Abstracts to the 31st Annual International Conference

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Society for Chaos Theory in Psychology & Life Sciences

Rediscovering Normalopolis

Society for Chaos Theory in Psychology & Life Sciences

31st Annual International Conference ONLINE, *July 22-24, 2021*

Keynote Speakers Abstracts

W. BRIAN ARTHUR
Santa Fe Institute, Intelligent Systems Lab in Palo Alto CA, Stellenbosch Institute for Advanced Study in South Africa

Foundations of Complexity Economics

Complexity economics relaxes the assumptions of neoclassical economics — the assumptions of representative, hyper-rational agents, each of which faces a well- defined problem and arrives at optimal behavior given this problem and, thus, gives a different style to economics. It is an economics in which the agents in the economy are realistically human and realistically diverse, in which path- dependence and history matter, in which events trigger events and in which the networks that channel these events matter. It is an economics in which equilibrium is not assumed, and if it is present, it emerges; in which rational behavior is not assumed, in general, it is not well- defined; in which the unexpected crises of the economy can be probed and planned for in advance; in which free markets are not assumed to be optimal for society but can be assessed realistically; and in which distributional issues are not covered up, but can be rigorously scrutinized.

PETER TURCHIN
Director of the Evolution Institute, University of Connecticut

Complex Causality in the Evolution of Large-Scale Societies

Over the past decade Turchin has been investigating two broad and interrelated questions: what general mechanisms explain the collapse of historical empires? And how did large-scale states and empires evolve in the first place? More specifically, what are the social forces that hold together huge human conglomerates, and under what conditions they fail? Turchin uses the theoretical framework of cultural multilevel selection to address these questions. Currently his main research effort is directed at coordinating *Seshat: Global History Databank*—a massive historical database of cultural evolution that our team is using in empirical tests of theoretical predictions coming from various social evolution theories.

List of abstracts in alphabetical order by Author or Presenter

Jacopo Biraschi, Clinical psychologist, private practice

Relational Fractal Dimension. From the Complexity of Psychological Interview to the Emergence of the Therapeutic Relationship

The psychological interview is a complex system that emerges from the interaction of its components, i.e. the patient and the psychologist, therefore it is presumed that it has a fractal structure whose dimension indicates its level of complexity. This paper presents a pilot study for a new assessment methodology of the fractal dimension of the psychological interview: the fractal

dimension of a series of 4 psychological interviews is calculated, obtained in relation to the amount of verbal content produced in them. The verbatim transcripts of the sessions were divided into Relational Verbal Units (RVU) obtained through the conversational turn taking that is naturally established in the patient-psychologist dyad and whose size is established by the number of words that compose them; it was then observed that the distribution of the RVUs in a size/frequency graph follows a power law distribution, from which it was possible to assess the Relational Fractal Dimension (⟦RF⟧_D) of the interviews. The values obtained range from a minimum of 1.39 to a maximum of 1.5, an indicative range of self-organized criticality. Recursion is the simple process behind complexity and fractal patterns emerge from recursion, the fractal dimension is a measure of the level of complexity of a system and its application to psychotherapy conceptualizes the therapeutic relationship as a complex adaptive system endowed with self-organization, self-similarity and long-term memory, paving the way for a conceptualization of clinical practice in terms of complexity theory and nonlinear dynamical systems.

James Caton, Agribusiness and Applied Economics, North Dakota State University, Fargo, ND

The Market Algorithm as Distributed Genetic Algorithm: An Evolutionary Agent-based Paradigm

Portraying the market as a genetic algorithm requires that we define where in the market process 1) mutation and 2) cross-over (partial duplication) occur. In a traditional genetic algorithm, agents are typically created to optimize some value on a fixed landscape. Attributes of an agent are mutated at a modest rate and the attributes of the best performing agents are mixed through cross-over, giving a child agent attributes of its parents. In the marketplace, entrepreneurs learn from one another and don't necessarily know which strategies produce globally optimal results. All that is required for the metaphor of cross-over in a genetic algorithm is that entrepreneurs emulate the attributes of those another entrepreneur that is the best as far as they are aware and that some of these attributes mutate. Since learning happens in the course of exchange, agents in this model copy traits of the wealthiest trading partner with whom they have traded at some rate defined by the cross-over rate. Finally, the inclusion of failure in model allows for a tendency toward an improved mix of strategies. I draw from Kauffman and Levin (1987) to demonstrate how competition develops and refines knowledge that is distributed across an economy to approximate equilibrium outcomes over an objective landscape that exhibits a fixed, predictable set of behaviors. Kauffman and Levin use a predefined, static landscape and form an a priori conjecture implied by computational requirements for discovery marginal improvements by a single agent within the landscape. With each incremental improvement in fitness, there are fewer improvements available in the landscape. The cost of search increases. Improvement in fitness increases linearly over log-time. Their results cohere with this a priori conjecture. My model differs from Kauffman and Levin in that agents who interact and interpret a "physical" landscape are also part of the environment. However, if we think of the population of agents holding distributed knowledge as a meta-organism, then the logic of their model should still apply. Although we can observe changes in the mix of strategies and parameters, computational constraints require that we approach the problem abductively (Axtell and Guerrero 2019). The model approximates the same feature as that of Kauffman and Levin: population fitness improves linearly in log-time, specifically when time is measured in terms of the cumulative number of transactions that occur within a simulation. This improvement can only be observed using measures of average fitness across numerous simulations. The results recast our understanding of equilibrium, suggesting that generation competitive market processes are inherently tied to the creation of efficiency improving knowledge.

David Chan, Virginia Commonwealth University
Candance Kent, Virginia Commonwealth University

Rippled Almost Periodic Dynamics in a Phenomenological Model for Epilepsy

In this talk we examine a second order, nonautonomous difference equation model for neuron excitation that mimics seizure activity in the brain. We investigate the model's parameter space to show novel `rippled behavior' and relate this to seizure activity.

Rosalia Condorelli, University of Catania, Italy

Epistemology of Complexity and Sociology. Social discontinuity and Systems Thinking: Cultural Differentiation and Social Integration in Times of Globalization

Given the obsolescence of a linear, homeostatic and reductionist worldview unable to face current social discontinuity, the laceration of a stable universe of expectations marking world scenarios, the New System Theory has a strong heuristic power in understanding and managing, by emergent, nonlinear, unexpected, surprising and unpredictable systemic self-organization concept, circular causation between system and environ-mental and micro-macro co-essentiality conceptual

frameworks, social integration crisis in our culturally differentiated and globalized western modern societies. The discussion on normative multiculturalism validity (in particular neo-communitarian multiculturalism) and, therefore, on sufficiency of procedural foundations as device of cultural difference integration and social cohesion is controversial and far from reaching a turning point. To get out of this impasse and support policymaking processes able to face social integration crisis, the debate has to be brought on complexity epistemological plan. Systems Thinking could give new lymph to current debate, hooking it to a safer ground, made so by new acquisitions on systems working and evolution mechanism. On the one hand, understanding social complexity, the creativity inherent in meaning-making and world representation processes and the related emergence, uncertainty and unpredictability, of social systems in their self-organization morphogenetic process by the micro-macro co-essentiality rapport, remedies metaphysical consequences of a homeostatic and linear reductionism impressing multiculturalism functionalist logic. On the other hand, this intervenes usefully in justify the caution with which the normative multiculturalism model is believed that should be considered, by anchoring this caution to configuration of a society projected to dangerously visit that range of maximum differentiation among its components which should be avoided being identified as the range of disorder, irrelation, and ungovernability, in which systems no longer able to find meaning convergence, do not stabilize into a new order configuration and morphogenesis becomes impossible (the range of the chaos). Not only, in emergence logic, functionalist integration is just one of the many possibilities to which self-organization process is open, but in itself the functionalist muticulturalist logic makes this possibility unlikely. Many forms of Islamic radicalism, and many signs of xenophobia and nationalist extremism even where the recognition policy prevails, without curing enough about reciprocity and a platform, although minimal, of shared values, confirm this and show that it is not just a theoretical possibility. How to fill up this relationality deficit that normative multiculturalism institutes and avoid the risk of a society unable to regain order with coherence? The Complexity framework is where the whole debate must be kept. Here, the integration proposal of pluralism and interculturalism can gain greater meaning, avoiding the risks of mono-culturalism, on the one hand, and social balkanization, on the other hand.

Alexander Danvers, University of Arizona, U.S. Army Research Labs
Evan Carter, U.S. Army Research Labs
Derek Spangler, Pennsylvania State University
Erica Baranski, University of Houston
Esther Sternberg, **Matthias Mehl**, University of Arizona

Trait-Like Stability of Recurrence Quantification Analysis in Mobile Sensing

Dynamic information is often treated as an indicator of a stable, trait-like property of an individual. For example, fractal scaling of an individual s cardiac physiology taken at rest has been used to distinguish among individuals who are more (or less) likely to recover from myocardial infarction, and recurrence quantification analysis (RQA) of an individual s speech during the day has been related to personality. This current research uses a large scale mobile sensing study (N = 268, length = 60 days) to examine between person stability of RQA parameters across four commonly assessed channels: heart rate, heart rate variability, physical activity, and speech. Results indicate that determinism and number of lines are highly stable across channels when aggregating over a single week (ICC > .5). Entropy was less stable, indicating it is not a good measure for comparing individuals. Instead it may be better for estimating state-level changes. Mean levels of all variables were highly stable over just a single day s aggregation. Results suggest that certain dynamic parameters are more stable than others in general, across sensors, and suggest that dynamic patterning may be a cross-modality property of individuals.

Orlando Gomes, **Jorge Sequeira**, **Rui Borges Francisco**, ISCAL - IPL

The Labor Market with People In: Personality Traits and Employment Dynamics

Issues pertaining to the organization and efficiency of the labor market and to the dynamics of employment and unemployment have always been on the forefront of the concerns of economists. Typically, such issues are approached through the analysis of the conflicting interests of a representative worker and of a representative firm, each of which intending to maximize the corresponding intertemporal objective function. Much of the research undertaken on this subject neglects the fact that each person is unique and endowed with different personality traits that influence their educational attainment, their ability to access jobs, their productivity while employed, and also their willingness to support, through social welfare mechanisms, those who become unemployed. In this

research, a simulation model is proposed to approach the dynamics of the labor market. The model conceives an economy populated by a large number of individuals who, over their life cycles, acquire education, search for a job, receive a wage while employed, and access an unemployment benefit while out of work. Because individuals are endowed with different personalities, they will experience different degrees of professional success over their life cycles. Such a reasoning will lead to a labor market aggregate outcome characterized by emergent phenomena, out-of-equilibrium dynamics, path dependence, and other features that are characteristic of a complex evolving system. Individual life experiences are simulated, as well as the aggregate outcome. The personality of individuals is shaped, in the proposed setting, taking into account the big five personality traits of psychological analysis, namely openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism.

Stephen J. Guastello, Marquette University
Anthony F. Peressini, Marquette University

The Relative Influence of Drivers and Empaths on Team Synchronization

To further the understanding of how to build or reduce synchrony in a work team, we examined two principles for defining the optimal condition to produce or limit synchrony: (a) the empath-driver ratio (relative strength of the stronger influencer compared to the receptive strength of any member in the group), and (b) the balance between autocorrelated autonomic arousal (degree to which members signals are independent of other group members) and the degree of influence that transfers from each group member to other group members. In study 1, we employed a series of computational simulations designed to manipulate the four variables. The results indicated that there is a four-way balance between driver strength, empath strength, autocorrelational and transfer effects among team members. The relationship between the synchronization coefficient and the empath-driver ratio was moderated by whether the group adopted a network structure for group problem solving or command-and-control. In study 2 we analyzed autonomic arousal (electrodermal response) in four teams of five participants playing a first-person shooter computer game. The correlation between the synchronization coefficient and the empath-driver ratio was .280 ($p < .001$) based on 64 pairs of observations. The relationship was moderated by both the network structure and the statistical model that one adopted to analyze dyadic relationships within the group. The implications of these relationships for a growing theory of team synchrony are discussed.

Stephen J. Guastello, Marquette University
Andrea D. Guastello, **Ryan McCarty,**
Seth Downing, Joseph P. McNamara,
University of Florida Health Center

Approach and Avoidance Coping Dynamics during the COVID-19 Pandemic

The effect of approach-avoidance conflicts in behavior was one of the earliest applications of catastrophe theory. Although the correspondence between approach and avoidance dynamics and behavior made good intuitive sense relative to psychological theories of motivation and fight-flight reactions known at the time, empirical studies evaluating approach-avoidance dynamics have only started to appear recently. The present study reviews the extant research and expands the idea to approach and avoidance coping styles. Research participants were 333 adults from the general employed population recruited through Amazon Mechanical Turk. They completed measure of psychological symptoms, quality of life, approach and avoidance coping styles, and Covid-related stress. Cusp catastrophe models for symptoms ($R2 = .84$) and quality of life ($R2 = .89$) were supported with approach and avoidance functioning as bifurcation gradients; Covid stress was an asymmetry variable for symptoms. Both models provided more accurate representations of the data than the linear alternatives ($R2 = .54$ and .24 respectively). Approach coping played a larger role than avoidance coping in the reduction or prevention of psychological symptoms. Both types of coping were equally important for producing a higher quality of life.

Harold M. Hastings, **Tai Young-Taft**,
Bard College at Simon's Rock

Translating Ecology into Economics

A seminal paper by Robert M. May, Simon A. Levin & George Sugihara (Ecology for bankers, Nature, 2008) showed how the study of ecosystems [can] inform the design of financial networks in, for instance, their robustness against perturbation. Our presentation will build upon these ideas to translate an analysis of stability concepts and scaling rules from ecology to economics: for example, the relationship between MacArthur s (1955) and Hutchinson s (1959) argument that stability increases with increasing complexity, in contrast to May s argument that stability decreases with increasing complexity, and more generally resource partitioning in ecosystems, using the ansatz Economics = ecology + currency.

James Hazy, Leadership Science, LLC

Pardon Me for Being Human: Reimagining Leadership When Mixed-Reality in Human Interactions Overwhelms Traditional Organizing

As technology has become omnipresent, organizations have become more complex. As a result, the complex, and co-created nature of leadership has become more apparent. Further, the emerging mixed-reality (MR) workplace suggests that effective leadership will increasingly be dependent on information and computing technology. This paper explores the challenge of predictability across scale and how advances in knowledge of complex social networks and the use of technology platforms suggest a way to reimage leadership in today s organizations. The paper describes ways that technology may enable improved performance of organizing functions that have previously been attributed to a leadership process enacted solely by human agents. This perspective is particularly salient in cases when and where technology platforms use machine-learning and artificial intelligence to identify information signalled by universal scaling parameters within social networks that include human, artificial, and hybrid or mixed agents and do so in ways that augment social interaction environments. The time has come to consider and to maximize the potential contributions of human agents is a world where machines and mixed-reality networks are both faster and smarter than human-only networks when performing many tasks.

Bob Hodge, Western Sydney University

The semiotics of chaos theory: navigating from fractals, strange attractors and butterfly effects in phase space to real-life impacts and back

Chaos theory exists in a range of semiotic modes, from images on T-Shirts and accounts in popular culture to highly mathematical treatments. If Chaos theory is to become influential, as it surely should, the theory needs to have what Bateson called a meta-communication loop, which has a systematic account of all major modes Chaos Theory exists in, including the different degrees of validity each mode has, and ways to navigate between the different forms. The presentation will use three iconic ideas from chaos theory, fractals, strange attractors and butterfly effects (sensitivity to initial conditions) and show how analysis of the three of them in semiotic terms leads to a more convincing and grounded use of such ideas in empirical research in science, art and the social sciences.

Aleksander Jakimowicz, Institute of Economics, Polish Academy of Sciences

Macroeconomic Effects of Swiss-franc Loans on the Polish Economy

Mortgage loans indexed to Swiss Francs appeared in the Polish economy on a massive scale in the years 2006 2008, as they accounted for the vast majority of loans granted to consumers for the purchase of residential property at that time. Initially, they were advertised as more advantageous than loans granted in domestic currency due to their relatively lower interest rate. This resulted in the interest of a large number of consumers in Swiss-franc loans, as a result of which the total number of such loans is estimated at nearly one million. However, it quickly became apparent that consumers who had taken out such loans were exposed to unlimited foreign exchange risk. This was caused by a significant depreciation of the Polish zloty against the Swiss franc. The economic situation of consumers was also aggravated by the fact that they were charged for the bid-ask spread, the amount of which was freely determined by the banks. Since these loans were granted for several decades, their economic impact will be felt by at least several generations of consumers. In this context, the strong and long-term impact of these loans on the Keynesian consumption function is evident. The significance of these loans for the Polish economy was examined using the model by P.A. Samuelson, winner of the 1970 Nobel Prize in Economics (the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1970). The model is the basis for almost all contemporary macroeconomic textbooks. As it turns out, Swiss-franc loans reduce the marginal propensity to consume in a hyperbolic way. Consequently, society faces a declining Keynesian function of consumption, which creates an anomaly in Samuelson s model in the form of a destabilising impact of government expenditure. Thus, solving the problem of Swiss-franc loans requires systemic changes as provided for in the Council Directive 93/13/EEC of 5 April 1993 on unfair terms in consumer contracts, whereas government assistance in this area in the form of increased expenditure may prove ineffective. The declining functions of consumption and their effects were analysed in greater detail in the first report of the Club of Rome in 1972 entitled, The Limits to Growth.

David Kreindler, Dept. of Psychiatry, University of Toronto, ON

Sample Entropy and Pathological Data Normalization

Sample Entropy (SampEn) is a complexity measure that quantifies the predictability (rate of information production) of a time series; it was developed specifically with reference to short and noisy data sets encountered in cardiovascular and other biological studies (Richman and Moorman 2000) - i.e., nonlinear dynamical (NLD) systems. Normalization of data (by re-scaling the data so that the standard deviation (SD) = 1) is typically recommended as part of the data-preparation process for SampEn; however, since NLD systems are frequently not normally distributed (i.e., Gaussian), this is theoretically problematic. Synthetic data from a variety of NLD systems, noise generators, and self-organized critical systems were used to calculate SampEn with and without normalization. Results: SampEn of normalized data generated spurious results in some cases. Conclusion: normalization should be used cautiously when calculating SampEn.

Oksana Kulikova, Siberian State Automotive and Highway University
Mikhail Zimin, 2554620 ONTARIO LTD.

Using Clusterization and Non-Linear Dynamics for Recognition of Dependences between Covid-19 Epidemic Processes through the Example of North America

To find dependences between epidemic processes of new coronavirus infection in North America, it is taken into account that such phenomena have non-linear wave-like character. Therefore, statistical technology and methods of non-linear dynamics are used. Research is performed according to statistics from site of 'Our World in Data' (https://ourworldindata.org/). Parameter of Daily new confirmed COVID-19 cases per million people is utilized. Analysis is performed with the help of spatial clustering, Breakpoint Unit Root Test, Hurst exponent and is realized in Python. Hence, methodology of recognition of dependences between epidemic processes of coronavirus infection in North America is developed. Correlations are investigated for each wave for different territories. It is found that interconnection is absent, if time series describing disease contagion are white noises. These results can be used for solving problems of short-term and strategic plans in health care and government politics against epidemics.

Ryan Meidinger, **Vivien Marmelat**, Department of Biomechanics, University of Nebraska at Omaha

Fast and Preferred Metronomes may Tune Brain Activity but the Effect is Impacted by History

Much of human movement and brain activity are rhythmic. Brain activity does not synchronize with self-generated movements, but it does with external rhythmic stimulation (i.e., metronomes) with movement synchronization. When external rhythmic stimulation is removed healthy young adults can recreate the rhythm (continuation), but it is not known if synchronized brain activity also continues. Variability of intervals produced without the metronome is increased by metronomes faster or slower than the person's self-generated rate (detuning), but it is not known how this relates to changes in brain activity during continuation. It is our hypothesis that brain activity will remain synchronized with the metronome during continuation, but the amplitude of synchronization will be reduced by detuning. We qualitatively report results from finger tapping on a midi device and electroencephalographic recordings while participants synchronize with three different metronomes (2x preferred, 1x preferred, and preferred). The results from 3 participants suggests that brain activity continues after the metronome is removed most consistently for conditions with the 2x preferred and preferred metronomes. In the slow metronome condition brain activity, appears to remain unphased by the metronome. In the participants observed, there also appears to be an order effect that results in drifts toward the prior metronome during continuation and increased amplitude responses in later trials. It is unclear if these results will be continued but may suggest neural tuning to synchronization with the metronome and a possible hysteresis dependent on the initial conditions of the prior synchronization.

Augusto Mellado , **Mariane Krause**, Pontificia Universidad Catolica de Chile,
Claudio Martinez, **Alemka Tomicic,** Universidad Diego Portales

Self-organization in psychotherapy sessions of a female adult patient diagnosed with Borderline Personality Disorder (BPD)

Aim, & Framework: To identify fractal dynamics in sessions of successful psychotherapy of a female adult patient diagnosed with BPD. One of the markers of self-organization is the presence of Inverse Power Law (IPL) in the size and frequency distribution of certain events (Pincus, & Guastello, 2005). Fractal processes (IPL distribution) are more adaptive to internal and environmental changes (West, & Shlesinger, 1990), and have been observed in therapeutic processes (Schiepek, 2009), or patterns associated with patients self-injurious behaviours (Pincus et al., 2014). Methods: Through the Model of Analysis of Discursive Positioning in Psychotherapy [MAPP, Martinez & Tomicic, 2019], subjective exchange of the patient and her therapist were identified. Then the sessions that reached stable subjective configuration and low entropy (12 sessions, Hs < 2.5), and those where such configuration could not

be clearly identified, and with high entropy (6 sessions, Hs > 3), were selected. In each group of sessions, patterns were identified using ORBDE (Peressini, & Guastello, 2014). Finally, a comparison was made considering the fit to the IPL distribution of the patterns, using R^2 and the b parameter (fractal dimension) of a non-linear regression model. Results: The entropy of the subjective exchange patterns found in the first group was Hs= 4.9, while in the second it was Hs= 5.1. Both groups presented an acceptable fit to the IPL distributions (R^2= .86; and .88), and a fractal dimension Df= 1.9, and Df= 2.1, respectively. Discussion: According to the fractal dimension described, sessions, where a stable subjective configuration could not be clearly recognized, were more complex than those where they were. These sessions may present a fractal structure as the basis for the non-linear emergence of a more stable pattern structure, possibly related to therapeutic change.

Anita Lee Mitchell, Florida State University

Data Science for Research into Learning Complexities

Data scientists study how to turn data into knowledge to support reasoning and decision-making in uncertain or ill-defined systems. The complex, dynamic and nonlinear, nature of learning leaves many uncertainties about factors, contexts, and processes that influence learning outcomes. A growing body of literature explores learning and education from this complex systems perspective. This research relies on a wide variety of methods, from qualitative inquiry (Bloom, 2001; MacGillivray, 2010; Rowland & Kitchner-meyer, 2018; Tosey, Mathison, & Michelli, 2005) to computational modeling (Guevara & Porta, 2016; Lamb, Cavagnetto, & Akmal, 2016; Marder & Bansal, 2009; Maroulis, Bakshy, Gomez, & Wilensky, 2014; Stamovlasis, Stavropoulou, & Karastergiou, 2020). This variety can make designing research into learning complexities an intimidating process. Data science methods appropriate for this variety of data are summarized here in the context of learning research. An overview with examples can be a helpful starting point when designing research projects. This summary relies on a literature review to identify use cases for data science methods in learning research. This summary will cover the full spectrum of data science tools: descriptive methods that answer, What is happening? ; exploratory methods that answer, What if this trend continues? ; predictive methods that answer, What will actually happen next? ; and prescriptive methods that answer, What is the best possible thing that could happen next? (National Academies of Sciences, Engineering, and Medicine, 2017).

Kenneth Moselle, Vancouver Island Health Authority
Ernie Change, Consultant,
github.com/ecsendmail/MultiverseContagion

Temporally homogeneous vs heterogeneous transmission dynamics in simulated contagion-based epidemics with divergent vaccination outcomes

Typical equation-based epidemiological compartmental models of contagion-based infection assume homogeneous dispersion of susceptibles and infectives. This mass action incidence assumption sets an epidemic on course for a smooth exponential rise in cases until saturation effects or risk mitigations cause the curve to come down. These dynamics can be reproduced using systems of ordinary differential equation. However, this mass action assumption is almost invariably counterfactual in the early stages of an outbreak. Further, at any stage in an epidemic, the dynamics governing real-world transmission events in the local contexts where they occur are characterized by heterogeneity and stochasticity. In this presentation, we configure a stochastic agent-based model (CovidSIMVL) to generate two classes of simulations marked by distinct dynamics that we term "PARTICLE" and "WAVE". Transmission events in CovidSIMVL are a product of agent movement within a delimited physical space. No assumptions are made up front about infection reproduction numbers. Without any mid-course changes to simulation parameters, the PARTICLE dynamic produces epidemics that are well described by the typical smooth logistic growth curves that arise with exponential spread of a virus in an environment with finite resources. However, by appropriately setting initial conditions relating to stochastically varying agent movement, we produce a dynamic that is temporally heterogeneous, marked by multiple pronounced slope and curvature discontinuities within simulations, and variability between simulations. We present the results of simulated vaccine trials with varying age-stratified vaccination schedules in which the outcomes reflect impacts of these different PARTICLE vs WAVE transmission dynamics.

Jose Navarro, **Aleksander Lozanov, Elsa Marquinez**, **Ariadna Torrens**, University of Barcelona

Emotion and motivation at work: Exploring the potential influences of emotions on work motivation applying neural networks

The affective events theory (Weiss and Cropanzano, 1996) is a framework that allows us to understand the causes and consequences of affect and emotions in work contexts. This framework proposes that in work settings

there are events that are not neutral and generate affective responses that, in turn, influence employees behaviors and attitudes. Using this framework, we have collected data during 10 working days from 42 workers from different occupational backgrounds gathering a total of 416 repeated assessment and using the event reconstruction technique (Kahneman et al., 2004). Applying linear and nonlinear analysis (e.g., growth modeling and neural networks) we have found support for the importance of events in generating emotions. Specifically, familiarity, valence (positive or negative) and relevance of events are significantly related to some of the basic emotions (anger, joy, sadness, fear, disgust and surprise). For example, unfamiliar events produce the reaction of surprise; or relevant events produce reactions of joy or fear. In addition, some of these emotions, for example joy, are also significantly related to later motivation in the task at hand. The latter is especially relevant since 1) it is known that our work motivation is changing in the short term (e.g., through days and weeks) and 2), however, the main causes of these motivational changes continue to be unclear. In this communication we explore the advantages of using nonlinear techniques in contrast to the linear ones. For example, the assumptions of the nonlinear techniques fitted better in this case in which the different emotions presented significant relationships among them, supposing a problem of multicollinearity regarding the linear techniques. From a practical point of view, the theoretical framework used and the results found invite us to consider two elements in human resources practices. First, we should pay attention to the emotions that our employees experience on a daily basis, for example, having evaluation systems to gather this information. And second, it would be necessary to do a detailed analysis on what type of work events generate these emotional responses.

Anthony F. Peressini, Marquette University,
Stephen J. Guastello, Marquette University

Large-scale Databases for Nonlinear Phenomena: Sync Coefficient SE and Variations

In theory, a correlation matrix has a distinctive analytic structure: it is symmetric and positive semidefinite (has nonnegative eigenvalues). But such matrices often go awry in applications involving asynchronous or missing values, employing robust estimators (e.g., trimmed means), or when the correlation matrix is constructed from pairwise correlations or estimates based on forecasts from different sources. In these cases, the matrices need to be brought back to being positive semidefinite for analysis by employing a numerical technique for finding the nearest true correlation matrix to the flawed one. Highham (2000) developed just such a technique, which has become important in applications in fields as diverse as finance, genetics, emotion categorization, and public health modeling. We applied this technique to our measure of synchronization, SE, for teams of three or more members (Guastello & Peressini, 2017). SE grew out of a recognition that many social dynamics are related to the synchronization of individuals physiological signals (e.g., electrodermal responses, EEG, volitional movements) and a need for a sync measure for larger groups. Here we compared the original version of SE with two variations, each of which uses the same underlying logic, but varies the structure of the matrix of correlations that ground the calculation of SE: (a) nPD pre-conditions the matrix by mapping it to the nearest positive (semi-)definite matrix, and (b) nCor pre-conditions the matrix by mapping it to the nearest correlation matrix. Part 1 compared electrodermal response data from four teams of five participants playing a first-person shooter computer game as to whether the two SE variations capture more sync than the original. Part 2 is an external validity study examining whether the two variations make improvements over the original with respect to predicting concordance with an external criterion; in this case, the dependent variable was concordance experts ratings involving 42 groups with 3 to 7 members playing Subarctic Survival, with independent variables being SE coefficients from three parts of the activity. Results from Part I indicated that nPD captured more sync than the original and nCor less. Part 2 results indicated about a 4% increase in the amount of variance accounted for in the dependent variable by nPD and nCor over the original version; the new variations did not significantly differ from each other.

David Pincus, Psychology, Chapman University
Bernard Ricca, Department of Mathematics, Computer Science, and Statistics at St. John Fisher College
Jenkins Brooke, **David Frederick**, **Julia Boehm**, **Vincent Berardi**, **Amy Moors**, Psychology, Chapman University

Emotional Balance and Resilience at the Start of the Covid-19 Pandemic

Self-organizing systems are capable shifting between flexibility and robustness in response to perturbation, which highlights their potential to provide theoretical grounding for the fragmented field of human resilience. One hallmark of self-organization is a network structure conforming to an Inverse Power-Law (IPL). Prior research has found that self-organization as evidenced by IPL (or associated) patterns predicts health and resilience in psychological systems including personality structure, patterns of physical activity, affect, behavior patterns, and interpersonal dynamics. The present

research extends this theoretical line of inquiry to understanding emotional resilience. The study used ratings of intensity (1-5 Likert scale) across 12 emotions (six positive and six negative) collected as part of a survey of adults (N = 4142) pandemic experiences and health in the USA in April 2020 (at the start of the USA pandemic response). To examine self-organization among these emotions, the difference scores (n = 66) in emotions ratings were tested for fit with IPL distributions. Depending on the degree of fit found, it was predicted that better fit (i.e., higher R2 values) and/or higher flexibility (i.e., flatter shape parameter, β) would be associated with a range of functional outcomes including health, mental health, and pandemic stress. Results include: (1) a range of R2 values, from 0 (no IPL fit) to 1 (strongest IPL fit), with 22% having an R2 > .70. (2) Higher R2 values were consistently associated with better mental and physical health, better coping, and less pandemic related distress, even when controlling for mean levels of happiness, and the simpler measure of variance in emotional differences. Results will be discussed in relation to the growing body of empirical results examining emotional and psychological flexibility in understanding human resilience, and the utility of self-organization as an integrative theory.

David Pincus, Psychology, Chapman University

Fractal Self-structure and Psychological Resilience: A Replication and Extension

Pincus et al., (2019) found that reaction times to items on the MMPI-2 gathered from a forensic sample of court referred adults generally conformed to inverse power-law (IPL) distributions and that higher rigidity in those distributions (i.e., larger short to long reaction-time ratios) was associated with higher levels of psychopathology. The present study replicates these results and extends them in the following ways: (1) the M5-50 (five factor model) was used instead of the MMPI-2; (2) an undergraduate college sample rather than a forensic sample; (3) fewer measures of psychopathology (i.e., DASS versus MMPI-scale scores); and (4) an examination of pre- versus post-pandemic correlations between self-complexity and psychopath-ology. Results included the following: (1) mean IPL fit and shape were consistent for the pre-pandemic (N = 438) and post-pandemic (N = 152) samples; (2) Students on average had clinically significant mean levels of depression, anxiety, and stress prior to the pandemic. Stress and depression increased statistically, but anxiety did not, and none of the measures showed clinically significant change; (3) Personality rigidity using shape of IPL item response-times was associated with higher anxiety pre-pandemic, while post-pandemic rigidity was associated with anxiety, depression, and stress. These results suggest that claims of a mental health crisis due to the pandemic may ignore some significant pre-existing mental health problems, at least within undergraduate university samples. The results also lend further support for (a) the use of item reaction-time distributions to personality inventories as a valid measure of self-complexity; (b) the idea that personality is a self-organizing system; and (c) the use of personality flexibility as component of psychological resilience.

Dave Pruett, James Madison University

Entropy, Chaos, and Evolution: Toward a Metanarrative of Life

In What is Life? (1946), quantum physicist Erwin Schroedinger associates life and thermodynamics; i.e., life is characterized by its extraordinary ability to feed on negative entropy. In The Phenomenon of Man (1955), French paleontologist-priest Teilhard de Chardin proffers two sweeping metanarratives: cosmogenesis and complexity-consciousness. First, the entire cosmos evolves, not just the life within it. Second, biological evolution is not directionless; it tends toward greater biological complexity with concomitantly higher consciousness. Teilhard further intuits that thermodynamic decay within the physical cosmos drives counter-entropic complexification in the biological cosmos. In Order Out of Chaos (1984), Nobel chemist Ilya Prigogine establishes necessary conditions for the emergence of order from a chaotic system: 1) nonlinearity, 2) dissipation, and 3) being far from equilibrium (FFE). Life on Earth satisfies all three. Finally, in Every Life is on Fire (2020), rabbi and MIT physicist Jeremy England establishes that life-like structures arise naturally in FFE chaotic systems. The talk will connect these dots to arrive at biochemist Arthur Peacocke s stunning synthesis linking cosmogenesis and consciousness: [R]ecent thermodynamic analyses . . . [suggest] the movement of the [entropic] stream itself inevitably generates . . . large eddies . . . in which far from there being a decrease of order, there is an increase [both] in complexity and . . . functional organization. . . . There could be no self-consciousness and human creativity without living organization, and there could be no living dissipative systems unless the entropic stream followed its general, irreversible course in time.

Lucero Rodriguez Rodriguez, **Yun Kang**, **Polemnia G. Amazeen**, **Abba Gumel**, **Nancy J. Cooke**, **Demir Mustafa**, Arizona State University

Jason S. Metcalfe, U.S. Army Research Lab

Mathematical Modeling of Humans and Autonomous Agents Interaction Dynamics

Modern interactions with technology have been moving away from simple human use of computers as tools to the establishment of human relationships with autonomous entities that carry out actions on our behalf. Thus, it is imperative to understand the human-autonomy interaction dynamics in order to have the best outcomes and ensure human safety in dangerous tasks. In this project, we develop a two-agent interaction framework in discrete-time that could apply to human-autonomy interaction. We

analyze our model and validate it through experimental data. Our study shows that the model has rich dynamics including multiple attractors. Combined with data, our work is able to investigate team members' characteristics that would drive the team to succeed in a given task. We compared the communication dynamics and agents' characteristics between low, medium, and high performing teams. In addition, our model could potentially help us to select team members that could work together efficiently, and train members in the established team to collaborate better.

Barkley Rosser, James Madison University

Complexity and the Future of Economics

This paper considers how complexity theory id influencing the future of economics. It considers the broad pattern of the evolution of economics, a broad view of the nature of complexity, what cutting edge complexity economics research is, how this is changing research methods, how this affects macroeconomics research particularly, what are implications for public policy, and the paradox arising from economics itself being a complex adaptive system. What is seen is a move from a view of rationality, greed, and equilibrium to one of purposeful behavior, enlightened self-interest, and sustainability.

David Schuldberg, University of Montana, Missoula

More We Can Learn About COVID-19 From Nonlinear Dynamics, and Vice Versa

This paper builds on a talk given last year at SCTPLS which attempted to catalog the various things that we could learn about nonlinear dynamics from the COVID-19 pandemic. Last year's paper listed aspects of the pandemic implicating nonlinear phenomena, and the contributions of NDS theory for our understanding of and hopefully dealing with the pandemic. The current paper examines developments during the last year, focusing on such phenomenon as spikes, outbreak dynamics and management, vaccine distribution and penetration, new developments with supply chains, effects of prevention programs, and, of course, the status of the quest for heard immunity in the USA, internationally, and globally. Modeling approaches will be discussed, with a review of some of the methods used by Mangiarotti et al. (2020). Special attention will be paid to some of the things one can do with widely available time series datasets of COVID cases, updated daily. Mangiarotti, S., Peyre, M., Zhang, Y., Huc, M., Roger, F., & Kerr, Y. (2020). Chaos theory applied to the outbreak of COVID-19: An ancillary approach to decision making in pandemic context. Epidemiology & Infection, 148(e95), 1 9.

Sarah Stanfield, **Allan Combs**, California Institute of Integral Studies

Emergence and Self-Organization in Memes

In this theoretical paper we consider the meme as a nonlinear self-organizing emergent phenomenon that arises within the complex system of social networks. At its core, a meme is like a simple program or prototype with a basic set of instructions, and yet the process that unfolds as a meme propagates through the collective consciousness yields unexpected novelty, increasing the complexity of the social world. Recently, memes have been at the source of explosive shifts in collective behavior. Meme culture has caused rapid fluctuations in the prices of publicly traded securities; subverted the official narrative of news cycles; and upended the traditional workings of U.S. presidential elections. The aim of this paper is to analyze the nature of the meme as a dynamical system in order to better understand the physics of meme propagation. How does a meme behave like fluid in the turbulent regime? How might a meme be considered a bit of information? How is a meme similar to a genetic algorithm? Can meme propagation be modeled as a cellular automaton unfolding like a Game of Life? This paper should find relevance within any field that studies the dynamics of social, biological, and evolutionary processes.

Arabella Thaïs, **Allan Combs**, California Institute of Integral Studies

Rhythm Analysis and a Cosmic Consciousness

Genuine poetry communicates before it is understood wrote T. S. Eliot, speaking of Dante s Divine Comedy. Except Eliot did not actually speak Italian. We argue that what is communicated is the non-verbal rhythmic language of the Huxley s Mind-at-Large and that this rhythm is fractal and as such is found in expressions of superlative literature and music as a result of this higher mind merging or communing with the mind of the artist. This idea is corroborated by studies that disclose fractal and multifractal patterns in literature such as Virginia Woolf s The Waves and James Joyce s Finnegan s Wake, indicating a relationship between patterns of consciousness and abstract mathematical patterns. Other inter-disciplinary studies find fractals in classical music Beethoven, Hyden, Adams, etc. We address the fundamental question of how such authors and artists intuitively encode this abstract shape of the cosmos into their work, positing a methodological exemplar that expands upon disciplinary syntheses thus far, and coalesces mathematics, literature**,** ontology and cosmology. Doing so, we suggest furthering the notion of Gaston Bachelard's Rhythmanalysis to create a methodology that could be applied to both the creative work and the aesthetic experience. Beyond fractals, innovative mathematical models such as algebraic topology come in useful.

Catherine Van Holder, Futurist, Private Practice, Belgium **Koen Depryck**, Educational Sciences, Vrije Universiteit Brussel, Belgium.

The Interpretative Application of a Complex Systems Perspective in Futures Studies

While various foresight methodologies incorporate concepts from complexity science such as bifurcations and systemic interdependence, there remains a vast amount of unexplored applications of a complex-systems perspective to the practice of exploring and envisioning futures. This article explores its interpretative value vis-a-vis DESTEP (demographic, economic, socio-cultural, technological, ecological and political) factors habitually used in foresight practice. DESTEP factors are those macro-environmental factors or signals of change that are believed to have a profound impact on a particular systems' future. In this paper, we illustrate how the political factor polarization can be meaningfully unpacked and understood within a micro-macro isomorphic vantage point of the complex evolutionary dynamics of differentiation and integration. The research is exploratory in nature and situated within an epistemological framework. Combining findings and concepts from complexity science, political sciences and psychology, we describe how a complex-systems perspective sheds new light on this particular political factor, as an illustration of how such an approach might be of value to a variety of DESTEP factors on which futures scenarios and visions are built. Hence, present paper indicates how incorporating the interpretative application of complex-systems in the futurists toolbox is of value to the participatory envisioning approaches commonly found in futures studies.

Tai Young-Taft, **Harold M. Hastings**,
Bard College at Simon's Rock

Universality in GDP scaling

In Hastings and Young-Taft (2020) we considered empirically observed GDP scaling over time, finding stable regimes including a high-end power law tail, a middle scaling region where GDP decreases exponentially with rank, and a more rapidly decaying low-end tail, exponentially with rank squared, over the 40 year period from 1980 to date. Montroll and Shlesinger (1982) argued for a basic lognormal distribution as a consequence of multiplying many independent random variables, together with a power law high-end tail (as we later observed) because the very wealthy generally achieve their superwealth through amplification processes that are not available to most. We identify universal patterns in GDP scaling by applying curve registration techniques to the evolution of GDP as a function of rank order and time. References: Hastings, H.M. and Young-Taft, T. 2020. Empirical scaling and dynamical regimes for GDP: challenges and opportunities. International Conference on Complex Systems, virtual, July 2020. Montroll, E.W. and Shlesinger, M. F. 1982. On 1/f noise and other distributions with long tails. Proceedings of the National Academy of Sciences, 79, 3380-3383

Susannah Zhang, Vassar College and University of Georgia
Jenny Magnes, Vassar College
Harold Hastings, Bard College at Simon's Rock

Evaluating markers for chaos in C. elegans locomotion: The role of surrogate data in establishing significance

The small (1 mm) nematode Caenorhabditis elegans has become widely used as a model organism; in particular the C. elegans connectome has been completely mapped, its locomotion has been widely studied, c.f. wormbook.org. We had previously described the use of the far field diffraction signal of C. elegans locomotion to identify markers of deterministic chaos, including finite-dimensional Takens embedding and a positive Lyapunov exponent (Magnes, J., et al. (2020). Chaotic markers in dynamic diffraction. Applied Optics, 59(22), 6642-6647; Magnes, J., et al. (2017) Fourier-based diffraction analysis of live Caenorhabditis elegans. JoVE (Journal of Visualized Experiments), 127, e56154). Here we use surrogate data methods to gain additional insight into the correlation dimension associated with Takens embedding and more generally, non-linear determinism. We also use surrogate data methods to complement our previous use of recurrence plots and recurrence quantification analysis as further markers of chaos (to appear). In particular, analysis of surrogate data demonstrates the statistical significance both of previous quantitative results and non-linear determinism.

Susannah Zhang, Vassar College and University of Georgia
Jenny Magnes, Vassar College
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Experiments), 127, e56154). Here we use surrogate data methods to gain additional insight into the correlation dimension associated with Takens embedding and more generally, non-linear determinism. We also use surrogate data methods to complement our previous use of recurrence plots and recurrence quantification analysis as further markers of chaos (to appear). In particular, analysis of surrogate data demonstrates the statistical significance both of previous quantitative results and non-linear determinism.

Kashif Zia, Sohar University

Cultural Dynamics of Honor Culture: An Agent-Based Model and Simulation

Honor culture is the willingness of an individual to retaliate for the sake of reputation, without any risk and cost consideration. Nowak et. al. [Nowak, Gelfand, Borkowski, Cohen, and Hernandez 2016] proposed an agent-based model of the spread of honor culture, in which, each of the agents (of four types, namely, aggressor, institutional, honor, and rational) interact within its network. Thus, the population evolves where agents with lesser strength are replaced by the new ones. Their simulation conformed to theories that honor culture is directly related to both institutional weakness and environmental toughness. Although the simulations performed by Nowak et. al. analyzed the time dynamics, the spatial dynamics were largely ignored. In Zia et. al. [submitted to ANNSIM 21], we examined the spatial dynamics generated as a result of the evolution of agent population, with a particular focus on the correlation of population strengths and segregation. The simulation results revealed that time to reach an equilibrium among the agents belonging to different types decreases with an increase in the effectiveness of the institutions and environmental toughness. Additionally, both the strength of agents and population segregation increase with the increase in effectiveness and toughness. In this paper, we propose to further extend the study of spatial dynamics of honor culture, by using Axelrod's model of cultural diversification [Axelrod 1997] so that a proportionate population of agents can be instantiated on different cultural entities. This, certainly, would bring the model closer to real life and enable us to ask more focused questions, particularly, concerning the effects of demographic features of the population on the spread of honor culture and that of cultural diversification (itself) and segregation.

Mikhail Zimin, **Maxim Zimin**, 2554620 ONTARIO LTD.

Stochastic Probability Density Functions and their Application for Chaos Description

In current times, theory of chaos is rapidly developed. Hereat, elaboration of mathematical description of such conditions presents some features of interest. Measurements of predictors for forecast remaining life of equipment show that some value may be out of [-6σ, +6σ] interval, where σ is mean square deviation. Moreover, samples have considerable differences. According to performed analysis such samples are as if they were under stochastic character of mean value and mean square deviation of measured parameters. Gaussian Low and exponential law are considered. Their optimum characteristics are computed with the help of Monte-Carlo Method. The problem reduces to finding extreme point of function of 6 variables. Minimum of sum of square deviations from empirical cumulative distribution function is used as a criterion of optimum. Calculations shows that mean values typically distributed by Gaussian low and mean square derivation values follow exponential law. Combination of such approach with 6 sigma methodology can permit to improve safety and provide non-defective structures.

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Modeling Trend of Expressiveness Of Dangerous Phenomena S Precursors

Expressiveness of precursors of various natural phenomena often do not remain constant. They may increase or decrease, in some cases asymptotically approaching any value. Accordingly, it is necessary to choose functions of a special type to approximate their dependence on time. Adequate choice of type of function is important, because it reflects real risk. For example, if the dependence has the form of a constant function, danger does not increase due to the passage of time and can often times be acceptable. Situation may be catastrophic, if exponential function gives optimum approximation. Hazard lessens, if decay function apprises data in the best possible way. It should be also noted, that only limited sample of initial information can actually be obtained, so used methodology of reconstructing dependences should compare data amount and complexity of resulting function. In such case, method of structural minimization of risk is the most appropriate technology, in which such possibility presents. Application of Chebyshev polynomials in method of structural minimization of risk is described in [1]. If complex functions are utilized, the values of yi = f(ti) are first calculated, where i is the number of an experimental point, t is time, f is a function. For instance, f may be th(ati), where a is unknown coefficient. Then, using Chebyshev polynomials the dependence of z(y) is reconstructed, where z is expressiveness of precursors of various natural phenomena. Utilizing obtained dependences in practice shows that they usually repulse trend of real processes. It permits to improve prognosis of dangerous phenomena and decreases risk of ominous consequences.