Nonlinear Dynamics, Psychology, and Life Sciences, Vol. 2, No. 2, 1998

Book Review

Fractals of brain, fractals of mind: In search of a symmetry bond. Edited by E. MacCormac and M. I. Stamenov. John Benjamins Publishing Co., Amsterdam/Philadelphia, 1996.

This book is the seventh of a series edited by Maxim I. Stamenov (Bulgarian Academy of Sciences) and Gordon G. Globus (University of California at Irvine), entitled "Advances in Consciousness Research."

Since antiquity the search for a symmetry between mind and nature based on mathematics has been one of the fundamental goals of science. Fractals could be a new necessary ingredient in these symmetries, now also in the self-organization of brain and behavior, but "we do not yet comprehend how symmetry operates in these fractal-like patterns" (p. 1). In the Introduction a citation by Walter Freeman (1992, p. 480) defines the problem: "It is still unproven mathematically and experimentally whether chaos does or does not exist in the brain, and if it does, whether it is merely an unavoidable side effect of complexity that the brain has learned to live with, or is essential for the formation of new patterns of neural activity . . ." This is considered by the Editors as an "unexpected move" from one of the masters of chaos research in neuroscience. Thus the Editors are compelled to consider that if "there is some place for chaotic processing of information by the brain, it does not automatically mean that chaos matters for the formation of mind" (p. 1). Chaotic patterns, if they appear in brain dynamics, can remain mere "brute neurophysiological patterns" (Searle, 1992).

From these problematic assertions starts the rationale of this book, which is summarized as the convergence of several directions of study: (a) development of formal models of brain and mind processes, (b) brain research, (c) several branches of psychology. The characterization of the nature of several basic concepts as "representation," "process," and "symbol" should be one of the first things to do. As Wittgenstein (1953) stated, drawing lines and agreeing on rules should be the necessary prologue both for

1090-0578/98/0400-0149$15.00/0

a tennis game and a scientific exploration. Otherwise, we are compelled to "make the rules as we go along."

The Editors declare a basic hypothesis: "What is the type of formalism that can implement both brain and mind? Our own opinion is that the nonlinear dynamic systems implementation of mind is a massively parallel brain-implemented computational system, the numerical variables of which formally correspond to fine-grained fractal-like features directly accessible, for example, in consciously experienced perception" (p. 7). By this path the Editors reach the conclusion that fractal(-like) patterns could function as a formal (computational) interface between brain and mind. Fractal patterns would be "mind" to the degree they are accessible to experience to the extent that they would be projected on the visual perception of natural objects. They would be brain" to the extent that fractal-like patterns can be detected in brain dynamics. It is, in any event, dubious whether this kind of fractal (true fractals? which type of fractal?) may form an interface layer, or if they are patterns for symmetry or isomorphism. These are some of the general problems situated at the framework of this book's project. Some of its chapters are examined next.

"Edge of Chaos Dynamics in Recursively Organized Neural Systems" by D. M. Alexander and G. G. Globus traces the differences between monolithic and stratified neural networks and defines how recursive modularity in the brain can be better represented by the latter. The power of brain organization is embedded in the number of scales of neural organization supported. Reviewing research by C. Langton and W. Freeman they conclude: "we propose that edge-of-chaos dynamics are utilized at all scales of organization in the nervous system" (p. 44). They examine influence between scales of organization, and, using a flow metaphor derived from a paper by Shaw on laminar and turbulent flows, they propose also that edge-of-chaos dynamics could be considered as phenomena of "between-scales influence" (p. 45). This is a very suggestive hypothesis, and may be fruitful, if there is any empirical confirmation. Partial evidence can be found in some studies by W. Freeman on the influences between neural scales. Neural systems should be considered as fractally embedded oscillators. This vantage point leads to the final hypothesis of this chapter "that the edge of chaos dynamics is self-similar across multiple scales of neural organization, utilizing a limit-cycle attractor for recognition, participation, engagement states and utilizing a chaotic attractor for ready, receptive disengaged brain states" (p. 57).

"Fractal Time and the Foundations of Consciousness: Vertical Convergence of 1/f Phenomena from Ion Channels to Behavioral States" by Carl M. Anderson and Arnold J. Mandell is an exploration through the ubiquity of "1/f spectrum," one of the most common time series fractals found in nature. We can find this kind of pattern in astrophysical phenomena, earthquakes, volcanic activity and tides, but also in many physiological events. "If we are organized around this recurrent motif we may be particularly sensitive to natural phenomena that mimic 1/f processes" (p. 77). And the symmetry is even wider:

> The measurements suggest that music is imitating the characteristic way our world changes in time. Both music and 1/f noise are intermediate between randomness and predictability and like fractal shapes there is something interesting on all scales. The sum of 1/f processes is again an 1/f process and is theoretically possible. that the sum of 1/f fluctuations in ion channels in neurons may result in fluctuation in attention processes, leading to 1/f distribution in traffic patterns (p. 78).

Unfortunately, there are many mathematical procedures to generate 1/f processes, but "there is no one generic explanation of 1/f noise in nature," and no universal model. In any case there is evidence for convergence of 1/f processes across levels of neurobiological organization: from clustering in K+ fluxes to bunching in spike trains, as well as a consolidation of convergent 1/f processes during the developmental self-organization of neural systems and behavioral states, like bunching of breaths and bunching in REMs, or attentional states and mind wandering. Bak, Tang, and Weisenfeld (1988) suggested that every kind of 1/f process could be viewed as "snapshots of self organized critical processes," spatial or temporal fingerprints of self-organized criticality (SOC). They also suggested a "sand pile" metaphor for this kind of process. A well-known implication of this approach implies that healthy systems should maintain this SOC state, and a degeneration of the system is usually linked to a reduction of complexity. A logical consequence should be that "therapeutic implications" suggest "different forms of 1/f stimulations" (p. 112) for various types of medical problems: from chronic pain, to stress relief. Sources of 1/f experimental therapeutic stimulation were digitally filtered Gaussian white noise, long period frequency changes in music and magnetic stimulation. Study of 1/f processes has an enormous scientific value, and could have many clinical implications.

"Fractal Thinking: Self-organizing Brain Processes," by Earl R. MacCormac is a general review concerning the computational metaphor and an approach towards a mathematical description of neuronal processes through a rational reconstruction rather than simulation. This attempt is made passing through an analogy between neuronal processes and glycolysis, treated as generating vectors of global activity. Links between these indicators and cognitive states are suggested. The Positron Emission Tomography (PET) as a non invasive imaging of brain activities "suggests that the concept of mind exists as a subset of neuronal processes" (p. 149). As a self reflexive process, mind can be represented in a series of nonlinear algorithms, "and these algorithms can generate computer images different from, but related to, computer generated PET images of mental activity" (p. 149). This can be a very fruitful research program.

"n-Dimensional Nonlinear Psychophysics: Intersensory Interaction as a Network at the Edge of Chaos," by Robert A. M. Gregson concerns the applications of nonlinear dynamics in the field founded maybe 150 years ago by Weber and Fechner. They used linear and stochastic theories to treat isolated phenomena in sensation and perception. The author and his group work on "n models (n simultaneous channels)" on open systems' topics such as "adaptation level in domestic fowls, the size-weight illusion, binary up to quaternary odor mixtures, sensory overload in brain damage, vibrotactile perception on the human forearm, response latency frequency distributions" (p. 155). It can be recognized for sure that "the psychophysical evolution from stimulus to response has a dissipative component and is nonstationary" (p. 157). The Γ recursion is an evolution equation, defined as the cubic complex polynomial:

$$Yj + 1 = a(1-Yj)(Yj-ie)(Yj+ie) \qquad I = -1$$

There is also a Julia set for the Γ recursion, and it highlights the fractal features of its basins of attraction. The system has alternate stable regions which can support individual differences in response modes, and regions with high error variance. Intersensory interaction is modeled in a scheme of two nonlinear recursive loops in parallel and cross-coupled, as well as intersensory induction effects. This chapter concludes with some considerations on problems in modeling brain/mind activities: "I see no reason why we should ever be able to understand our own brains [. . .] we can however disentangle some subsystems provided that we never forget they are not closed in their dynamics" (p. 177).

"Fractal Neurodynamics and Quantum Chaos: Resolving the Mind-Brain Paradox Through Novel Biophysics," by Chris King, after a brief global introduction to some fundamentals in chaos theory, defines consciousness and free will as the main challenges in the mind/brain relationships. These relationships could be represented in the metaphor of the multiple drafts by D. Dennett which "makes some physiological sense because an asynchronous parallel architecture allows the brain to make optimally rapid but arbitrarily complex calculations" (p. 189). After a review of some basic aspects in brain architecture there is an exam about implications of nonlinear dynamics in the nervous system. This can bring us to the "fractal link between chaos and quantum mechanics" which is embedded in the complexity of form in the Eukaryote excitable cells. The evolutionary origins of fractal processing should be linked to the "computational intractability of survival in the open environment." Finally there is a suggestion for a "supercausal model" which also combines quantum theory and relativity in the evolution of chaotic neurosystems.

"The Fractal Maximum-power Evolution of Brain, Consciousness and Mind," by Larry Vandervert, proposes "a fractal interpretation of Einstein's concept of thinking as well as James' stream of consciousness." "All the foregoing journey through the delightful minds of Einstein and James has been to provide a plausible background for a description of my own everyday thought processes (as well as for those similar flights of imagination of the reader) that led me to the neuroepistemology I call Neurological Positivism (NP)" (p. 240). So, the first hints on fractal mind are rooted in the author's realization that complex world dynamics must have a self-similar dynamical counterpart in the brain. This is explained in the "fractal maximum-power instantiation of the space-time" as an activity framework for consciousness. This view incorporates an evolutionist approach through the self contained activity of consciousness as an "encapsulation of the activity of the Lotka in its algorithmic structure which instantiate isomorphism between brain, mind and environment."

"The Fractal-like Roots of Mind: A Tutorial in Direct Access," by Maxim I. Stamenov, is concerned with "the possibilities for fractals to 'be' mind," and "more than just mathematical models." These chances are explored through the work of two "phenomenologists," Benoit Mandelbrot and James J. Gibson. This exploration starts with a phenomenological inquiry on the question, "can one see a fractal?" This question highlights some important issues brought up in the everyday culture by the "fractal revolution," and in the physiological limits of our perception. New mathematics bring new horizons on the old matter regarding relationships between real and abstract shapes, our capacity to know reality. Fractals gave new impetus to the questions on mathematical imagination-representation and structures of perception. The next step in this approach is the analysis of the phenomenology of visual microstructures following Gibson's approach, where the focus is on what is direct or filtered in perception, and what is the role of representations. "Perception does not pick up forms, it picks up sequential transformations" (p. 289), "when we perceive the external world, we perceive it directly, but not through the mediation of some images." The purport of this theory in the context of formal modeling of the visible aspects of natural objects. The logical consequence of this approach derived from Mandelbrot and Gibson is that there is a direct correspondence between the mind/brain and the world and that this isomorphism should be rooted in fractals. This kind of symmetries should be found also in linguistic structures as a sort of fractal interface between mind and world (p. 315).

"Chaotic Dynamics and the Development of Consciousness," by John R. Van Eenwyk, starts with a classical statement: "Consciousness can drive one mad, for it is based on a paradox: Consciousness can be explored only through consciousness" (p. 323). For this reason C. G. Jung lamented a lack of an Archimedian point to balance his explorations. The core of this paper is an experiment which "consist[s] of looking at a folktale through the lens of Jung's theory to see if the symbols and metaphors bear any trace of chaotic dynamics" (p. 325). This assertion is followed by brief tutorials on Jung and chaos theory, and finally on "Jung and chaos." At this point we can follow the psychological analysis, in Jungian terms, of some short folk tales: "The Water Nixie," "The Old Man and his Grandson," and "The Old Woman in the Wood." In this way the author concludes his dissertation stating that "the similarity between Jung's theory of the development of consciousness and deterministic chaos is reflected in narratives that are collectively determined—primarily, but not limited to, folktales and myths—challenges the skeptic to propose alternative hypotheses" (p. 344).

This book presents an interesting illustration of some common features of psychological studies, as just observed several years ago by Ludwig Wittgenstein (1980). In psychology there is a general tendency towards philosophical and metaphysical generalizations. This general bias is often linked to a lack of shared agreement on the use of scientific definitions, acceptance of fuzzy semantic boundaries for the most common terms, and conceptual stretching of empirical findings. This book mixes useful reviews of nonlinear dynamics in neuroscience with vast metaphorical generalizations. Suggested hypotheses are not sharply differentiated from empirical findings, and there are no clear suggestions on how to test or falsify what today is still unproven, but which could become empirically true in the near future. This situation causes confusion about the nature of the book: is it an introductory tutorial for newcomers? Probably not, because explanations and definition are hardly provided. Is it a review of the current and past literature? Maybe not, because there are evident insufficiencies. For instance, all the European and Russian productions in synergetics are absent. Moreover there is not any explicit agreement between the authors on the main conceptual tools they share. Fractals, for instance, are defined by several precise mathematical features and they are divided in various types, each marked by different mathematical and empirical destinies (Peitgen, Jorgens, & Saupe, 1992). This preliminary framework, maybe necessary in a book with this title, is absent. Consciousness means very different things for various authors in the book (we could cite, for instance, Van Eenwiyk and MacCormac), but this is left under silence. Finally, there is almost no place for clinical implications, which, as we know from the general literature in neuroscience, could be very rich. The attempt of the book is ambitious, but results do not maintain promises. We know from Mandelbrot and Barnsley that fractals are everywhere, but now we would want to know something more.

It could be useful here to add a brief reflection on metaphor and science. For instance, the discovery of microtubules and related quantistic effects in cellular protoplasm, has led to the generalization of quantum dynamics in human thinking. This is both a form of reductionism, and the metaphorical use of a scientific discovery. A scientific find or a well-known rule can be valid for one scale of events, but not for another. A generalization could be useful in a metaphorical usage, but it should be overtly declared to have avoided any equivocation. Metaphor has been seen in the rhetorical tradition as brief similarity (*similitudo brevior*). In metaphor the overlapping of a small part of the semantic fields of two different terms allow the use of one in the place of the other. The use of language is a basic part of our knowledge of the world and metaphor is a tool in the creative use of language. We may recall the well-known example of the Eskimo names for "snow" to demonstrate that words make us see things. Metaphor builds, through additions and subtractions of semantic links, new areas of meaning and understanding of reality. Sometimes, as in the so-called hermeneutics, this power of the metaphorical process is used for endless fugues in the linguistic universe. This use of metaphor is closer to the arts, for instance poetry where it reaches aesthetic and creative results, than to science where a symbol should be related to a specific event. It is a logical consequence of the geometries of language as highlighted by Peirce's (1908/1953) definition of meaning as "interpretant." Metaphors are to literature what models are to science, they are a creative second thought attempting to "cut the world" in a new way. The passage from mythological to scientific thinking is related to the stabilization of a metaphor in the form of a model or a rule, maintaining robust correlations with experience, falsifiability, inner coherence, and verifiability.

"Metaphoric uses sometimes can verbalize subtleties that mathematical modelling might overlook. Metaphoric uses often imply that while we may not have formalized a math model, the parsimony and power of dynamical processes obeying the usual mathematical properties but yet unexpressed may be lurking as driving the processes we describe metaphorically. That is, the insights of the math approaches empower the metaphoric. Both of these ideas suggest a powerful synergy" (Abraham, 1997, personal communication). Unfortunately, sometimes, metaphors are crystallized in metaphysics. Nonlinear dynamics provide us with a number of new metaphors such as "fractals, self-organization, strange attractors, degrees of freedom" etc. which may play a part in all kinds of disciplines. These metaphors are closer to the features of the fields of mind sciences and could be bridges to allow a transition to a more appropriate and non-reductionistic mathematical and quantitative approach.

Franco F. Orsucci,
Rome International University
Institute for Complexity Studies,
Rome.

REFERENCES

Bak, P., Tang, C. & Wiesenfeld, K. (1988). Self-organized criticality. *Physical Review A, 38,* 364-374.

Freeman, W. (1992). Tutorial in neurobiology: from single neurons to brain chaos. *International Journal of Bifurcation and Chaos, 2,* 451-482.

Peirce, C. S. (1953). *Letters to Lady Welby* (Lieb IC Ed). Originally 1908. New York: Whitlock.

Peitgen, H.O., Jorgens, H., Saupe, D., (1992). *Chaos and fractals: New frontiers of science.* New York: Springer-Verlag.

Searle, J. (1992). *The rediscovery of the mind.* Cambridge, MA: MIT Press.

Wittgenstein, L. (1953). *Philosophical investigations.* Oxford, UK: Basil Blackwell.

Wittgenstein, L. (1980). *Remarks on the philosophy of psychology.* Oxford, UK: Basil Blackwell.