

# Nonlinear Dynamics, Psychology, and Life Sciences



## Special Issue: Chaos, Complexity, and Creative Behavior

*Introduction by Stephen J. Guastello, Marquette University, and M. Jayne Fleener, North Carolina State University*

### **Nonlinear Dynamics and Neo-Piagetian Theories in Problem Solving: Perspectives on a New Epistemology and Theory Development**

*Dimitrios Stamovlasis, Aristotle University of Thessaloniki, Greece*

In this study, an attempt is made to integrate Nonlinear Dynamical Systems theory and neo-Piagetian theories applied to creative mental processes, such as problem solving. A catastrophe theory model is proposed, which implements three neo-Piagetian constructs as controls: the functional M-capacity as asymmetry and logical thinking and the degree of field dependence independence as bifurcation. Data from achievement scores of students in tenth grade physics were analyzed using dynamic difference equations and statistical regression techniques. The cusp catastrophe model proved superior comparing to the pre-post linear counterpart and demonstrated nonlinearity at the behavioral level. The nonlinear phenomenology, such as hysteresis effects and bifurcation, is explained by an analysis, which provides a causal interpretation via the mathematical theory of self-organization and thus building bridges between NDS-theory concepts and neo-Piagetian theories. The contribution to theory building is made, by also addressing the emerging philosophical (ontological and epistemological) questions about the processes of problem solving and creativity.

## **Constraints-induced Emergence of Functional Novelty in Complex Neurobiological Systems: A Basis for Creativity in Sport**

**Robert Hristovski**, *Sts. Cyril and Methodius University, Macedonia*; **Keith Davids**, *Queensland University of Technology, Australia*; **Duarte Araujo**, *Technical University of Lisbon, Portugal*; and **Pedro Passos**, *Technical University of Lisbon, Portugal*

In this paper we present a model of creativity captured as exploration and production of novel and functionally efficient behaviors, based on the statistical mechanics of disordered systems. In support of the modelling, we highlight examples of creative behaviors from our research in sports like boxing and rugby union. Our experimental results show how manipulation of practice task constraints changes the exploratory breadth of the hierarchically soft-assembled action landscape. Because of action metastability and differing task constraints, the specificity of each assembled movement configuration is unique. Empirically, a movement pattern's degree of novelty may be assessed by the value of the order parameter describing action. We show that creative and adaptive movement behavior may be induced by at least two types of interventions, based on relaxing task constraints which we term direct and indirect. Direct relaxing is typically a function of changing task constraints so that the number of affordances that can satisfy goal constraints increases. Indirect relaxing of constraints occurs when a habitual action is suppressed by, for example, stringent instructional constraints during sports training. That suppression simultaneously relaxes other correlated constraints that enable larger exploratory capacity and new affordances to emerge for the athlete or team.

## **Chaos, Creativity, and Substance Abuse: The Nonlinear Dynamics of Choice**

**Tobi Zausner**, *Saybrook University, San Francisco, CA*

Artists create their work in conditions of disequilibrium, states of creative chaos that may appear turbulent but are capable of bringing forth new order. By absorbing information from the environment and discharging it negentropically as new work, artists can be modeled as dissipative systems. A characteristic of chaotic systems is a heightened sensitivity to stimuli, which can generate either positive experiences or negative ones that can lead some artists to substance abuse and misguided searches for a creative chaos. Alcohol and drug use along with inadequately addressed co-occurring emotional disorders interfere with artists' quest for the nonlinearity of creativity. Instead, metaphorically modeled by a limit cycle of addiction and then a spiral to disorder, the joys of a creative chaos become an elusive chimera for them rather than a fulfilling experience. Untreated mental illness and addiction to substances have shortened the lives of artists such as Vincent Van Gogh, Frida Kahlo, Henri de Toulouse-Lautrec, and Jackson Pollock, all of whom committed suicide. In contrast Edvard Munch and John Callahan, who chose to address their emotional problems and substance abuse, continued to live and remain creative. Choosing to access previously avoided moments of pain can activate the nonlinear power of self-transformation.

## **Innovation, Imitation, and Problem-Solving in a Networked Group**

**Thomas N. Wisdom**, *Indiana University, Bloomington, IN*; and **Robert L. Goldstone**, *Indiana University, Bloomington, IN*.

We implemented a problem-solving task in which groups of participants simultaneously played a simple innovation game in a complex problem space, with score feedback provided after each of a number of rounds. Each participant in a group was allowed to view and imitate the guesses of others during the game. The results showed the use of social learning strategies previously studied in other species, and demonstrated benefits of social learning and nonlinear effects of group size on strategy and performance. Rather than simply encouraging conformity, groups provided information to each individual about the distribution of useful innovations in the problem space. Imitation facilitated innovation rather than displacing it, because the former allowed good solutions to be propagated and preserved for further cumulative innovations in the group. Participants generally improved their solutions through the use of fairly conservative strategies, such as changing only a small portion of one's solution at a time, and tending to imitate solutions similar to one's own. Changes in these strategies over time had the effect of making solutions increasingly entrenched, both at individual and group levels. These results showed evidence of nonlinear dynamics in the decentralization of innovation, the emergence of group phenomena from complex interactions of individual efforts, stigmergy in the use of social information, and dynamic tradeoffs between exploration and exploitation of solutions. These results also support the idea that innovation and creativity can be recognized at the group level even when group members are generally cautious and imitative.

## **Is Research Publication a Catastrophic Phenomenon Among Medical Faculty?**

**David Katerndahl**, *University of Texas Health Science Center at San Antonio*

Studies seeking to predict publication rates among faculty have found contradictory results. The purpose of this study was to determine whether short- or long-term research publications among family medicine faculty were better accounted for using cusp catastrophe modeling (CCM) rather than linear modeling. This secondary analysis of annual research publications used data collected from family medicine faculty in a university department. To predict the number of research publications, two service variables — national service and administrative responsibility — were used. There were three bifurcation variables: Scholarly Activity, Professional Status, and “proportion of studies as principal investigator”. Research publications at two and five years were modeled using CCM as well as two linear models. Based upon the amount of variance explained, while linear models accounted for more variance in publications at 5-year intervals, CCM was superior at explaining publications for all three bifurcation variables at 2-year intervals. Entering all of the

bifurcation variables into the models found that CCM explained more of the 2-year publication variance with Scholarly Activity and national service as significant predictors. In conclusion, short-term career planning needs to consider its irregular cusp behavior and to minimize the possible impact of bifurcation factors.

### **Artistic Forms and Complexity**

**J-P. Boon**, *Université Libre de Bruxelles, Belgium*; **J. Casti**, *IIASA and The Kenos Circle, Vienna, Austria*; and **R. P. Taylor**, *University of Oregon, Eugene, OR*

We discuss the inter-relationship between various concepts of complexity by introducing a complexity ‘triangle’ featuring objective complexity, subjective complexity and social complexity. Their connections are explored using visual and musical compositions of art. As examples, we quantify the complexity embedded within the paintings of the Jackson Pollock and the musical works of Johann Sebastian Bach. We discuss the challenges inherent in comparisons of the spatial patterns created by Pollock and the sonic patterns created by Bach, including the differing roles that time plays in these investigations. Our results draw attention to some common intriguing characteristics suggesting “universality” and conjecturing that the fractal nature of art might have an intrinsic value of more general significance.

### **Innovation Diffusion Modeling: The Deterministic, Stochastic and Chaotic Case**

**Christos H. Skiadas**, *Technical University of Crete, Chania, Greece*; and **Charilaos Skiadas**, *Hanover College, Indiana*.

The field of innovation diffusion modeling showed a tremendous growth process during the last decades. Numerous qualitative and quantitative studies have been presented followed by significant applications in various scientific fields. This review paper explores the main quantitative developments on innovation diffusion and the gradual progress from the original deterministic models to their stochastic and chaotic alternatives. Related applications are presented.

### **Diffusion Models for Innovation: S-curves, Networks, Power Laws, Catastrophes, and Entropy**

**Joseph J. Jacobsen**, *Milwaukee Area Technical College, WI*; and **Stephen J. Guastello**, *Marquette University, Milwaukee, WI*

This article considers models for the diffusion of innovation would be most relevant to the dynamics of early 21<sup>st</sup> century technologies. The article presents an overview of diffusion models and examines the adoption S-curve, network theories, difference models, influence models, geographical models, a cusp catastrophe model, and self-organizing dynamics that emanate from principles of network configuration and principles of heat diffusion. The diffusion dynamics that are relevant to information technologies and energy-efficient technologies are compared. Finally, principles of nonlinear dynamics for innovation diffusion that could be used to rehabilitate the global economic situation are discussed.

*Cover image: “Photograph” by Tim Durham, www.timdurham.ie* The annual art feature article, which appears in the January issue of *NDPLS*, explains the cover artists’ theses for combining imagery from nonlinear dynamics with concepts from psychology and the life sciences. The 2011 feature is Bubble Art. The Fractal Fern (below), which has become an icon for *NDPLS*, is part of the Fractal of the Day collection by J. C. Sprott.

