Thank you Newton, welcome Prigogine: 'Unthinking' old paradigms and embracing new directions. Part 1: Theoretical distinctions[1]

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Abstract

The premises and propositions of the Newtonian-Cartesian model associated with classical science – determinism, linearity, reversibility, timelessness, equilibrium, etc. – are applicable primarily to closed systems. Prigogine's theory of dissipative structures has affirmed that nonlinearity, irreversibility, unpredictability, chaos and far-from-equilibrium conditions characterize interdependent open systems. Because closed systems are rare in nature, the linear findings of empirical studies tied to the presumptions of classical science face a potential challenge. The challenge to reductionism is dismantling the hierarchical order of natural science, social science, and humanities, thereby paving the way for a common epistemology. The field of communication stands to gain by emphasizing post-Parsonsian systems thinking to explore the nonlinear dynamics of dissipative structures.

Keywords: classical science, dissipative structures, Eastern philosophy, Newton, Prigogine, systems thinking.

Introduction

The 'new' systems thinking involving nonlinear dynamics – variously identified as dissipative-structures theory, chaos theory, catastrophe theory, self-organized criticality, new science, new systems approach, and complexity studies (Mathews, White, and Long, 1999) – has its strong proponents and opponents. The hostility, however, appears to be the result of not comprehending the complementary nature of the classical linear model and the nonlinear 'chaos' model. Therefore, this essay tries to document the thesis that communication theory and research can make vast strides by paying more attention to nonlinear dynamics than by continued allegiance to the positivistic classical model alone. Communication, including journalism and mass communication, should re-

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cognize the new challenges that have emerged from the evidence against Newtonian presumptions, as well as from the emergence of new approaches variously identified as cultural studies, critical methodologies, postmodernism, postcolonial studies, and feminist studies.

Early investigators of chaos – irregular, unpredictable behavior of natural structures – included physicist Mitchell Feigenbaum, fractal inventor Benoit Mandelbrot, and mathematician Edward Lorenz (Lorenz discovered that a minute happening in one spot, such as the flap of a seagull's wings, could produce a storm in another spot, a phenomenon identified as the attractor or the 'butterfly effect'). Complexity theory, which presumes that all things tend to organize themselves into patterns, had its beginnings with Norbert Wiener's cybernetics, Ludwig von Bertalanffy's general systems theory, and John H. Holland's computerized artificial life simulation.

Thermodynamically, all living systems or dissipative structures – including people, communities, and nation states – thrive in open environments exchanging energy (kinetic and potential: heat and work), matter (solid, liquid, gas or plasma), and information with outside sources. Dissipative structures have the ability (a) to increase and store information in the form of increasing levels of internal structuration, and (b) to export disorganization or entropy to their immediate environment. Such structures are grounded in the dynamics of deterministic chaos. They are inherently historical, far-from-equilibrium, boundary-testing, ontologically layered, and thermodynamically constituted configurations that evolve through mechanisms of assisted bifurcations and symmetry-breaking processes. Social systems are a special class of naturally constituted dissipative systems (Harvey and Reed, 1994; Nicolis and Prigogine, 1989).

These open structures normally produce dynamic nonlinear relations that the covering laws of classical science, which presume linear relations as normal, cannot predict. Linearity reflects the situation where an effect is proportional to an incremental change in the cause, and the resulting ratio is independent of any previous change. Nonlinearity, which can be functional or longitudinal, reflects the situation where effects are not invariantly proportional to their causes. Iteration over time represents longitudinal linearity. The relationship of variables in the model, machine, or system shows functional linearity. Stroup (1997) says, "Functional nonlinearity appears in many guises, for example, (1) simple interaction between two terms; (2) cubic, quadratic, or logarithmic terms; (3) or thresholding" (127). Dynamic systems exhibit three necessary conditions: iteration, nonlinearity, and sensitivity to initial conditions. Iteration or recursion refers to feedback (resulting from repetitive application of linear and/or nonlinear rules) under which a system process becomes

structure. Sensitivity to initial conditions means that the system's asymptotic behavior varies when the initial conditions are changed by even a small amount: the 'butterfly effect'. Although some may argue that most equations of the classical model, including Newton's second law of motion $F = ma$ (Force = mass × acceleration), are not linear, such equations exclude the realities of the 'butterfly effect' or asymptotic behavior because of their ceteris paribus presumptions. As sociologist David L. Harvey (personal communication, January 17, 2003) explains, Newtonian mechanics, as well as the differential calculus from which it is generated and in which it is expressed, prohibits the interaction of system components. Newtonian modeling is always additive, that is, it presumes a complex system's global dynamics to be the sum of the trajectories of the individual components of the system. It excludes the possibility of emergent behavior.

Dissipative structures are what van Ginneken (2003) refers to as complex adaptive systems. Kauffman (1980) describes a system as "a collection of parts which interact with each other to function as whole" (1). Such interaction produces both negative and positive feedback. Negative feedback negates changes or disturbances in the system thereby bringing about a degree of stability. On the other hand, positive feedback, a process that amplifies any disturbance in the system, can be so powerful that it can bring about vast changes within a short period. Complex systems are both nonlinear and adaptive. Their asymptotic behavior pattern is often unpredictable (e. g., weather, public opinion, epidemics, stock market) although short-term prediction may be possible.

This essay will unfold the 'new' science – 'new' in a relative sense to 'old' science – in hopes of encouraging communication research to pay greater attention to open systems. However, at the very outset, it is pertinent to dispel some myths about the "new" science. For instance, as Eve (1997) has clarified, chaos does not mean complete randomness; systems can be both chaotic and stable – not either or – depending on when one observes it; and the new science does not rule out the applicability of empirical social science because much order exists in chaotic systems, and "the old causal modeling techniques are probably useful much of the time" (278). What the new paradigm demonstrates is that "knowledge gained under the old paradigm is true under specific boundary conditions" (275). As Eve (1997) further explains:

> [In] our search to create elegant and parsimonious models, typically in the form of path diagrams and the sets of simultaneous equations, we found it necessary to make simplifying assumptions. If we didn't, the coefficients that resulted from "solving" these sets of equations were of a very small magnitude. So we tended to impose linearity on

> the universe (or at least nonlinearity that was easily mimicked by log transformations and similar data tweakings). Perhaps worst of all, we tenaciously clung to the belief that a stable coefficient was the natural outcome of our computations … What chaos theory implies, of course, and what makes it anathema to many of us, is that the whole business of trying to describe the world with summary digits is likely to often be quite impossible. (277)

Background

Presenting some background will help the beginners, even though students of systems theory may consider it redundant. Western science arose in the 17th century “in opposition to the biological model of a spontaneous and autonomous organization of natural beings” (Prigogine and Stengers, 1984: 291). With the onset of the so-called Industrial Revolution during the late 18th and early 19th centuries, the intellectual elites of the West compartmentalized knowledge into three hierarchies: natural/physical science, social science, and philosophy/humanities in descending order of prestige. Natural/physical sciences followed the ‘universal laws’ and rationality associated with the Newtonian-Cartesian model. Sir Isaac Newton (1642–1727) formulated the laws of universal gravitation and motion, which he used to explain a wide range of natural phenomena. René Descartes (1596–1650), also known as Cartesius, held that one could discover certain universal, self-evident truths by means of reason alone; and that one could derive deductively from those truths the remaining content of philosophy and the sciences.

What used to be historical social science split into three nomothetic fields – sociology/anthropology, economics, and political science – and the idiographic field of history (In 1838, Auguste Comte coined the term *sociology* to describe the field that would discover the laws of human society.) The three nomothetic fields vied for prestige by doing their utmost to follow the path of reductionist classical science. History, together with philosophy, became part of the third hierarchy called the humanities (Wallerstein, 1999, 2000, 2001).

The supremacy of the Newtonian-Cartesian model remained for more than three centuries despite two main challenges. One was the second law of thermodynamics, the law of entropy, which Clausius advanced in 1865 (Prigogine and Stengers, 1984: 117). This law states that the entropy – that is, the disorder – of a closed system can never decrease. Thus, when an isolated system reaches maximum entropy, it is in equilibrium and can no longer undergo change. In general, entropy represents the degradation of matter and energy. Penrose (1989) explains that, in rough terms, “the entropy of a system is a measure of its manifest disorder”

(308). This law, as Prigogine and Stengers (1984) state, "presented the first challenge to a concept of nature that would explain away the complex and reduce it to the simplicity of some hidden world" (8). The other was quantum physics that, in the early 20th century, provided a theoretical frame to describe the incessant transformation of particles into one another. Nevertheless, quantum theory "retained a number of conceptual positions of classical dynamics, particularly as far as time and process are concerned" (Prigogine and Stengers, 1984: 11). It is pertinent to note that the incorporation of the law of relativity had little bearing on these conceptual positions.

The nomothetic social sciences, which showed remarkable growth through the mid-20th century, have predominantly followed the path of the Newtonian-Cartesian model in their research agenda, even though some researchers addressed the issues of dynamics, complexity and nonlinearity as random deviations from the normal. The 'complexity studies' associated with the Brussels school of the natural sciences (e. g., Prigogine, 1980) pointed out that it was the Newtonian paradigm that suffered from questionable presumptions. Harvey and Reed (1994) point out that, at the turn of the 20th century, French mathematician Henri Poincaré was "one of the first to recognize the intractable limits that non-linear systems placed on conventional science" (376). For the next seven decades, however, Newtonian scientists relegated the nonlinear domain to that of random disorder and, therefore, of little scientific interest. Beginning late 20th century, ideas reflecting Prigogine's theory of dissipative structures have infiltrated most of the natural/physical and social sciences (Straussfogel, 2000). However, scholars in the communication field, including those in journalism and mass communication, have been slow in embracing the 'new' science of complexity although systems theory, in its various forms, did attract a few steadfast adherents (Fisher, 1975, 1982; MacLean, 1967; Monge, 1973, 1977; Watzlawick, Beavin, and Jackson, 1967).

New systems approaches replaced the old systems approaches of the structural-functionalist Parsonsian school from about the middle of the last century, when the cybernetic systems perspective, followed by 'chaos' theory in the 1960s, generated much interest and debate within the social and behavioral sciences (Berrien, 1968), including communication (Benson and Pearce, 1977; Ruben and Kim, 1975), psychology and social psychology (Latané and Fink, 1996; Streufert, 1997), anthropology (Rodin, Michaelson, and Britan, 1978), and archeology (Plog, 1975). Thayer (1968) claims that from 1948 to about 1951, four important 'tributaries' influenced the communication field: information theory, cybernetics, general systems theory, and the tradition of communication 'nets' studies (327).

Baran and Davis (1995) have devoted a chapter of their mass communication theory text to systems theories of communication processes. However, they failed to identify any communication scholar who has applied the complexity theory, and they devoted most of the chapter to a discussion of quasi-systems theories such as the knowledge gap model, social-political marketing theory, and information processing theory. They overlooked the work of Kincaid (1979, 1987) and Krippendorff (1987), two of the early communication scholars who saw merit in the Prigoginian model. Kincaid developed the convergence model of communication using the basic concepts of information theory, cybernetics, and general systems theory. He used Prigogine's work on nonequilibrium thermodynamics and self-organization to develop a conceptual framework integrating the micro- and macro levels of analysis. Barnett and Kincaid (1983) have pointed out that this model called for a change in the nature of the research questions asked, for new research designs, for new instruments of observation and measurement, and for new methods of data analysis and inference. However, not many communication researchers have taken up this challenge except for Barnett and his colleagues (Barnett and Houston, in press) and a few others (e. g., Hammond, 1997; Houston, 1996).

It seems that communication scholars have generally avoided or slighted (see Contractor, 1994) studies related to nonlinear trajectories in complex porous systems even though nonlinearity represents much of reality. For example, no researcher has applied the chaos theory to study the far-from-equilibrium state within the world system of communication-outlets over space and time. Such a study could examine the kind of 'energy and matter' the system absorbed from outside and dissipated to its environment; the type of positive feedback that pushed the system to the threshold of bifurcation, and the singular perturbation (or the so-called seagull or butterfly effect) that sparked the bifurcation toward either more complex disorder or reorganization. By studying chaotic occurrences, a researcher can create more accurate probability models. Chaos theory also offers a more realistic framework to study the organization and operation of wire services, newsrooms, and other mass media environments.

More recently, a few specialists in psychology have drawn the attention of communication scholars to the connection between communication and chaos principles embedded in their Dynamic Social Impact Theory, which relates cognitive, cultural, and social processes (Latané and Fink, 1996). DSIT allows examination of the linkages of concepts and their nonlinear effect on attitude change and attitude structure. It employs a neural network model in discussing attitude structure and

change, and it considers important attitudes to exhibit catastrophes. The model takes into account the characteristics of chaos, complexity, non-linear dynamics, and reorganization.

Outline

In this essay, I shall elucidate the theoretical distinctions between the 'old' and the 'new' sciences by providing a brief outline of the premises and propositions of the Newtonian-Cartesian classical model that have come under the microscope, and then by sketching out the new scientific findings associated with Prigogine's theory of dissipative structures. Thereafter, I shall discuss how communication theory and methodology can accommodate the 'new' scientific environment through 'new' systems thinking. In the process, I shall cite the work of pioneer (mass) communication system-theorists who too predominantly used 'old' systems thinking.

Comparison of 'Old' and 'New'

Classical (Newtonian) Model

The Newtonian-Cartesian model, the spread of which coincided with the rise of a factory civilization associated with the so-called Industrial Revolution, presented a mechanistic view of the world (universe) in which chance played only a peripheral part. Its presumptions included the following (Wallerstein, 1999, 2000; Wiseman, 2002):

- That precisely determinable initial conditions determined every element in natural processes.
- That trajectories of most natural phenomena are linear and that such trajectories always tend to return to equilibrium conditions.
- That time is not relevant to the understanding of natural processes because all laws are mathematically 'reversible' as the fundamental relations of those processes never evolve. As Penrose (1989) explains: "The deterministic equations of classical physics (or the operation of U in quantum physics, for that matter) have no preference for evolving in the future direction. They can be used equally well to evolve into the past. The future determines the past just the same way that the past determines the future" (306).
- That knowledge is universal and can ultimately be expressed in simple covering laws.

Thus, 'Newtonianism' presumed the ability of science to predict outcomes with the knowledge of the initial conditions and the relevant universal law. However, in 1931, mathematical logician Kurt Gödel pro-

duced a startling theorem that cast doubt on the infallibility of mathematical schemes deemed to make such prediction possible (Penrose, 1989). Gödel's complicated theorem showed that one could not prove the propositions on which the mathematical system is in part based because it is possible, in any logical system using symbols, to construct an axiom that is neither provable nor disprovable within the same system. One had to use methods of proof from outside the system to prove the self-consistency of the system (*Encarta Encyclopedia* 2002).

As Wallerstein (1999) explains, the classical model asserts that the function of science is to uncover the universal natural laws that govern everything in the real material universe. The model also asserts that empirical investigation involving precise measurement, which is possible through perfectible measuring instruments, is the only reliable, or useful, method of uncovering these universal laws. Additionally, the model presumes that most natural processes are closed systems, and that one can isolate the complex interactions among natural processes in the universe through the *ceteris paribus* (other things being equal) ploy. Napinen (2001) asserts that the "futurological predictive studies [based on the Newtonian model] … are not only misleading but even dangerous [because it is] not correct to reduce all the acts of people to the achievement of predictable events" (161).

Complexity-Studies model

The Brussels school (e. g., Prigogine, 1980; Prigogine and Stengers, 1984)) jolted the scientific community with Prigogine's theory of dissipative structures. This landmark theory, which helped Prigogine earn the 1977 Nobel Prize in chemistry, unified dynamics (the physics of being) and thermodynamics (the physics of becoming) to prove that irreversibility emerges from instability. Prigogine demonstrated the limitations of the applicability of Newtonian mechanics, as well as its extensions known as Boltzmann's statistical mechanics. Boltzmann (1844–1906) claimed that one could explain the second law of thermodynamics by statistically analyzing the motions of atoms.

> [T]here exists in nature systems that behave reversibly and that may be fully described by the laws of classical or quantum mechanics. But most systems of interest to us, including all chemical systems and therefore all biological systems, are time-oriented on the macroscopic level. Far from being an 'illusion', this expresses a broken time-symmetry on the microscopic level. Irreversibility is either true on *all* levels or on none. (Prigogine and Stengers, 1984: 285)

Prigogine and Stengers (1984) used the concept of entropy to distinguish between reversible and irreversible processes. Entropy increases only because of the irreversible movement of thermodynamic processes. Newtonian mechanics, by contrast, presumes a static (reversible) frame of analysis when studying dynamic systems whereas Prigogine's paradigm takes the dynamic (irreversible or evolutionary) view.

> There can be no doubt that irreversibility exists on the macroscopic level and has an important constructive role ... Therefore there must be something in the microscopic world of which macroscopic irreversibility is the manifestation (258). Time flows in a single direction, from past to future. We cannot manipulate time, we cannot travel back to the past (277).

Prigogine derived his theory of dissipative structures by focusing on the second law of thermodynamics; the law of entropy, which introduced time and history into a universe that Newtonian physicists "had pictured as eternal" (Briggs and Peat, 1989: 135). The second law says that in a closed system, disorder increases relentlessly until the system reaches equilibrium (or random dispersal of particles). Thus, the law implied that all the matter and energy in the universe would ultimately degrade to a state of tepid, inert uniformity (equilibrium) or heat death. Prigogine turned away from this negative view by identifying the universe as an open system where the disorder associated with a state of far from equilibrium would bring about order through spontaneous reorganization.

> At all levels, be it the level of macroscopic physics, the level of fluctuations, or the microscopic level, nonequilibrium is the source of order. Nonequilibrium brings 'order out of chaos' (Prigogine and Stengers, 1984: 287)

Prigogine made this intuitive leap from his observation of a phenomenon known as the Benard Instability. Tucker (1983) explains that Benard Instability

> "occurs when a liquid is heated from below. As heating intensifies, the mixture suddenly begins to 'self-organize,' taking on a striking spatial structure sometimes resembling miniature stained-glass cathedral windows, with ovals of brilliant colors arranging themselves in kaleidoscopic patterns. [These] ... patterns resembled living cells, [and] within each cell, ordered molecular motion occurs."

Prigogine reasoned that if this was possible in fluid dynamics, it would also be possible in chemistry and biology. This self-organization of matter represented to him a critical link between animate and inanimate matter. It could even provide a clue to the spontaneous eruption of life's beginnings. Chemical processes known as the Zhabotinsky Reactions (named after a Russian biophysicist who discovered them) confirmed Prigogine's theory. Thermodynamically, Prigogine (1997) affirmed, "All arrows of time in nature have the same orientation: They all produce entropy in the same direction of time, which is by definition the future" (102).

Prigogine's comprehensive theory of change, as Alvin Toffler has outlined in Prigogine and Stengers (1984), contains the following salient points:

- Although some parts of the universe may operate like machines, these are closed systems, which form only a small part of the physical universe. Most are open systems, exchanging energy or matter (as well as information) with their environment. Because biological and social systems are open, it is not possible to understand them in mechanistic terms. Most of reality is seething and bubbling with change, disorder and process, and not orderly, stable and equilibrial. Prigogine and his collaborators, who make a distinction between free energy and bound energy, see three forms of thermodynamic systems: isolated, near-to-equilibrium, and dissipative. Equilibrated, steady state systems such as crystals, minerals, and mechanical systems that cannot evolve internally belong to the isolated category. Systems that are organized around the principle of minimum entropy production and therefore cannot evolve internally, such as chemical clocks, belong to the near-to-equilibrium category. Evolving systems found in enriched, free-energy environments, and whose far-from-equilibrium configurations are non-replicable over time belong to the dissipative category (Harvey and Reed, 1994). This paper identifies the first two categories as closed systems.
- Fluctuations occur in an open dissipative structure when energy flows become too complex for the system to absorb. When a single such fluctuation or a combination of them musters enough power through positive feedback, a singular moment or bifurcation point arises that forces the system to reorganize. Each reorganization produces greater complexity and greater likelihood of random fluctuations, viz., evolution. It is impossible to determine in advance the direction of the system change: whether it will disintegrate into 'chaos' or give rise to a new, more differentiated, higher level of 'order'.

– Nonlinear relationships prevail when a system is in a far-from-equilibrium state, whereupon it becomes inordinately sensitive to external influences. A small perturbation or fluctuation can bring about startling, structure-breaking waves that replace the old with a new system (thereby bringing order out of chaos); a finding that has analogical significance for the social sciences. In contrast, a system in equilibrium may have reached maximum entropy where molecules are paralyzed or move around at random; the state toward which the universe is heading, according to the second law of thermodynamics. Nothing much happens in a near-to-equilibrium system as well because it is comparable to an energy well in which the system loses heat as fast as it gains heat.

Briggs and Peat (1989) explain that in a nonlinear equation, "a small change in one variable can have a disproportional, even catastrophic impact on other variables." A nonlinear solution tends "to be stubbornly individual and peculiar." Plots of nonlinear equations "show breaks, loops, recursions – all kinds of turbulence." Nonlinear equations have terms that "are repeatedly multiplied by themselves" to allow for feedback (24). Gleick (1987) says that nonlinear systems "generally cannot be solved and cannot be added together" (23–24).

Thus, as Wallerstein (1999) puts it, the science of complexity "sees instability, evolution, and fluctuation everywhere" (165). It sees a 'narrative' (rather than a 'geometrical') universe, in which the problem of time is the central problem. Probability is the only scientific truth there is. "Probability derives from the fact that there are always new statistical solutions of dynamic equations. Interactions within systems are continual, and this communication constitutes the irreversibility of the process, creating ever more numerous correlations" (166). The holistic view of the dissipative structure is its macroscale. All its internal subsystems are known as the microscale. The interaction of macro-and microscales is fundamental to the dynamics of dissipative structures (Straussfogel, 2000).

Accommodating 'new' science

Accommodating the 'new' science requires adopting 'new' systems thinking to explore nonlinear dynamics in communication systems, which are dissipative structures. Communication can certainly emulate the field of social psychology, which has already adopted some of the ideas of nonlinear dynamics (Streufert, 1997). This does not mean the wholesale abandoning of the Newtonian model, which, as we shall see in Part 2, is applicable to phenomena that are linear (e.g., low-energy equilibrium

systems) and to those constituting the lower ontological levels of dissipative structures. At the higher, more abstract, ontological levels, historical and philosophical narratives become the more appropriate method of analysis. The iconological method, associated with nonlinear dynamics, is most suitable at the middle ontological levels.

'New' systems thinking, which involves the recognition of nonlinear dynamics, is vital to grapple with theoretical paradigms associated with complexity studies. Systems thinking in its traditional sense focused on part-whole interdetermination. 'New' systems thinking shifted the focus to system-environment openness. More recently, systems thinking has also focused on self-referential autopoietic systems.

Luhmann (1995) points out "profound changes in general systems theory and associated interdisciplinary efforts" (1). He distinguishes three levels of analysis: systems in general at the first level; systems subdivided into machines, organisms, social systems, and psychic systems at the second level; and social systems subdivided into interactions, organizations, and societies at the third level. He points out that comparisons among different types of systems must restrict themselves to one level.

Luhmann (1995) reminds us that the tradition of speaking about wholes that are composed of parts stems from antiquity. The problem with this tradition was that "the whole had to be understood in a double sense: as the unity and as the totality of its parts" (5). To resolve the problem, the first move was to replace the difference between whole and part with that of system and environment, which enabled one to interrelate the theory of the organism, thermodynamics, and evolutionary theory. Although theoretical concerns also focused on the difference between open and closed systems, Luhmann says, now "the open-systems paradigm has been asserted and accepted within systems theory" (8). Luhmann claims his theory of self-referential systems to be "a universal sociological theory" (15). It conceptualizes society as a composite of operationally closed but cognitively open autopoietic subsystems. Each subsystem – economy, politics, mass media, law, politics, and so on – undergoes self-referential reproduction through recursive meaning production of communication related to its own binary code. For example, the mass media operate through reproduction of communication confined to the information/non-information binary code whereas the economy operates similarly within the payment/nonpayment binary code. The lifeworld and psychic systems provide the environment for each of the social systems. Luhmann's (post-1984) systems theory is built upon Husserl's phenomenological concept of communication, not individual action. Whitaker (1995) provides an overview of autopoietic theory. Luhmann borrowed the term 'autopoiesis' from Maturana and Varela (1980) and applied it to social systems of communicative events resulting

from the consummation of information, utterance, and understanding. Mingers (2002) has criticized Luhmann for paying little attention to the relationship between communicative events and the people who generate those events whom Luhmann places in each social system's environment.

In the field of communication, scholars (e. g., Benson and Pearce, 1977; Cronen and Davis, 1978) had been debating the relative merits of three theoretical approaches to research – covering laws, systems, and rules – just about the time that Prigogine broached his theory of dissipative structures, a system-environment paradigm. The covering laws approach, championed by Berger (1977), represented the logical empiricism of the Newtonian-Cartesian school of thought. The rules approach (Shimanoff, 1980) represented the qualitative movement that emerged in reaction to the cold, lawful, quantitative empiricism of the Newtonian-Cartesian model. The systems approach, championed by Fisher (1975), questioned the linear understandings of time. Shimanoff points out the Ellis and Fisher (1975) study on the phases of conflict in small group development as a good example of systems research.

Elaborating on the explanatory potential of laws, rules, and systems approaches, Shimanoff (1980) concluded that "systems theory is the only one that offers all four types of explanation" (230), namely, mental concept, reason-giving, and causal. The laws approach was deficient in reason-giving, whereas the rules approach was deficient in causal explanation. Furthermore, Shimanoff asserted, "If systems theory includes both law-and rule-related phenomena, then it will be able to predict both mechanistic and prescriptive relationships" (233). However, Shimanoff's discussion failed to distinguish between linear versus nonlinear approaches to systems thinking. (Nonlinear statistics merely estimates the probabilities of outcomes resulting from nonlinear dynamics in far-from-equilibrium dissipative systems whereas linear statistics associated with the classical model presumes the ability to predict relationships among variables).

Monge (1973) advocated the adoption of a systems paradigm for communication research because the criteria associated with the covering law model (particularly, universal generalization) were too stringent. However, what Monge had in mind was a *closed* system that enabled the researcher to subject linear equations to regression analysis. Subsequently, Monge (1977) explained systems theory in terms of "at least three and perhaps four alternative logical paradigms" (21): general systems theory (open systems), general systems theory (closed systems), cybernetics, and structural-functionalism. He argued that the systems perspective had the "ability to incorporate important aspects of the alternative positions" (29). (Prigogine, however, asserted that most systems of interest to social scientists were open and historical, not closed ones).

Fisher (1982) outlined the following elements of system theory: holism and nonsummativity, openness, hierarchical organization, organized complexity, and self-regulation. Neither Monge nor Fisher appears to have been familiar with Prigogine's work. Lilienfeld (1978) placed six separate disciplines under the general heading of 'systems thinking': biological philosophy (von Bertalanffy), cybernetics (Weiner, Ashby), information and communication theory (Shannon, Weaver, Cherry), operations research (Williams), games theory (von Neumann, Morgenstern), and techniques for simulating social and environmental processes by computers (Forrester). Lilienfeld, however, condemns system theory as "the latest attempt to create a world myth based on the prestige of science" (249).

Reed and Harvey (1992) make a distinction between the "earlier systems approaches," such as the Parsonsian systems theory, as well as its extension by Luhmann (1982) before Luhmann embraced autopoiesis, and the "new family of systems theories" (353) grounded in chaos theory. Primarily referring to the latter, Straussfogel (2000) says the study of systems – which includes the subfields dealing with chaos theory, dissipative structures, organizational cybernetics, and soft system science – offers enormous challenges to uncover social processes. Checkland (1999) illustrates the application of soft system methodology. His study of structural change in a publishing company (183–189) may be of particular interest to communication researchers.

When von Bertalanffy began developing his general systems theory in the mid-20th century, systems notions got the attention of several communication researchers. Among those were Westley and MacLean (1957) who proposed a new model of communication processes with feedback loops. MacLean (1967) points out several mass communication studies that applied the principles of early sociological systems analysis; Rosten's (1937) study of Washington correspondents, White's (1950) wire-news "gatekeeper" study, Swanson's (1949) research on the news staff of a mid-city daily, Gieber's (1956) study of 16 wire editors on Wisconsin dailies, McNelly's (1959) study of the international flow of news, and the Rileys' (1959) model of mass communication that emphasized the influence of social context, primary groups, and reference groups on the actions and interpretations of communicator and receiver alike.

Later, Ruben and Kim (1975) produced an edited book connecting human communication and general systems theory. These systems thinkers borrowed their concepts from information theory and cybernetics. However, their models were not robust enough to analyze far-from-equilibrium open systems, which spontaneously produced bifurcation points associated with nonlinear reactions of immense magnitude. Kincaid's (1987) convergence model of communication, which used Prigogine's

concepts, represented a ceteris paribus 'idealization': a partially closed, open-ended system (215). Krippendorff's (1987) models applying second-order cybernetics to understand the role of communication in societies undergoing planned and unplanned change still require greater refinement. Krippendorff identified the network-convergence paradigm (Rogers and Kincaid, 1981) as rooted in first-order cybernetics and systems theory, and he traced the paradigm of autopoiesis to theoretical biology.

> What the paradigm of autopoiesis does is relate information to processes of organization of production (in the ecosphere), encourage the conception of changes in the domain of information (noosphere) in terms of certain generative processes, and promote the view that communication is also a major stabilizing force, marking a social organization, a culture, or a society as a distinct identity and, being a constitutive part of that organization, producing its organization at the same time (Krippendorff, 1987: 207).

In more recent work, the old structural-functionalist systems thinking is reflected in Spitzberg's (2000) model of inter-cultural communication competence, Kim's (1995) cross-cultural adaptation theory, and Jia's (2001) social constructionist model of *lian/mian* transformation. In mass communication, Hendrickson and Tankard (1997) suggested the application of a systems perspective to reporting, as well as to refine news beats and routines. However, the application of the 'sciences of complexity' in communication research is rare although some may claim that the use of path analysis incorporates the possibility that two variables each exert causal force on the other, and that the introduction of stochastic mathematical models has offered an alternative to simple causality. Eve (1997), however, points out that path diagrams and the sets of simultaneous equations that describe them are attempts to create elegant and parsimonious models based on simplifying assumptions, which impose linearity on the universe.

Other defenders may claim that even the traditional social sciences have addressed some of the complexity issues through the application of modeling interactions using the elaboration paradigm (see Babbie, 2001), simultaneous system changes using structural equation modeling (see Hoyle, 1995), and nonlinear regression (see McClave and Sincich, 2002). Also known as the interpretation method or the Lazarsfeld method, researchers use the elaboration model to understand the relationship between two variables through the simultaneous introduction of additional variables. SEM is a comprehensive statistical approach to testing hypotheses about relations among observed and latent variables. SEM requires formal specification of a model to be estimated and tested. They

may further claim that social sciences have been largely influenced by the probability theory and they have histories and principles of their own. However, as pointed out earlier, traditional social science has operated under the presumption that nonlinear dynamics were random exceptions to the normal. Classical physics used probability to fill the gap left by ignorance while statistical mechanics used probability to estimate likely pressures and entropies. However, the realization that probability was intrinsic and unavoidable came only with quantum physics in the early 20th century. Yet quantum physics too did not dispute the presumption of reversibility of time.

In France, members of the Lyon-Grenoble team have applied the principles of the general systems theory to journalism historiography even though, according to Dooley (1990), the team's work has so far had little impact. Edgar Morin (1971) was the first theorist to do so with the 1960s student rebellion furnishing his ideal case. Morin (1977, 1980, 1987) has since produced a three-volume summa of systems theory in relation to communications. The theory suggests that societies undergo a dynamic and continuous process of development, wherein all elements are interconnected. Thus, it has discouraged looking at journalistic reporting as a closed system. Consequently, it has dismantled the distinction between the upmarket (elite) and downmarket (popular) journalistic outlets.

Because of the broadening and deepening of systems theories, analyses and methodologies over the last three or four decades, communication scholars now have access to a rich literature to use systems thinking more creatively (e. g., Adams, 1988; Altmann and Koch, 1998; Briggs and Peat, 1989; Dawkins, 1986; Gleick, 1987; Kauffman, 1995; Leydesdorff, 2001; Salthe, 1985; Waldrop, 1992). 'New' systems thinking is vital for unthinking the 'old' paradigm (Wallerstein, 2001). Systems thinking has become much more relevant with rapid globalization, which requires adopting a very holistic approach to problems and issues.

> It [systems thinking] takes a 'big picture' approach, with the clear understanding that human issues are very complex, integrated, and unpredictable in the long term; that they contain both quantifiable and non-quantifiable elements; that interdependence is a key feature of the survival of human systems; and that to separate out subsystems to be studied in isolation changes the very nature of the system and the problem. (Straussfogel, 2000: 171)

Thus, the 'new' systems approach need not be the exclusive domain of the quantitatively oriented scholars. In fact, Fisher (1975) has argued that qualitative analysis is essential to future communication research.

Fisher says, "[T]he difference between qualitative and non-qualitative analysis is the difference in emphasis upon linear causality and predictability" (202). He points out that whereas non-qualitative analysis addresses causes and effects, qualitative analysis addresses forms, variations, structures, classifications, etc., of the phenomenon under investigation. One does not have to be adept in quantitative analysis and modeling to look into linkages and interactions between variables at the higher ontological levels of dissipative systems. For instance, world-system theory emerged from the application of historical social science, not from nomothetic empiricism. Moreover, systems thinking is the hallmark of Buddhist philosophy. Siddhartha Gautama did not use quantitative modeling to explain the functional dynamics of the tangible and intangible constructs of the samsaric (chain of rebirth) system.

Summary and Conclusion

This essay has focused on the theoretical distinctions between the classical model of nomothetic social science and the nonlinear model of complexity studies congruent with 'new' systems thinking. It has used Prigogine's theory of dissipative structures, rather than Luhmann's (1995) highly abstract theory of autopoietic social systems, to draw these distinctions. Furthermore, this essay has traced the early attempts of communication researchers to use the old structural-functionalist (or linear) systems thinking while drawing attention to the dearth of research based on the nonlinear model of systems thinking.

Although the modern origin of nonlinear dynamics is embedded in the second law of thermodynamics, which helped elucidate the connection between entropy and irreversibility of time, one can easily see striking similarities between Eastern philosophy and nonlinear dynamics (e. g., the Buddhist concepts of impermanence, interdependence, and rebirth; the Chinese and Hindu concept of unity of all things; etc.). Perhaps, nonlinear dynamics may serve as the bridge between Western science and Eastern philosophy.

In the concluding part of this essay, I shall examine the potential of such a 'bridge' through a merger of dissipative structures theory with world-systems theory. The concluding part will focus on the pragmatics of applying nonlinear dynamics in communication research.

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Notes

1. This article is a revised version of a paper the author presented to the International Communication Division of the Association for Education in Journalism and Mass Communication at its annual convention in Kansas City, Mo., July 30–Aug. 2, 2003.)
2. The second part of this essay, entitled, “Thank you Newton, Welcome Prigogine: Unthinking old paradigms and embracing new directions. Part 2: The pragmatics” will be published in *Communications* volume 29, issue 2

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