced methodologies is at the disposal of applied science and much of the dynamics of our nature are based on non-linear mechanisms.

Of course I have previously mentioned that we can find certain statistical regularities in the quantitative features. This is the basic concept of Recurrence. The conceptual counterpart is that one of Variability that I continue to investigate with great interest.

The method of Recurrence Plot (RP ) was introduced by Eckmann et al. in 1987 [4] . The aim of the method was to visualize the time dependent behaviour of the dynamics of systems, which

can be pictured as a trajectory in the given n-dimensional phase space. The plot represents the recurrence of the phase space trajectory to a certain state, which is a fundamental property of deterministic dynamical systems.

The recurrence quantification analysis (RQA) is a method of nonlinear data analysis which quantifies the number and duration of recurrences of a dynamical system presented by its state space trajectory.

J. Zbilut and C. Webber jr [5] developed the Recurrence Quantification Analysis (RQA) method to quantify an RP. The RQA method records currently hundreds and hundreds of applications in every field of applied sciences. Prof Joseph P. Zbilut was my friend. A distinguished scientist and a great man , died before of his time four years ago. I feel the moral duty to remember him in this special issue. The chapter written by C.Webber is here reproduced with the kind permission of Charles Webber and Michael Riley. It is reprinted from Webber, C.L., Jr., & Zbilut, J.P. (2005). Recurrence quantification analysis of nonlinear dynamical systems. In M.A. Riley & G.C. Van Orden (Eds.), *Tutorials in contemporary nonlinear methods for the behavioral sciences* (pp. 26-95). Retrieved from http://www.nsf.gov/sbe/bcs/pac/nmbs/nmbs.jsp.

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