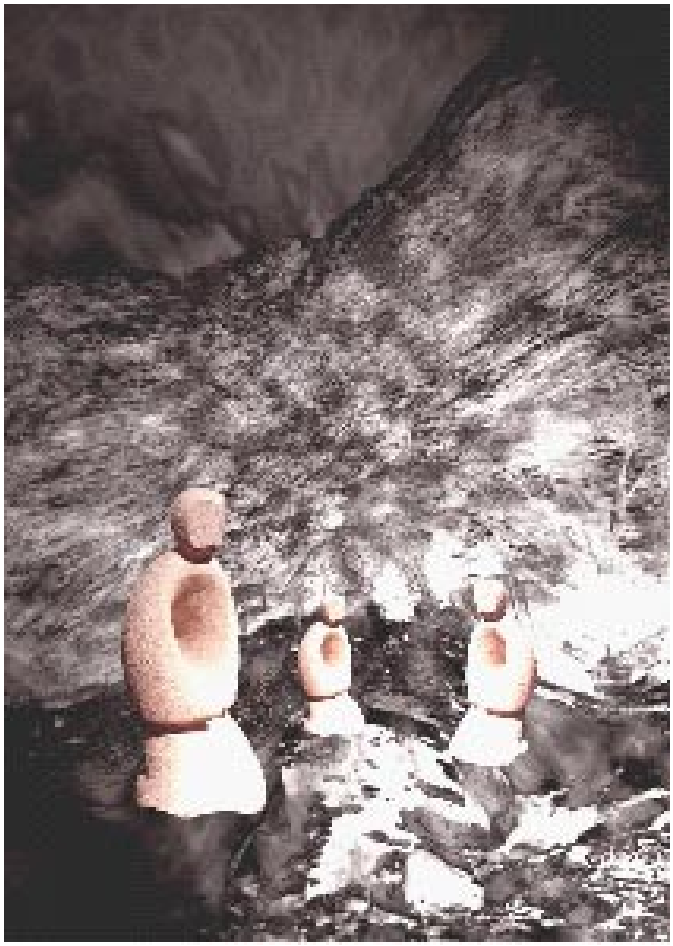
October 2010
Volume 14, Number 4
NDPLS 14(4) 349-542 (2010)
ISSN 1090-0578
http://www.societyforchaostheory.org/ndpls/

Nonlinear Dynamics, Psychology, and Life Sciences



Special Issue: Medical Practice

Cracking the Linear Lens,
David Katerndahl, *Guest Editor*

Nonlinear Dynamics in Biopsychosocial Resilience
David Pincus and Annette Metten, *Chapman University, Orange, CA*

Theory and methodology from nonlinear dynamical systems (NDS) may provide considerable advantage to health scientists as well as health care professionals. For instance, NDS methodologies and topics in health care share a focus upon the potentially complex interactions of biological, psychological and social factors over time. Nevertheless, a number of challenges remain in creating the necessary bridges in understanding to allow researchers to apply NDS techniques and to enable practitioners to use the resulting evidence to improve patient care. This article aims to provide such a bridge. First, common concepts pertaining to self-organizing complex adaptive systems are outlined as a general approach to understanding resilience across biological, psychological, and social scales. Next, four data analytic techniques from NDS are compared and contrasted with respect to the information they may provide about some common processes underlying resilience. These techniques are: time-series analysis, state-space grids, catastrophe modeling, and network modeling. Implications for health scientists and practitioners are discussed.

Homeobios: The Pattern of Heartbeats in Newborns, Adults, and Elderly Patients

Hector Sabelli and Atoor Lawandow, *Chicago Center for Creative Development*

HRV has been found useful in the study of cardiological illness in adults and elders, as well as in monitoring prenatal health. Twenty-four hour Holter recordings of R to R intervals (RRI) in healthy newborns, adults, and elderly persons were analyzed with statistical, chaos, and recurrence methods. In persons of all ages, RRI series showed relative stability (as expected in homeostatic regulation), patterned daily changes in heart rate, evidence of causality or "determinism" (nonrandom pattern of the series of differences), and non-periodic irregular variations within limits, suggesting chaos. In addition, novel methods of analysis reveal creative features that are absent in chaotic attractors but found in bios, a non-stationary process that is generated mathematically by recursions of bipolar feedback (chaotic bios) or by the addition of sine waves. Wavelet and recurrence plots demonstrate time-limited patterns (e.g. clustering of recurrences in organized complexes) that follow each other in time indicating temporal complexity, in contrast to the temporal uniformity of chaotic attractors and of random changes. Recurrence quantification demonstrates less recurrence isometry than copies randomized by shuffling (novelty), and more consecutive isometries than shuffled copies indicating causal order. Statistical analyses demonstrate asymmetric distribution and diversification (increase in variance with the duration of the series analyzed) in contrast to convergence to an attractor. These studies indicate that the normal pattern of HRV is both homeostatic and biotic. A biotic pattern with homeostatic features (homeobios) is generated by combining bipolar feedback with negative feedback. Chaos and bios analyses may thus be useful in clinical studies.

Nonlinear Dynamics of Seizure Prediction in a Rodent Model of Epilepsy

Levi B. Good, *University of Texas Southwestern Medical Center, Dallas, TX* ; **Shivkumar Sabesan**, *Arizona State University, Tempe, AZ, and St. Joseph's Hospital and Medical Center, Phoenix, AZ;* **Steven T. Marsh**, *Department of Neurology Research, Barrow Neurological Institute, St. Joseph's Hospital and Medical Center, Phoenix, AZ* **Konstantinos Tsakalis**, *Arizona State University, Tempe, AZ;* **David M. Treiman**, *St. Joseph's Hospital and Medical Center, Phoenix, AZ;* **Leon D. Iasemidis**, *Arizona State University, Tempe, AZ, Mayo Clinic Arizona, Phoenix, AZ*

Epilepsy is a dynamical disorder with intermittent crises (seizures) that until recently were considered unpredictable. In this study, we investigated the predictability of epileptic seizures in chronically epileptic rats as a first step towards a subsequent timely intervention for seizure control. We look at the epileptic brain as a nonlinear complex system that undergoes spatio-temporal state transitions and the Lyapunov exponents as indices of its stability. We estimated the spatial synchronization or desynchronization of the maximum short-term Lyapunov exponents (STLmax, approximate measures of chaos) among multiple brain sites over days of electroencephalographic (EEG) recordings from 5 rats that had developed chronic epilepsy according to the lithium pilocarpine rodent model of epilepsy. We utilized this synchronization of EEG dynamics for the construction of a robust seizure prediction algorithm. The parameters of the algorithm were optimized using receiver operator curves (ROCs) on training EEG datasets from each rat for the algorithm to provide maximum sensitivity and specificity in the prediction of their seizures. The performance of the algorithm was then tested on long-term testing EEG datasets per rat. The thus optimized prediction algorithm on the testing datasets over all rats yielded a seizure prediction mean sensitivity of 85.9%, specificity of 0.180 false predictions per hour, and prediction time of 67.6 minutes prior to a seiz-ure onset. This study provides evidence that prediction of seizures is feasible through analysis of the EEG within the framework of nonlinear dynamics, and thus paves the way for just-in-time pharmacological or physiological inter-ventions to abort seizures tens of minutes before their occurrence.

New Directions Offered by the Dynamical Systems Approach to Bimanual Coordination for Therapeutic Intervention and Research in Stroke

Rita Sleimen-Malkoun, Jean Jacques Temprado, Viktor K. Jirsa, Eric Berton, *Université de la Méditerranée et CNRS, Marseille, France*

In the present paper, we review the main concepts of the dynamical systems approach to bimanual coordination and propose applications to therapeutic intervention for functional recovery of coordinated movements in stroke. Further, we describe the behavioral alterations of discrete bimanual coordination resulting from cerebral vascular accident (CVA) lesions and speculate on the possibility of mimicking the mechanisms of CVA lesions via symmetry breaking in dynamic systems.

Sexual Affordances, Perceptual-motor Invariance Extraction and Intentional Nonlinear Dynamics: Sexually Deviant and Non-deviant Patterns in Male Subjects

Patrice Renaud, *Université du Québec en Outaouais, Insitut Philippe-Pinel de Montréal, Canada;* **Mathieu Goyette**, *Université de Montréal, Insitut Philippe-Pinel de Montréal, Canada;* **Sylvain Chartier**, *Université d'Ottawa, Canada;* **Simon Zhornitsky**, *Université de Montréal, Canada*; **Dominique Trottier**, *Université de Montréal, Insitut Philippe-Pinel de Montréal, Canada;* **Joanne-L. Rouleau**, *Université de Montréal,Canada;* **Jean Proulx**, *Université de Montréal, Canada*; **Paul Fedoroff**, *Université d'Ottawa, Canada;* **John-P. Bradford**, *Université d'Ottawa, Canada;* **Benoît Dassylva**, *Insitut Philippe-Pinel de Montréal, Canada;* **Stéphane Bouchard**, *Université du Québec en Outaouais, Canada*

Sexual arousal and gaze behavior dynamics are used to characterize deviant sexual interests in male subjects. Pedophile patients and non-deviant subjects are immersed with virtual characters depicting relevant sexual features. Gaze behavior dynamics as indexed from correlation dimensions (D2) appears to be fractal in nature and significantly different from colored noise (surrogate data tests and recurrence plot analyses were performed). This perceptual-motor fractal dynamics parallels sexual arousal and differs from pedophiles to non-deviant subjects when critical sexual information is processed. Results are interpreted in terms of sexual affordance, perceptual invariance extraction and intentional nonlinear dynamics.

Modeling Early Sexual Initiation among Young Adolescents Using Quantum and Continuous Behavior Change Methods: Implications for HIV Prevention

Xinguang Chen, *Wayne State University School of Medicine, Detroit, MI;* **Sonja Lunn**, *Office of AIDS, Bahamas Ministry of Health, Nassau, The Bahamas;* **Carole Harris**, *West Virginia University, Morgantown, WV;* **Xiaoming Li**, *Wayne State University School of Medicine, Detroit, MI;* **Lynette Deveaux**, *Office of AIDS, Bahamas Ministry of Health, Nassau,The Bahamas;* **Sharon Marshall**, *Wayne State University School of Medicine, Detroit,MI;* **Leslie Cottrell**, *West Virginia University, Morgantown, WV;* **Bonita Stanton**, *Wayne State University School of Medicine, Detroit, MI*

Behavioral research and prevention intervention science efforts have largely been based on hypotheses of linear or rational behavior change. Additional advances in the field may result from the integration of quantum behavior change and catastrophe models. Longitudinal data from a randomized trial for 1241 pre-adolescents 9-12 years old who self-described as virgin were analyzed. Data for 469 virgins in the control group were included for linear and cusp catastrophe models to describe sexual initiation; data for the rest in the intervention group were added for program effect assessment. Self-reported likelihood to have sex was positively associated with actual initiation of sex (OR=1.72, 95% CI: 1.43-2.06, $R_2 = 0.13$). Receipt of a behavioral prevention intervention based on a cognitive model prevented 15.6% (33.0% vs. 48.6%, OR = 0.52, 95% CI: 0.24-1.11) of the participants from initiating sex among only those who reported "very likely to have sex." The beta coefficients for the cubic term of the cusp assessing three bifurcating variables (planning to have sex, intrinsic rewards from sex and self-efficacy for abstinence) were 0.0726, 0.1116 an intervention based on a model of continuous behavior change did produce a modest impact on sexual initiation, quantum change has contributed more than continuous change in describing sexual initiation among young adolescents, suggesting the need for quantum change and chaotic models to advance behavioral prevention of HIV/AIDS.

Recurrent Patterns of Daily Intimate Partner Violence and Environment

David Katerndahl, **Robert Ferrer**, **Sandra Burge**, **Johanna Becho**, *and* **Robert Wood**, *University of Texas Health Science Center, San Antonio*

Although predictors of violent relationships have been identified, we are only beginning to understand the day-to-day dynamics of domestic violence. The objective of this study was to identify commonly seen patterns and strings of consecutive days involving verbal or physical abuse, and their preceding and subsequent events. Adult women (n=20) seen in a primary care clinic who experienced violence within the past month were enrolled. Subjects completed a daily telephone assessment of household environment and marital relationship for two months using Interactive Verbal Response (IVR). Results were analyzed using orbital decomposition, an analytic technique based on symbolic dynamics, in which categorical time series data are used to identify recurrent patterns of strings and quantify their complexity. While days without abuse had varied patterns involving arguments, stress levels, daily hassles, husband's alcohol intake, and sense of closeness (27 unique patterns), days involving verbal or physical abuse included a narrower range of patterns (15 patterns for verbal and 16 patterns for physical abuse). Daily patterns appear to cluster in triplets (3 consecutive days) of activity and show nonlinearity with 6 triplets involving verbal abuse and 8 triplets involving physical violence. Triplets involving either verbal or physical abuse were associated with arguments and high stress, but differed in the consistency of association with hassles, alcohol intake, and closeness. Finally, physical and verbal abuse tended to self-propagate. However, days involving verbal abuse did not precede days involving physical violence. In conclusions, while patterns of violence and household environments followed a nonlinear trajectory, only a limited set of patterns were observed. Although violence led to more violence, verbal abuse did not necessarily lead to physical aggression. In fact, verbal abuse and physical violence differed in the consistency of their relationships to hassles, husband's alcohol intake, and closeness.

The Dynamics of Health Care Reform – Learning from a Complex Adaptive Systems Theoretical Perspective

Joachim P. Sturmberg, *Monash University, Melbourne and Newcastle University, Newcastle;* **Carmel M. Martin**, *Northern Ontario School of Medicine, Canada*

Health services demonstrate key features of complex adaptive systems (CAS), they are dynamic and unfold in unpredictable ways, and unfolding events are often unique. To better understand the complex adaptive nature of health systems around a core attractor we propose the metaphor of the health care vortex. We also suggest that in an ideal health care system the core attractor would be personal health attainment. Health care reforms around the world offer an opportunity to analyse health system change from a complex adaptive perspective. At large health care reforms have been pursued disregarding the complex adaptive nature of the health system. The paper details some recent reforms and outlines how to understand their strategies and outcomes, and what could be learnt for future efforts, utilising CAS principles. Current health systems show the inherent properties of a CAS driven by a core attractor of disease and cost containment. We content that more meaningful health systems reform requires the delicate task of shifting the core attractor from disease and cost containment towards health attainment.