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   Titolo Application of Nonlinear Analysis to the Study of Complex Systems in Neuroscience and Behavioral Research

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   Sommario/riassunto Although nonlinear dynamics have been mastered by physicists and mathematicians for a long time (as most physical systems are inherently nonlinear in nature), the recent successful application of nonlinear methods to modeling and predicting several evolutionary, ecological, physiological, and biochemical processes has generated great interest and enthusiasm among researchers in computational neuroscience and cognitive psychology. Additionally, in the last years it has been demonstrated that nonlinear analysis can be successfully used to model not only basic cellular and molecular data but also complex cognitive processes and behavioral interactions. The theoretical features of nonlinear systems (such unstable periodic orbits, period-doubling bifurcations and phase space dynamics) have already been successfully applied by several research groups to analyze the behavior of a variety of neuronal and cognitive processes. Additionally the concept of strange attractors has lead to a new understanding of information processing which considers higher cognitive functions (such as language, attention, memory and decision making) as complex systems emerging from the dynamic interaction between parallel streams of information flowing between highly interconnected neuronal clusters organized in a widely distributed circuit and modulated by key central nodes. Furthermore, the paradigm of self-organization derived from the nonlinear dynamics theory has offered an interesting account of the phenomenon of emergence of new complex cognitive structures

from random and non-deterministic patterns, similarly to what has been previously observed in nonlinear studies of fluid dynamics. Finally, the challenges of coupling massive amount of data related to brain function generated from new research fields in experimental neuroscience (such as magnetoencephalography, optogenetics and single-cell intra-operative recordings of neuronal activity) have generated the necessity of new research strategies which incorporate complex pattern analysis as an important feature of their algorithms. Up to now nonlinear dynamics has already been successfully employed to model both basic single and multiple neurons activity (such as single-cell firing patterns, neural networks synchronization, autonomic activity, electroencephalographic measurements, and noise modulation in the cerebellum), as well as higher cognitive functions and complex psychiatric disorders. Similarly, previous experimental studies have suggested that several cognitive functions can be successfully modeled with basis on the transient activity of large-scale brain networks in the presence of noise. Such studies have demonstrated that it is possible to represent typical decision-making paradigms of neuroeconomics by dynamic models governed by ordinary differential equations with a finite number of possibilities at the decision points and basic heuristic rules which incorporate variable degrees of uncertainty. This e-book has include frontline research in computational neuroscience and cognitive psychology involving applications of nonlinear analysis, especially regarding the representation and modeling of complex neural and cognitive systems. Several experts teams around the world have provided frontline theoretical and experimental contributions (as well as reviews, perspectives and commentaries) in the fields of nonlinear modeling of cognitive systems, chaotic dynamics in computational neuroscience, fractal analysis of biological brain data, nonlinear dynamics in neural networks research, nonlinear and fuzzy logics in complex neural systems, nonlinear analysis of psychiatric disorders and dynamic modeling of sensorimotor coordination.