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Conservation of Information: Reverse engineering dark social systems

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Introduction

      We concentrate in this paper on unsolved fundamental problems in social science, a non-mathematical overview of a theory of interdependence[1], ι (*iota*), that solves these fundamental problems, and an outline of the conceptual physics behind the mathematics of ι (i.e., bistability). Compared to the concepts, however, the mathematics of the theory is well-established (for Fourier pairs, see Lawless et al., 2009a; for metastable Lotka-Volterra-like equations, see Turchin, 2003; and König et al., 2009). But the difficulty in understanding bistable and ι concepts is illustrative. We will argue again and again against traditional, or classical, perspectives in social science.[2] However, even at the level of atomic physics (Bohr, 1955), the paradox is that "meaning" is based on classical perspectives which are the only ones available to humans, organisms, or machines and artificial agents. Despite the reduced value of "meaning", prediction from a physics of ι increases in value (as Newton argued, "intuitive conclusions based on immediate observations are not always trusted for they sometimes lead to the wrong clews", in Turchin, 2003, p. 22).

      We will draw the conclusion that the reliance on self-reports from individual agents by social scientists has led to a break-down in applying social theory to social ι. Regarding self-reports, Baumeister and his colleagues (2005) complained that they saw no other means of collecting social psychological data from individuals other than by self-reports. Regarding ι, Kenny and his colleagues (1998) published an influential technique to statistically remove ι from self-reported data collected with the methodological goal of replicating experimental effects across independent samples, but with the unintended consequence of directing attention away from a theory of ι. Our goal is the opposite of Baumeister's and Kenny's. We envision ι as a tool to construct better decisions, improve organizational and system performance (e.g., as we have successfully done for military Medical Department Research Centers, or MDRCs; see below in the summary of Field Results), and a mathematics of social dynamics to control mixes of human-robot-machine organizations and systems. We assume that social-psychological science without a theory of ι is likely to produce inferior policies (e.g., the commonly expressed view favoring collectivist policies over capitalist ones leads instead to a reduction in social welfare, as in Cuba, especially in response to national emergencies, as in China; Lawless et al., 2010a).[3] But from our research perspective of ι, we also make the provocative assumption that instead of the well-defined organizations and social systems seen everywhere by traditional social scientists, we expect a dark social system (DSS) commensurate with the technological prowess and skills of an organization compensated by the mathematical tools that permit us to study the bistable tradeoffs made by ordinary humans to reverse engineer a DSS.

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[1] Interdependence in its bipolar form, signified by the Greek letter *iota*, ι, is taken here as equivalent to bistability, but their differences are addressed under the section on limitations.

[2] In considering the application of social psychology to terrorism, Ginges (2009), concluded that the effect of "dissonance [as in Nash equilibria] may differ in magnitude across cultures, and perhaps be more prevalent in collectivist, community oriented cultures." However, being that a radical group is a DSS, the only realistic tool to study terrorists prospectively is physics (Lawless, 2009).

[3] Solnit (2009), premised on the notion that capitalism produces an alienation compared to tribes in supposed states of collective grace, proposed that "elite panic" in the aftermath of Hurricane Katrina promoted by elites [of white mobs] caused the deaths of many minorities and poor people in New Orleans, but she provided no supporting documentation (see the criticism in the *Washington Post* by D. Baum 8/23/09, www.washingtonost.com). Solnit's idea of elite panic was borrowed from the sociologist K. Tierney.

From the traditional assumption that the information produced from the social interaction is stable,[4] collecting information from individuals to study organizations with social network analysis (SNA) or other analytics is straightforward. Thus, for "dark" social networks comprised of illicit drug gangs or terrorists (Carley, 2006), uncovering information to compute an SNA is significantly more difficult. However, even when the information is readily available from well-established organizations and networks, the signals collected for SNAs (in NRC, 2009), game theory (Schweitzer et al., 2009), or data mining (NRC, 2008) have not led to valid predictions of social or organizational behavior (Pfeffer & Fong, 2005). These problems have led to a requirement for a new social theory to better understand the physics of interdependence, ι, in organizational complexity (Jasny et al., 2009), social networks (NRC, 2009), effects-based operations (Hillson et al., 2009), organizations (Kohli & Hoadley, 2006), and in the law and economics (Ahdieh, 2009). Barabási (2009) concluded that room needs to be made for a new theory "to understand the behavior of the systems … [and] the dynamics of the processes ... [to] form the foundation of a theory of complexity" (p. 413).

Traditional social and game theories, known collectively as methodological individualism, have been used for decades to study ι (paraphrased from Turchin, 2003, p. 11: while valid, the methodological individualism principle that "individual movement is determinant" is also reductionist; it underpins game theory, modern economics, social learning theory and the law; Ahdieh, 2009). Game theory was one of the first to model ι mathematically and to solve it in the laboratory for two sets of non-cooperative opponents. In the form of Prisoners Dilemma Games, these "toy" problems have a solution known as a Nash Equilibrium (NE; see Nash, 1951).[5] But Luce and Raiffa (1967) concluded that an NE results in unfair distributions of a game's resources among participants, an untested assumption that prevails among game theorists (as an example, see Happel, 2009). Further, Axlerod (1984) concluded that the unfair distributions from "the pursuit of self-interest" (p. 7) in games could be controlled with punishment sufficient for the evolution of cooperation to maximize the payoffs between game participants; Nowak and his colleagues concluded that rewards are better than punishment at generating cooperation in games (Rand et al., 2009). Regardless, the finding from laboratory games that favors cooperation enjoys wide support; e.g., a lack of cooperation is "maladaptive" (Nowak & Sigmund, 2004). Even President Obama reportedly favors collectivism over competition as less likely to compromise moral values and principles.[6] And yet his administration has constructed a successful

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[4] We define information as Shannon information; we define knowledge as analogous to an algorithm that generates zero information (Conant, 1976).

[5] A Nash equilibrium is usually defined as a stable state where participants cannot improve their self-interests based on the choices made by other participants; e.g., when two market firms compete directly, "aggressive moves … trigger ruinous price wars" (Lindstädt & Müller, 2010). In what follows, however, we reinterpret an NE as a set of opposed positions defended by self-interests. More importantly, those who occupy an NE drive their relatively stable views into a stable opposition with the ultimate goal of obtaining widespread social, financial, or political support for their self-interests. From our perspective, with reality being not easy to access or capture (Parsons et al., 1953, p. 202), an NE plus feedback provide sufficient information and knowledge to computationally solve difficult, intractable, or otherwise ill-posed problems (Lawless et al., 2009a).

[6] From *New York Times* (2009, 5/14), Commencement speech at Arizona State University by President B. Obama, 5/9/10: "Now, in the face of these challenges, it may be tempting to fall back on the formulas for success that have been pedaled so frequently in recent years. It goes something like this: You're taught to chase after all the usual brass rings; you try to be on this "who's who" list or that top 100 list; you chase after the big money and you figure out how big your corner office is; you worry about whether you have a fancy enough title or a fancy enough car. That's the message that's sent each and every day, or has been in our culture for far too long -- that through material possessions, through a ruthless competition pursued only on your own behalf -- that's how you will measure success.

competition for education proposals from among the States that may revolutionize public education.[7]

Luce and Raiffa (1967) also warned that it was unlikely that "any sociology be derived from the single assumption of individual rationality" (p. 196). Madison, the architect of the American Constitution, concluded that a government based on individual morality instead of checks and balances was the least likely form of government to succeed (Hamilton et al., 1787). The lack of checks and balances among scientists in the Department of Energy (DOE) allowed DOE management to corrupt its practice of science and to wide-spread contamination on and off of DOE's facilities (Lawless, 1985; Lawless et al., 2005).[8] Allport (1962) identified the shift between methodological individualism to ι in groups as the major unsolved problem in social psychology. Jones (1990), a leading social psychologist, went further to conclude that the interaction was unknowable, and that games in particular had failed to produce a science of ι (Jones, 1998). Similarly, Weick and Quinn (1999) concluded that the hardest thing to visualize is collective sense-making (cf. our previous discussion of "classical perspectives"). Yet, whether for one-shot, iterated or Folk (many player iterated) games, one of several theoretical problems with the traditional view of NE is that these are 2-D solutions of games in the laboratory that lead to assertions of gains in social welfare while ignoring evidence of social welfare in the real world (as an example, see Insko et al., 2005;[9] a notable exception is evolutionary game theory; also see Turchin 2005 and White, 2007). The call for a new theory of ι leaves us unsurprised that outside of the laboratory, game theory has not been validated (Sanfey, 2007) nor has it produced satisfactory solutions (Schweitzer et al., 2009); instead of empirical social facts, game theory justifies decisions based on pre-existing social norms (e.g., Körding, 2007), supplying scientists with justifications that substitute morality and religion for empirical evidence.

Another of the problems with game theory is that the social learning methods used by game theorists to justify or encourage cooperation draw the least cognitive power from humans. Neither punishment (Axelrod, 1984) nor rewards (Nowak & Sigmund, 2004) require human intelligence to be effective; they can be applied to mimic the behaviors of any organism(s); are simple enough to be used with agent-based models (ABMs); and yet this simplicity bearing on social complexity, such as computationally derived autonomy, is likely why computational agent

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… [Such] poverty of ambition … may lead you to compromise your values and your principles … [instead, do] what helps others …"

[7] *The New York Times Magazine* (2010, May 17) "The Teachers' Unions' Last Stand. How President Obama's Race to the Top could revolutionize public education": the "… contest called Race to the Top … has turned a relatively modest federal program (the $4.3 billion budget represents less than 1 percent of all federal, state and local education spending) into high-yield leverage that could end up overshadowing health care reform in its impact and that is already upending traditional Democratic Party politics. The activity set off by the contest has enabled Schnur's [Jon Schnur runs a Manhattan-based school-reform group called New Leaders for New Schools] network to press as never before its frontal challenge to the teachers' unions: they argue that a country that spends more per pupil than any other but whose student performance ranks in the bottom third among developed nations isn't failing its children for lack of resources but for lack of trained, motivated, accountable talent at the front of the class."

[8] The need for peer review (checks and balances) to correct DOE science practices (Lawless et al., 2005) is similar to the call for more peer review by climate scientists as their corrective to "climate gate", where words like "trick" and "hide" were used in referring to climate model practices, where scientists conspired to prevent unfriendly publications (Jasanoff, 2010), and where evidence was described as "incontrovertible" by physicists (APS, 2010).

[9] Insko and his colleagues (2005), using games in the laboratory, concluded that individuals were more cooperative than the same individuals in groups or organizations, and that trust improved with cooperation, the opposite of what we have found in the field with Department of Energy (DOE) Citizens Advisory Boards (CABs) making decisions on the environmental cleanup of DOE sites contaminated with radioactive wastes from years of mismanagement by DOE (Lawless, 1985; Lawless et al., 2005; Lawless et al., 2008).

systems have not been validated (e.g., Bankes, 2002; Conzelmann et al., 2004). Until we can model the complexity of humans, organizations or systems, ABMs are unlikely to be effective (Lawless et al., 2009a). Human society and decision-making require a more fundamental theory than the traditional social learning theory of social science. Our point is that autonomy may one day become effective with sufficient computational power, but not efficient. For example, Skormin (2009) used traditional multi-agent technology to control airspaces in combat zones by separating interacting aircraft, where spacing between aircraft increases in proportion to the degree that the airspace is contested, but a solution made inefficient by not exploiting the power of bistability or ι, which increases as human agents become closer and mutually aware of each other's presence (Lawless et al., 2009a). As a second example, swarms of non-cognitive but stable agents probably do not work well because even bacteria exhibit the complexity found with bistable decision-making (i.e., quorum sensing; in Czárán & Hoekstra, 2007).

Summary of game and social learning theory problems

Of the several assumptions in game and social learning theory that have not been validated, including the new field of quantum game theory (Busemeyer et al., 2008), we have focused on these:
1. The assumption that cooperation is more valuable than competition in generating positive social welfare benefits (however, instead of scientific facts, game findings replicate normative beliefs, such as religious or cultural beliefs; see Körding, 2007).
2. The expectation that games between two competitors can rationalize and optimize social welfare (but the 2-D model of competition precludes evidence that a democratic society with a free market and open political system can decide what is in its interests; in Lawless et al., 2009a; an example of rational expectations occurs when agents inside of an economic, social or ideological model assume the validity of its predictions, rejected by Sharif & LeBoeuff, 2002; an example of a social system that rejects the rational expectations made within it was illustrated in the panic among Democratic political elites brought on by a Republican unexpectedly winning the Massachusetts Senate seat vacated with the death of Ted Kennedy,[10] or among incumbent Republicans after the defeat of a senior Senator, B. Bennett, a moderate Republican of long standing and whose father was also a Senator, by the new conservative Tea Party members in Utah[11]).
3. The assumption that a theory of self-reports can be created to fully capture the relationship between beliefs or preferences and actions (but for a review of the failure of this assumption in games, see Kelley, 1992; in social psychology, see Baumeister et al., 2005; in management, see Bloom et al., 2007; and in the education of USAF combat fighter pilots in air-combat maneuvering, see Lawless et al., 2000).
4. The assumption in methodological individualism that emotion is not central to social decision-making (e.g., Ahdieh, 2009; Turchin, 2003; but emotional responding indicates a lack of cognitive or physical skills; in Landers & Pirozzolo, 1990; and "expertise" in a physical task generates low emotional responding; in Lawless et al., 2007).

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[10] "G.O.P. Senate Victory Stuns Democrats"; see www.nytimes.com/2010/01/20/us/politics/20election.html

[11] NPR, (2010, 5/12) *Utah's Sen. Bob Bennett On His Primary Defeat*, "Senator Bob Bennett of Utah was denied his bid for a fourth term over the weekend. He was removed from the ballot at a Republican convention dominated by activists in the Tea Party movement. Retrieved 5/20/10 from www.npr.org.

A solution. Part One (ι)

Lawless and his colleagues (2009b) have proposed a solution of ι control. Unlike game theory, the new theory of ι offered by Lawless and his colleagues is set in 3-D to specifically include feedback from an audience or a society; has been developed in both the field and laboratory; and makes predictions, a few of which have been confirmed in the field.

While a theory of ι is necessary to control autonomous mixed teams of humans, machines, and robots (Lawless et al., 2009b), working with ι intelligent agents is very difficult (Jamshidi, 2009). And yet the problem of ι has been recognized since the beginning of recorded history. Solving aspects of this problem have revolutionized scientific paradigms: an observer's perspective shifts between the earth and sun led Copernicus to propose that earth was not the center of our planetary system (Kuhn, 1970); Heisenberg's (1958) uncertainty principle for atomic systems requires, for example, shifts between the choice for position or velocity accuracy (see especially Bohr, 1955); and Bohr's criticism of game theory with shifts between sociology and psychology, based on the Heisenberg uncertainty principle, not only animated our theory, but led von Neumann and Morgenstern (1953) to fear, if correct, would make a rational model of the interaction "inconceivable" to them (p. 148).

But why is reality difficult to access or understand? In a word, bistability

Bistable or ι information. By definition, stable information does not change over time, like the military tank depicted in Figure 1A. Soldiers are trained to recognize a tank's features, promoting the value of camouflage. An example of simple ι is a bistable illusion, where a single database produces two mutually exclusive interpretations (Figure 1B). Illusions are common.[12] Both of two opposed interpretations of a bistable illusion cannot be held in awareness simultaneously (Cacioppo et al., 1996). Bohr (1955) concluded that multiple interpretations underwrite different cultures. Further, given the importance of feedback to social dynamics (Lawless et al., 2007), the possibility of shifts between bistable interpretations of ι states increases uncertainty in the non-observed interpretation, creating sources of conflict between social groups (e.g., the courtroom debates essential to justice; in Freer & Purdue, 1996), and evidence of COI, characterized as tradeoffs between ι but incommensurable views. We propose that measurements of bistable phenomena collapse to produce the stable classical information found in self-reports, decreasing uncertainty in the reported aspect of a bistable phenomenon but _increasing_ uncertainty in its non-reported aspect (e.g., Tajfel's, 1970, insider-outsider minimal inter-group effect). The simple bistable illusion in Figure 1B could represent the electorate in the U.S., with the "older woman" _arbitrarily_ representing the ι incommensurable beliefs of conservatives and the "younger woman" arbitrarily representing the incommensurable beliefs of liberals. A winning plan becomes the persuasion of neutrals to a well-defended position or belief, consequently decreasing conflict (Kirk, 2003) by increasing cooperation, but making a rational perspective (situational awareness) unlikely or unstable (Lawless et al., 2008a).

To summarize briefly, a bistable illusion (Figure 1B) represents any database containing a degree of uncertainty in the data sufficient to support two incommensurable interpretations; to

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[12] In 2005, Ben Bernanke, current chair of the Federal Reserve, said a housing bubble was "a pretty unlikely possibility" (2010, 1/6), "Fed missed this bubble. Will it see a new one?", *New York Times,* retrieved 1/6/10 from nytimes.com.

create competition between a minimum of two groups holding conflicting self-interests; and to engage interdependently an audience (e.g., polls that indicate a tie between politicians plus a large fraction of those who remain undecided by interested).

Figure 1A. On the left is an image of an Abrams M1A1 Main Battle Tank that generates a stable interpretation (e.g., www.army-technology.com/projects/abrams). All who view the tank reach the same interpretation. **Figure 1B**. On the right is a bistable illusion of two-women that creates an ι interpretation (an older woman facing downward and to the observer's left; or a younger women looking away and over her right shoulder). In a bistable illusion, an observer is incapable of "seeing" both interpretations of its single data set at the same time (Cacioppo et al., 1996).

Illusions and Signal Detection Theory (SDT)

The brain contains two independent systems, one for action and one for observation (Rees et al., 1997). As Bohr (1955) concluded, action and observation form ι uncertainty conjugate factors (tradeoffs). How do these tradeoffs affect images constructed by the mind? Adelson (2000) used a checkerboard illusion (Figure 2) to conclude that unlike a photometer, the brain distinguishes a white surface in dim light from a dark surface in bright light. This "lightness constancy" combines and constrains three brain processes to form classical perspectives: Processing images at lower levels (perception), mid-levels (Gestalt groupings), and high-levels (e.g., a worldview constructed from experiences with objects). Classical perspectives are not random processes, but based on experiences that form and shape a visual context or situational awareness. At these highest levels of cognition where experiences or intuitions operate, cognitive dissonance plays the critical role by permitting either more random interpretations of data guided by intuition, but requiring large amounts of energy (Gardner's, 1978, "Aha" insights characterized by gamma waves as evidenced of "brain flashes"; in Sheth, Sandkühler & Bhattacharya, 2008), or adapting some form of the available interpretations based on experiences, requiring significantly less energy (for a review of cognitive dissonance, see Axsom & Lawless, 1992). In case of a tie at the highest level between two classical but incommensurable perspectives, cognitive energy peaks (Hagoort et al., 2004). Continuing with Adelson, statistical processes and configural information map light reflectances to illuminate surfaces as an individual estimates the inverse transfer function adaptively like a filter (convolution). In SDT, a low-pass filter produces long-term averages in images, while a high-pass filter adds details (Lawless et al., 2009a). This permits us to assume that SDT forms a lower bound for decision-making under uncertainty, where the resolution of uncertainty is central to human social behavior (Carley, 2002), enabling COI.

Figure 2. The Checkerboard illusion (Adelson, 2000). The brain construes the shadowed area in checker square B to be lighter than the darkened square in A, but both are equally dark.
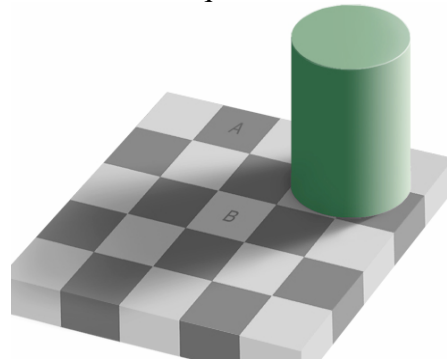
From cognitive illusions to rotations to Nash equilibria (NE)

Generalizing to social situations, in our field research with Department of Energy (DOE) citizens advisory boards (CABs) assigned the task of advising DOE on the cleanup of its radioactive waste contamination across the U.S. (Lawless et al., 2008a), not only does consensus-seeking dampen conflict during decision-making as expected (Bradbury et al., 2003), but we also found that risk perceptions (illusions) abound unchallenged under enforced cooperative decision strategies (consensus or minority rule; CR) compared to competitive strategies (majority rule; MR). That is why cooperative processes reduce social learning compared to competition (Dietz et al., 2003). As an example, the DOE Hanford site and its consensus CAB in Washington State have experienced "gridlock" (similarly, with global warming negotiations, see Oppenheimer et al., 2007). In contrast, MR promotes a competition for the best ideas (Holmes, 1919). Moreover, under MR and with significant numbers of neutrals among the deciders, conflict and ill-will are moderated to promote what we have named an "action consensus" (Lawless et al., 2008a). COI is enacted, we propose, by debate that creates a rotation of concepts in the minds of neutrals as an argument oscillates back and forth between partisan advocates, while the audience collectively works through the conflicting tradeoffs by listening to the proposals and rebuttals and by processing the dissonance in these exchanges. These sources of social-psychological dissonance are strikingly similar to the description of Nash equilibria (Luce & Raiffa, 1967).

How do humans naturally solve bistable problems?

In our new fundamental theory, an NE becomes a natural mechanism to solve the complex ill-defined problems posed by a society. Nash equilibria act when conflict is sufficient to drive a public's attention back and forth as a conflict is driven across time by opposed self-interests, generating a model of a social-psychological harmonic oscillator (SPHO). Given that an NE is composed of two stable but conflicting viewpoints, an SPHO is an oscillator that exists in the minds of an audience neutral to the conflict. An equilibrium exists whenever self-interests

are opposed and balanced, but to exist an oscillator requires an audience.[13] Once conflict and competition from an NE are moderated by an audience and indirectly under its control (Kirk, 2003; Simmel, 1964), an SPHO is formed in the audience that serves to improve complex learning (Dietz et al., 2003), political processes (Coleman, 2003),[14] and the environmental cleanup of nuclear wastes (Lawless et al., 2009a). The combination of an NE and an SPHO best models the disambiguation of solution paths for robots (Bongard et al., 2006). The combination best models decision-making in the courtroom (Freer & Purdue, 1996) and the price-setting of stocks by non-neutral brokers acting as "barkers" to persuade neutral investors to invest or sell, generating a random walk over time (Fama, 1964). The combination best models the checks and balances in the American three-branch government (Madison, in Hamilton et al., 1787-8) that promote the compromises that have helped the U.S. to avoid the paths taken by the failed governments of Europe during the 20th century (Schlesinger, 1949). In contrast, the absence of the combination indicates the consensus-driven minority rule of a monopoly or dictatorship that reduces social welfare (Hayek, 1944). Theoretically, the competition-driven oscillations for an SPHO represent the fluctuations that produce the information characteristic of an organization's stability response that cooperation can exploit (Lawless et al., 2008b). The physics of this information forms the central part of our model of the conservation of information (COI).

Simply put, competition generates information, cooperation consumes it; interference in this fundamental equation is either constructive (amplification) or destructive interference (dampening) for the information patterns produced by different social systems where, in general, constructive interference occurs in liberal republics with free markets at one end, and destructive interference increases in socialist and then more so in authoritarian political economies at the other extreme. For example (Lawless et al., 2010a), we found that an increase in freedom promotes the competitiveness of a nation, the development of its human capital and its overall reduction of corruption (cf. Putnam, 2000, p. 19). Conversely, fully developed social capital makes a nation more capable of preparing for and responding to national emergencies. Competition builds wealth and promotes integration. Overall, we found that the European Union (EU) was doing better for its citizens than communist China, but not as well as the completely integrated USA for its citizens.

We have postulated that NE generated information forms a Gaussian distribution interdependently coupled to its Fourier transform as a Fourier pair that ideally equals a constant, producing the Heisenberg uncertainty principle at the atomic level; signal detection theory at the macro level (Gershenfeld, 2000); and, we argue, COI at the organization or system level (Lawless et al., 2009a,b). For organizations, we have so far identified four mathematically

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[13] As examples of social-psychological oscillators from the common to esoteric, the first might be a husband and wife in therapy who both argue their positions equally well to a perfect therapist who is able to listen patiently to both sides; a prosecutor and a defense attorney who argue equally well to a perfect jury that listens patiently to both sides; or the market traders perfectly neutral to which firm in a market or politician in a contest wins, but not neutral to the information that leads the traders to making a winning bet (e.g., see www.intrade.com).

[14] A current example comes from editorials on the recent U.S. Supreme Court decision about the expenditure of money by corporations in political campaigns: First, from the *New York Times* (2010, 1/22), Editorial: 'The Court's blow to democracy', "Congress must act immediately to limit the damage of this radical decision, which strikes at the heart of democracy" (retrieved 1/22/10 from nytimes.com). Second, oppositely, from the *Wall Street Journal* (20110, 1/22), Review & Outlook, 'A free speech landmark', "the Supreme Court issued a landmark decision supporting free political speech …. a sensible step now would be for Congress to remove all campaign-finance limits subject only to immediate disclosure", p. A16.

equivalent sets of interrelated Fourier pairs that describe ι in organizations, systems, or systems of systems (Lawless, 2009a).

The first set of Fourier pairs deals with bistable tradeoffs in the time-frequency domain (Lawless et al., 2009a). That larger organizations are more stable (lower stock market volatility over time) than smaller organizations motivates organizations to grow in size organically or via mergers and acquisitions (M&A; Andrade et al., 2001). Unlike the dissolution that occurs from fragmentation (Parsons et al., 1953, p. 164), mergers are pursued in an attempt by a social element in a sector of society to control other elements in that segment by forcing them to cooperate with a new leader after it has grown in size (for examples not of mergers but of attempts at control after using mergers: Apple versus Microsoft in software; the attempt by the Catholic Church to exploit the fragmentation in the Anglican Church;[15] and weaponized Predators versus the Taliban in Afghanistan). In the tradeoff for size, however, the larger an organization becomes, the more its slowing response becomes a control issue (Gershenfeld, 2000; cf. our discussion of Turchin and White below).

The second set of Fourier pairs deals with bistable skills. Based on the conclusion by Conant and Ashby (1970) that negative feedback for an organization is less efficient than a perfect algorithm, then for well-known organizations, the more skilled they become, the "darker" should become their signals to observers *but also* to themselves (Landers & Pirozzolo, 1990; Lawless et al., 2007). This gap allows illusions to exist. For example, Bloom and his team (2007) found only a minimal association between assessments by managers of their firms and their firm's performance. But if our theory is true, it would mean that the more expert an organization becomes, the more inaccurate it is in articulating its expertise to others or to itself, accounting for the failure of expert business organizations when a market changes suddenly, necessarily rejecting Simon's (1992) theory of bounded rationality for experts.[16] As an example of how "darkness" affects an expert's awareness of its skills even to itself, consider Lehman Brothers. During a restructuring in 2007 (Tomre, 2008), Lehman significantly expanded its risk portfolio, eventually reaching a highly leveraged market position in 2008 at a time when the similarly leveraged Bear Sterns collapsed (Cohan, 2009; Bear collapsed during March 2008[17]). In April 2008, Lehman Brothers' Chief Financial Officer E. Callan stated in an interview with CNBC that rumors by short-sellers had hurt the firm: "Unfortunately, we're in a market where perception trumps reality" (news by Motley Fool, 2008). In June 2008, Lehman had reported a loss of $2.8 billion, its first ever (Bloomberg, 2008a); while its risk performance targets were criticized as unrealistic and insufficient, motivated by its loss and the collapse of Bear, Lehman raised $4 billion in new capital and began to deleverage. But after Lehman was successful when its public offering was oversubscribed, Callan concluded that Lehman had learned its lesson about the 1998 credit crunch (news by Bloomberg, 2008b). However, the value of Lehman resumed its fall, the stock held by its employees alone dropping by over $10 billion during the summer:

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[15] CNN (2009, 10/20), 450 years after King Henry VIII broke from Rome to create the Church of England, "Vatican welcomes Anglicans into Catholic Church", ending a "period of uncertainty" for Anglican groups that wanted more unity with the Catholic Church; retrieved 10/20/09 from www.cnn.com.

[16] Simon's (1992) "talking out loud" protocol assumes that experts have full access to their expertise, that this expertise can be articulated to scientist observers, and that the information so derived is valid; but see Tversky's finding that justifications of behaviors and actual behaviors were unrelated, since then determined to occur with experts, too; in Shafir & LeBoeuf (2002). For a criticism of Simon's rational perspective in economics, see Ahdieh, 2009.

[17] *The Wall Street Journal* (2008, 5/29), "Bear Stearns Neared Collapse Twice in Frenzied Last Days. Paulson Pushed Low-Ball Bid, Relented; a Testy Time for Dimon.*"*

"Everyone knows that [Lehman] has been on the ropes since May" (interview of T. Truman, former Fed official; see news by WSJ, 2008). Contradicting Truman, "In a matter of just days, Lehman's fate has spun out of the firm's control" (WSJ, 2008b). Lehman filed for bankruptcy on September 15, 2008. Tomre (2008) concluded that, abetted by a restructuring that quashed dissenting opinions, "Clearly the leaders … really did not understand what types and amounts of risk they were taking on …".[18]

The third set of Fourier pairs regards the social bistability between actors and observers. Analogous to the frequency and time domain (Lawless et al., 2007), when certainty in one factor grows, uncertainty in its paired Fourier-transformed factor grows, creating orthogonal, conjugate variables. The result is a duality (bistability) between actors and observers (Bohr, 1955) that makes reality hard to access (Parsons et al., 1953, p. 168), including for scientists (Kuhn, 1970). This duality may explain why self-reports often may not match behavior. Illustrating this point for self-reported and interview data, the meta-analysis by Baumeister and his colleagues (2005) found that self-esteem, arguably the most studied phenomena in psychology, was negligibly correlated to academic and work performance. Similarly, regarding his review of game theory in social-psychology, Kelley (1992; see also Jones, 1998) found no association between self-reported preferences and the choices made in the actual games played. Extending the finding on action-observation tradeoffs, Lawless and his team (2000) found a zero multiple regression between knowledge of air-combat maneuvering (ACM) as taught by USAF educators and the performance of USAF combat fighter pilots actually engaged in ACM. Together these findings indicate that observation and action can produce orthogonal sources of information.[19]

The fourth set of Fourier pairs deals with bistability in social fragmentation over space. That is, the more focused an organization's operational center-of-gravity, the more able it should be to control its business model geospatially (Lawless et al., 2009a). We have found that fragmentation inside of and among US military Medical Department Research Centers (a fictitious name) teaching physicians the experimental method has precluded the system from being able to determine whether its mission is being carried out effectively, restricting its ability to control or even to measure the productivity of its medical scientists (Lawless et al., 2007). Fragmentation can also occur among the best public companies, such as J.P. Morgan Chase's split between its USA and European operations (WSJ, 2009a). Taken to an extreme, fragmentation can split apart even successful firms, such as Chieftan Capital Management, an investment business with a "strong two decade track record … [that] generated annual gains averaging 18% …" (WSJ, 2009b)

A solution. Part Two (ι effects)

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[18] An NE challenges an illusion. After Kraft's initial hostile bid for Cadbury, Cadbury's CEO R. Carr dismissed Kraft as a "low-growth conglomerate" and its offer as "derisory" (2010, 1/19, retrieved from guardian.co.uk). The *Wall Street Journal* reported that just last week, Carr dismissed Kraft's management as unworthy and said "there was no strategic, operational, managerial or financial reasons" why Cadbury should merge with Kraft, but then on Monday, Carr and Cadbury's board reached consensus to accept Kraft's improved offer of $19.4 Billion, ending Cadbury's existence of 186 years as an icon of UK history ("Cadbury faces rhetoric shift after accepting Kraft bid", retrieved 1/19/10 from wsjonline.com).

[19] This conclusion that observation and action are incommensurable, while explaining reports on self-esteem and academic behavior, or differences between say what a coach and a sports announcer see, is unlike prospect theory, which critiques the rational expected utility model used in economics by finding that choices made by individuals vary as a function of risky prospects (Kahneman &Tversky, 1979).

By studying how an organization or a system responds to the fluctuations it daily experiences across these four pairs of interdependent cofactors, COI suggests that it is possible with physics to reverse engineer an organization, including a DSS like a highly skilled organization or a street gang, from the information that it produces in response to mundane but also planned perturbations (e.g., by diplomats or the military; in Hillson et al., 2009). However, to complete our theory, we need dynamic models and objective measures of an audience's decisions about its social welfare constructed from a methodologically social-psychological perspective, contradicting the assumptions in methodological individualism (e.g., Turchin, 2003, p. 11). We assume that an audience is in a state of ι (Hasson et al., 2004), placed there by the two oppositely directed drivers of an NE.[20] To model an audience's decisions, we use limit cycles (e.g., König et al., 2009; Turchin, 2003).

Replacing the "frictionless" oscillations produced by Lotka-Volterra-like equations to capture community effects with 3-D limit cycles, we plan a micro-level approach (May, 1973, p. 144). With parameter recipes to replace the macroscopic phenomenological constants in Lotka-Volterra-like equations, we plan to model the competition between the generation of information for resources and a community's utilization of these information resources. Information resources are to be modeled with integrals of the product between resources and utilization functions; information consumption is to be modeled with convolution integrals of the utilization functions. Initially, we can study the degree of optimal exploitation of the information resources available to a community with a best least-squares fit between the available information produced and the actual information consumed (what are being omitted in our plan at this time is the misinformation produced; weighting functions to renew or supplant information resources;[21] and wavelet models of resource utilization). In this model, a non-optimal but free population is under stress to move toward optimality; or an elite tribe of a non-optimal autocracy is under stress to further exploit and domesticate its captive population for the elite's self-interest.

We expect to see significant differences in how different communities solve problems. Liberal democratic republics accelerate social evolution by emphasizing the self-organization that leads to optimal fitness, adaptive renewal, an emphasis on innovation, and chaos among the tribes vying for control[22] (from Madison, in Hamilton et al., 1787-78; Lawless et al., 2007). In contrast, we expect to find that illiberal autocracies dampen the forces driving social evolution by emphasizing centrally controlled politics, command economies, non-optimal fitness with few effective tools for social renewal, but with a leading tribe(s) that lives very well by destroying or

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[20] Keller, B., Editor (2010, 4/25), Book Review: *Editor-in-Chief: The publisher. Henry Luce and his American Century*, by A. Brinkley, Knopf. In *The New York Times Book Review*: pp. 1, 10-11: "the wisdom of the crowds has replaced Luce … [with] a cacophony of today's media--in which rumor and invective often outpace truth-testing, in which shouting heads drown out sober reflection, in which it is possible for people to feel fully informed without ever encountering an opinion that contradicts their prejudices--plays some role in the polarizing of our politics, the dysfunction of our political system and the increased cynicism of the American electorate." (p. 11)

[21] Media outlets can also suffer financial setbacks, as in the case of AOL. In 2000, the merger of AOL and Time Warner was expected "to unleash immense possibilities for economic growth, human understanding and creative expression" (Arango, 2010). The merger was never effective, likely due to poor execution by management and the superiority of new broadband over dial-up technology; after a decade of un-bridged cultural differences and a "trail of despair", with the combination worth about 1/7th of its combined value at the time of merger, the firm split apart.

[22] In its attempt to become a global leader, Kraft's hostile takeover of Cadbury, an American Firm and a British firm, entails excessive debt that is likely to mean the loss of up to 27,000 jobs in the UK; "[But] in a free market, you simply cannot debate who owns companies … You've got to allow market forces to have their way … Now its going to claim one of the jewels in the British economy." (C. Parker, *City Wire* analyst, (2010) in *Al Jazeera* (retrieved 1/31/10 from english.aljazeera.net).

suppressing its opposition, especially the existence of NEs freely articulating self-interests (e.g., North Korea, Cuba, Iran, Zimbabwe, China, Russia …).[23,24] In our model, resource limits (carrying capacity) can be increased with technology (Mattick & Gagen, 2005; White, 2007).

Contrasting our model to the synthesis of a complex waveform with the superposition of Fourier components each with its own amplitude, the end result is an information resource spectrum approximating the different tribes by Fourier components and with the different audience sizes in the tribes approximated by the amplitudes of the Fourier coefficients. It may be possible, we speculate, with technology to analyze an NE existing between two tribes and those neutrals drawn interdependently into observing the competition.

In these equations, losers are either re-armed for the next confrontation (e.g., attorneys) or are replaced when insufficient support exists to further their self-interests.[25] As an alternative to losing, when an organization has been unsuccessful in a competition, or its technology is insufficient, or its staff is incompetent, it can merge with another organization to offset its vulnerabilities and to improve its competitiveness.[26] In general, the more cooperation and stability among the elites competing over the resources of a country, the more corruption is likely to be occurring; inversely, the less stability and more competition among elites, moderated by neutrals, the more social welfare should increase (Lawless et al., 2010a).

Despite the difficulty of controlling ι agents (Jamshidi, 2009), machines, humans or organizations, combining NE and limit cycles outlines our theory of ι not only to control them effectively, but to do so efficiently. Figure 3 gives us an example of what we expect to see.

Field results. A summary

The following summary provides a brief review of how COI was developed across the four sets of Fourier pairs. See the Summary Section for a discussion of known limitations.

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[23] "The success or failure of a command economy depended on the motivation and behavior pattern (power motive, vertical hierarchical pressures, etc.) of a large number of officials, while those of a market economy depended on the motivation and behavior pattern (profit motive, horizontal competitive pressures, etc.) of a large number of entrepreneurs. Institutions of bureaucracy and technocracy existed in both. But institutions facilitating the functioning of entrepreneurs might not exist in some of the command economies of long standing." (Sen, 1991, p. 549)

[24] As an example of reduced social welfare, 50 years after Cuba's "Triumph of the Revolution (in 1959)", it's $9,600 per capita GDP is less than one-fourth of the USA's, and "illicit emigration is a continuing problem … The US Coast Guard intercepted 2,656 individuals attempting to cross the Straits of Florida in fiscal year 2007. Cuba is principally a source country for women and children trafficked within the country for the purpose of commercial sexual exploitation and possibly for forced labor; the country is a destination for sex tourism including child sex tourism, which is a problem in many areas of the country; some Cuban nationals willingly migrate to the United States but are subsequently exploited for forced labor by their smugglers; Cuba is also a transit point for the smuggling of migrants from China, Sri Lanka, Bangladesh, Lebanon, and other nations to the United States and Canada." (CIA *World Factbook*, retrieved 5/20/10 from www.cia.gov).

[25] For example, Air-America, a politically liberal talk radio network, said that it would cease operations and file for Chapter 7 bankruptcy, its second bankruptcy since being launched in 2004 by comedian Al Franken, now a U.S. Senator (retrieved 1/26/10 from airamerica.com).

[26] To better compete against HP, IBM, Dell and Cisco, Oracle's $7.4 Billion merger with the hardware firm Sun has produced "shock waves through the technology industry" by returning the software giant to a business model where a single source provided turnkey solutions to industry; e.g., databases, software, servers, storage, network equipment, and the service competence to integrate these parts (*New York Times*, 1/27/10, from nytimes.com).

Figure 3. Instead of a limit cycle (i.e., portraying N_1 versus N_2; in May, 1973), the data are displayed with N over time, t. **Left**: The parameters are arbitrary and the result is "frictionless" oscillations. For an interpretation, at time 1 (and $t = 3.5$, 6 and 7), N_1 and N_2 are in direct competition. However, at time 2 (and $t = 3$, 4 and 5), the public has decided to act and social stability reigns. **Right**. Despite the arbitrary nature of the data on the left, in the campaign to become the Presidential nominee for the Democratic Party, it models the public bets made on the Iowa Electronic Market (IEM; www.biz.uiowa.edu/iem/index.cfm) in support of Clinton and Obama during a brief period of intense competition (during January 2008), followed by the IEM public's later decision to favor Obama (by February 2008).[27] (Postponed for future consideration is whether these data, already normalized, need to be further de-trended; see Turchin, 2005)
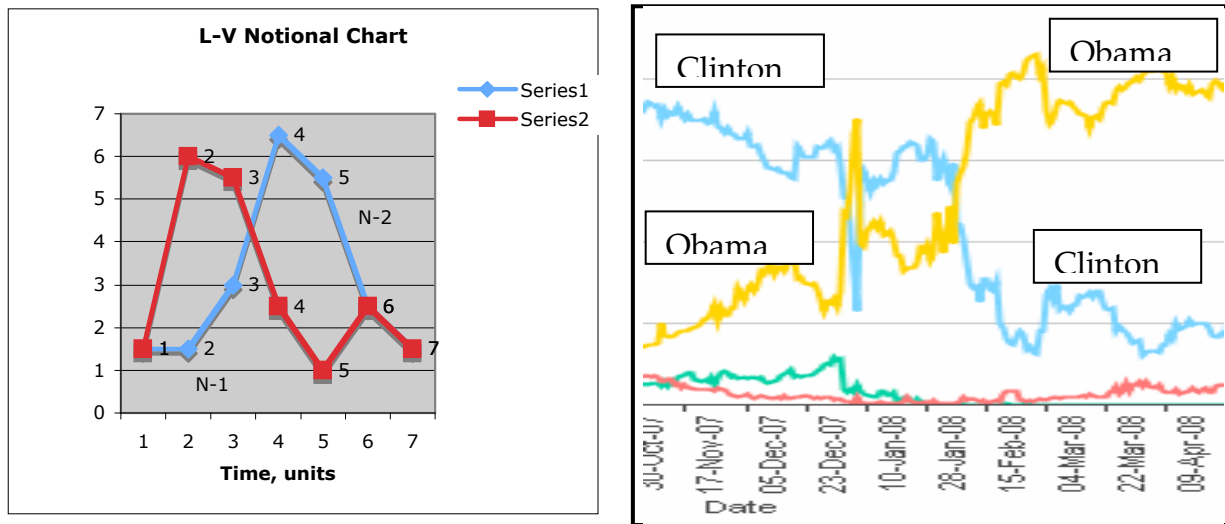
Observation-Action Tradeoffs

We began our study of COI with an experiment on cognitive dissonance (Axsom & Lawless, 1992) to find that scientific observers internal and external to a series of experiments misjudged the causes of the observed effects; in resolving this issue, by shifting our perspective to those of the subjects, we theorized and found that self-reports from subjects would not improve after an effortful treatment for a feared activity as had been predicted for over a decade because subjects were unwittingly being re-sensitized to the activity as they more closely

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[27] To model the parameters in 3-D with Monte Carlo estimates and as a means to control ι (Lawless et al., 2009b), we use the interaction rate equation: $\Gamma = N_{1,2} * N_\eta * f_{1,2: \eta} * v_{1,2: \eta} \, exp \, (-\Delta A/<A>) \approx \Delta x/\Delta t$, where η is for neutrals, f measures the frequency of belief or behavior matching, v measures information exchange rate, $exp \, (\bullet)$ measures the probability that an interaction will occur, and ΔA is the resources or skills required for an interaction and $<A>$ is the average resources or skills available to conduct the interaction. Applied to a gang (DSS), f reflects resonance from the agreement between a gang's capabilities and its market opportunities (Spulber, 2009, p. 231); v_{1-2} is the velocity of information exchanged between the gang, its competitors and the customers; and $exp(\bullet)$ is the probability of the interaction taking place based on the barriers or requirements for the interaction to occur ($-\Delta A$; e.g., higher barriers to market entry from the use of violence leads to fewer entrants into the market by competitive gangs) and the average wealth of the users available to consume an illicit drug from a target organization ($<A>$; the better the average level of wealth of the users in the pool of illegal drug consumers available to a dark gang, the greater the likelihood of its success; e.g., Hollywood starlets are more attractive targets than mid-America; see Reding, 2009).

approached it. Next, and as also mentioned before, we were tasked by USAF educators who wanted us to establish that the value of an education in the principles of air-combat maneuvering for air force pilots improved their outcomes in air-to-air combat (Lawless et al., 2000). But after the first experiment failed, the experiment was biased in favor of experienced combat pilots by using jargon that they were more likely to know compared to less-experienced combat pilots. Nonetheless, we found no association in multiple regressions between knowledge of air-combat maneuvering as measured by examination scores for those pilots who won or lost in controlled experiments conducted against an expert or machine pilot in virtual air-to-air combat. As we noted above, these two studies are in line with the disconnects found by Baumeister and his colleagues (2005) between self-esteem and academic or work performance; by Kelley (1992) between self-reported preferences and choices made during actual games; and by Bloom and his colleagues (2007) between the assessment by managers and their firm's performance.

Frequency-Time Tradeoffs

In the time-frequency domain, we first did a multiple regression across the stock market between market leaders and laggards for various factors to find significance only between market size and volatility, indicating that mergers occurred to reduce volatility across a market (Lawless et al., 2008b), but that a firm's inability to generate resources could reverse the process (spin-offs; a similar effect occurs after angiogenesis when a tumor's growth outstrips its blood supply; in Folkman, 1971; 2007). Then in a case study, we found the characteristics of COI in the tradeoffs between market size and volatility with the merger of Washington Mutual (WAMU) by J.P. Morgan Chase (Lawless et al., 2009a). With SDT as the lower bound for the signals that humans receive and react to from the environment, Fourier pairs should be equal to or greater than a constant (viz., ½; see the example in the Appendix); i.e., an increase in market size reduces volatility. However, in the latter study, Citi Group was also vying but failed to acquire WAMU. Had Citi succeeded, it would have questioned our finding in support of COI because its Fourier pair would have reflected two organizations grown more volatile by merging.

These findings largely agree with those on the dynamics of population and instability in cities from historical data by Turchin (2005) and White (2007). Turchin found limit cycles between population and his SPI index of social-political violence: as a population's growth rate increased faster than its growth of resources, instability and conflict were followed by population collapse. Focusing strictly on sections of his Figure 4 (from about 1450-1550 and 1740-1800), as population increased, instability initially decreased, in line with our findings on mergers. Estimating second derivatives in his graph (in Figure 4) at population troughs and peaks suggests that at the trough increasing population pressure reduced the available resources per capita to increase instability, with the inverse at population peaks. White's results support our speculation.

White applied Turchin's model to historical data from China (his Figure 8b, p. 29) to find population scale-up in city sizes initially also producing less volatility, that scale-up occurred from increased cohesion–acting something like a social glue or what we have described as a positive stable pattern of ι that we have found society to use when it reapplies a prior solution for one problem to a new problem. From his results, collapses occur as resources become insufficient, increasing social-political instability.

Taking a liberal interpretation of Turchin's and White's findings, we began our research on mergers by borrowing from Nicolis and Prigogine's (1989) model of amoeba and ant populations experiencing resource distress that aggregated and then relocated to a more opportune environment. This process suggested to us that a market in resource distress would

consolidate, seed new businesses when stresses moderated, or spin off when strategies did not work or conflicted with the main business. However, ι is not always a positive force for problem solving; sometimes it creates problems. In our research into the State mergers that formed the European Union (Lawless et al., 2010a), we also reported on the negative aspects of ι, i.e., in the later stages of a business cycle as the problem on how to exploit what appear to outsiders as unlimited resources also appears to them to be risk-free (e.g., AAA-rated insurance "swaps" that may have led to the financial collapse of 2007-8;[28] the real estate bubble in China today; and the dot-com collapse in 2000), a "gold-rush" mindset can occur followed by collapse and panic from misjudgments about the size of a targeted resource. The result, as in Greece today, is political miscalculation, corruption, and riots. The prior Greek administration had used derivative "swaps" sold to it by Goldman Sachs to cover-up the status of its budget crises from Eurostat, the EU's official statistics organization.[29]

Spatial-Spatial Frequency Tradeoffs

Our finding of the value of organizational size in markets led us to discover geospatial COI in a finding by Willis (2007) about the State of Israel's efforts to stop suicide bombings around Jerusalem by studying their pattern, leading the State to conclude that it "is always a tradeoff between model accuracy and area reduction than we can describe for any given model". In our own work, we looked at county-wide police data for the States of Georgia and South Carolina over time. We discovered an association between two counties separated by a river as the two-State boundary that we interpreted as an interstate information channel formed among burglars, assisted by the inability of local police in one State to overcome separate jurisdictional barriers that formed an interstate barrier to police, but not to burglars (Lawless et al., 2009a).

Decision-making Execution Tradeoffs

Department of Energy (DOE) Citizen Advisory Boards (CABs). In our search for a social-psychological organization uncertainty principle, we found in the field a tradeoff between consensus-seeking and majority rule decision-making as citizen advisory groups (CABs) were tasked by DOE to help it decide on complex issues in its cleanup from DOE's nuclear waste mismanagement before 1983 (Lawless, 1985). Two forms of consensus were found to exist: Worldview consensus and action consensus. The former is more likely to be derived from cooperative processes and the latter from competitive processes. In the first field study (Lawless et al., 2005), we looked at the decisions of all nine of the DOE's CABs as they responded to DOE's request to review its plans to speed the shipments of transuranic wastes to its repository in New Mexico as part of its mission to accelerate the cleanup of DOE facilities across the U.S. These nine DOE Citizen Advisory Boards were located at DOE sites where transuranic wastes[30] were being removed and shipped to the DOE repository (at WIPP in New Mexico). As predicted, four of five of DOE's majority-rule boards endorsed these recommendations, while three of four of its consensus-ruled boards rejected them. In addition, the time spent in deciding for majority-

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[28] *The Wall Street Journal* (2009, 11/ 23), REVIEW & OUTLOOK "AIG and Systemic Risk, Geithner says credit-default swaps weren't the problem, after all." And, *The New York Times*, Questions for Reform (2009, 3/28), Editorial: "the credit default swaps at the heart of the debacle at American International Group." Retrieved 5/21/10 from wsj.com and nyt.com.

[29] *The Independent Business* (2010, 2/15) "Goldman Sachs: the Greek connection. Investment giant's role in eurozone debt crisis falls under spotlight", retrieved 5/20/10 from www.independent.co.uk/news/business.

[30] Wastes contaminated with radionuclides greater than uranium, usually plutonium. The WIPP repository site is in NM; www.wipp.energy.gov.

ruled boards was significantly less than the time taken by the consensus-ruled boards. These results were our first findings based on physics in what has since become COI.

In a follow-on case study in the field for DOE consensus decisions by the Hanford CAB in Washington State and majority rule decisions at the Savannah River Site (SRS) CAB in South Carolina, citizen boards located at the two DOE sites with the largest cleanup budgets, we found that consensus rule decisions produced "gridlock" when the single worldview of the Board conflicted with DOE's vision, increasing social volatility (Lawless et al., 2008a). We found that gridlock is more likely under enforced cooperative decision making because of the inability to accept challenges to illusions (constructive interference for illusions, destructive interference for action; e.g., at Hanford, scientific facts are not permitted to settle a debate by its DOE CAB, in Bradbury et al., 2003, p. 134-6). In contrast, we have found that the cognitive disambiguation from competition improves social welfare with practical decisions that feedback amplifies or accelerates action (i.e., constructive interference for action, destructive interference for illusions).

In a third DOE study (Lawless et al., 2010b), we reviewed high-level waste tank closures at SRS as well as nuclear waste cleanups in Japan and the United Kingdom. Regarding SRS, tank closures were suspended due to a successful lawsuit against DOE, but restarted after the passage of a 2005 law by Congress.[31] The new law, however, gave the Nuclear Regulatory Commission the authority to review DOE's tank closure decisions and to report back to Congress should it dislike what was happening at SRS (or Hanford and Idaho), but gave no direct authority to NRC to stop the process. With neither federal agency having full responsibility, the process began to simulate endless or "frictionless" oscillations (May, 1973). We concluded that this simulated what often happens under those autocracies governed by consensus and why decision-making can appear to be interminable (also known as minority rule, it underscores why some autocracies rule by consensus, as in China; cf. White, 1998, p. 472[32]). The ability to exploit consensus rule by a minority is illustrated best by the reason that the European Union embarked on a new treaty: "The requirement for consensus in the European Council often holds policy-making hostage to national interests in areas which Council could and should decide by a qualified majority." (WP, 2001, p. 29)

US Military Medical Department Research Centers (MDRC; a fictitious name). The military (Wood, 2007) funded a web-based system at one of seven MDRCs for the submission by investigators of human and animal research protocols to an Institutional Review Board (IRB) (initiated following our study; see Lawless et al., 2007). The other six MDRCs were included in the evaluation of the eIRB[33] in order for them to be prepared to establish their own eIRB at their sites. The first eIRB included routing of submissions to IRB members; receipt of comments from IRB reviewers; transmission of modification requests to investigators; development of IRB meeting minutes; tracking of protocol status; automatic notification of investigators of continuing review deadlines; and incipient performance metrics. The technology also provided a platform for collaboration across the organization between Principal Investigators and team members proposing protocols to conduct research.

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[31] Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (NDAA) www.nrc.gov/waste/incidental-waste/wir-ndaa.html.

[32] From White, 1998, p. 472: "… hierarchy is relevant only if some enfranchised agent exercises a veto. If that member cannot be convinced by local colleagues to go along with a consensus, then the decision becomes subject to uncertainty from above. Various authors have called this procedure "management by exception", "delegation by consensus", or "the veto rule".

[33] eIRB is an electronic or web-based IRB.

The vision for this eIRB project was to achieve an end state to:

> allow all research proposals, supporting documents, and scholarly products to be submitted and managed by a secured web based electronic system that allows for the real time calculation of research metrics of workload, productivity and quality. Additionally, this kind of system will allow for better management of the necessary documentation for human research protection and ensure a better environment of operational security oversight for potentially actionable medical information. This will be developed with joint execution in mind and have input from our DoD counterparts. A system that effectively captures all aspects of the research process, from protocol submission and processing to publication of scholarly products or novel therapeutics will generate the highest quality data for productivity analysis and metric development. We believe this can best be achieved by development of an electronic protocol submission and management system with the capacity to generate real time metrics of productivity and quality. (Wood, 2007, pp. 4-5)

The eIRB, now in operation (Wood et al., 2010), has begun to provide MDRC with business intelligence (BI) for metrics with similar plans in the future for electronic medical records and stronger research relationships with extramural funding organizations (e.g., Pfizer). However, only until MDRC has database systems across all aspects of biomedical research and medical care delivery and the BI tools to link these systems together will it be able to generate real time data for next generation semantic-web machines to more fully study, define and improve MDRC processes. Once in place, MDRC can make decisions in real-time rather than with data months old thereby identifying the gap in its mission and vision to push the system towards innovation. With COI, we predict that the natural tension from the gap between its mission and vision, and between the collective demands of MDRC and the competitive demands of scientists, once exposed and nourished, will propel the evolution of the MDRC system along the pathway of transformation and organizational change.

Web-based technology and knowledge management were already demonstrated by the virtual collaboration used by the MDRC working group planning for the eIRB. Leaders geospatially separated were able to meet approximately thirty times over almost two years and work together to solve common problems in a manner that would have been cost-prohibitive in the past. MDRC leaders from Hawaii, Washington State, Texas, Washington DC, and Georgia worked as a networked virtual organization for approximately 60 hours using web-based collaboration technology with visual and audio communication that led ultimately to the eIRB system now operating.

Assessment of the MDRC Case Study. We began this case study (Lawless et al., 2007) by contrasting the organizational performance of MDRC against the specifics listed in its assigned mission: improving patient care in the field; reducing the costs of care; and increasing the impact of research products. We found no clear link between research products and the mission; no measure of publication impacts; and no direct way to measure organizational productivity against its peers (implying minimal states of interdependence). In general, the organizations in the MDRC network appeared to be fragmented, with each pursuing its own path to mission success. No overarching measure of system performance existed for the MDRCs that the separate organizations could follow to guide their collective behavior. As a consequence, long-term work practices and cultural differences predominated. Subsequently, the move to adopt a web-based

eIRB set the stage to turn around the lack of organizational and system-wide knowledge, and to improve on the practices of science across the system. Since then the eIRB's protocol system has become operational at two of seven military field sites (Wood et al., 2010). One of the two, the largest in the system, has reduced its time to clear papers for publication from an average of 30 days to 4 days, motivating the other MDRCs to join the eIRB. Without waiting for further evidence, DoD adopted the eIRB system DoD-wide, not only for the cost and time-savings possible, but because of the metrics it is enabling. To illustrate, early eIRB sessions led to the informal discovery of a surprising lack of effort by many members of the IRB, a lack of coordination by its coordinators, and a lateness by the IRB panel members in reviewing their assigned protocols prior to formal IRB meetings. This discovery has already led management to debate whether to disclose this information to the IRB panel members and to devise new policies for organizational performance, one of many dramatic organizational changes that we expect the system of researchers to confront, but, if successfully negotiated, not just for DoD's medical researchers.

Laboratory Results

Preliminary data from a laboratory experiment nearing completion with college students making recommendations to improve their college experiences appears to have replicated parts of our DOE CAB study (i.e., Lawless et al., 2005). In the laboratory study, we asked college students in randomly assembled *3-person* groups (N = 53 groups) at a historically black private college and a nearby public university to propose open-ended recommendations to improve school operations affecting students (e.g., campus security, parking, cafeteria food, library, student government, etc.). Groups were randomly assigned to make their recommendations by operating under either consensus (CR) or majority rules (MR). Time for both types of groups was held constant. In this ongoing study we tentatively found that CR produces significantly more discussions (oscillations), while MR generates significantly more total recommendations.

Increased dialog among CR group members might contribute to better recommendations through greater input from members; or, as we predicted, poorer proposals because of less time being devoted to crafting those recommendations. We subsequently asked student leaders and student services university personnel to independently rate each of the groups' decisions along two dimensions: whether the recommendation would be widely supported by the institution (popularity domain) and whether the recommendation would result in positive change (quality domain). As we anticipated, judges determined that recommendations generated under CR would be more popular on campus. But in contrast with our prediction, judges also provided significantly higher quality (constructive change) ratings to recommendations generated under CR.

We are considering several possible explanations for the latter findings, focusing at present upon the possibility that small *3-person* groups composed of strangers may discourage development of the dynamics we posit should contribute to superior decisions from operating under MR. We plan to directly test this by manipulating group size in a future study. Moreover, we will be taking psychophysiological measures during the decision-making process. We expect that MR individuals will be more emotionally and cognitively involved as indicated by higher autonomic arousal and/or greater autonomic variability. As MR group size increases, we hypothesize that the influence of a single strong leader will diminish, other group members will become more "energized", an NE will emerge along with neutrals, and the quality of decisions

will improve. In contrast, we anticipate that increasing CR group size will diffuse responsibility and involvement, thereby reducing decision quality. Supporting our hypothesis with research on changing the size of juries, Kerr and MacCoun (1985) found that "As group size increased, the observed probability of a hung jury increased significantly," indicating the existence of an NE; they also found that *3-person* groups, which we had used exclusively until now, processed decisions qualitatively different from larger groups, such as the *25-31 member* Citizen Advisory Board decisions we were attempting to model.

Future research

1. How stable, widespread, and predictable is the two-part solution to social-psychological ι? How resilient are NEs? Is it possible to establish a rational solution to an ill-posed problem without an NE?
2. Is the proposed mathematics of ι sufficient to control ABMs (see Lawless et al., 2009a)?
3. Can NE and Fourier pairs create a new theory of measurement to replace, revise, or reinterpret self-reports for mixed teams of humans, machines and artificial agents?
4. Can a theory of cognition and emotion be proposed based on reactance, NEs, and Fourier pairs? We recognize that the diffusion of emotional energy may be inexplicable due to the competition among organizational processes; e.g., tension between the individual and collective tends to "overflow its usual channels" (Parsons et al., 1953, p. 202). Wheeler (2009) suggested, however, that a solution at the atomic level may be Liouville's theorem which indicates that the density of phase space for a system is constant over time; applying Wheeler's insight to a social network, uncertainty converts our 3-D problem into a 6-D problem.
5. As an alternative to Wheeler's atomic structural dynamics to address social networks, weak structures (e.g., lattice theory) may be better able to capture complex situations, providing a wide field of application for the conceptual model of COI that we have proposed. More precisely: Bistablity finds cognitive groundings inside the disjunction (the logical "or"), a difficult problem for applied AI science. This disjunction has natural relations with "negation" as far as both are pure abstractions (there is no "natural" negation nor "disjunction"). From this logical point it may be possible to build a balanced set of ι states modeled by Galois lattices.
6. Can reliable non-self-report measures of ι be produced? Kenny and his colleagues (1998) devised a statistical method to partial away ι as self-reported bias (i.e., to remove or to control its effect). In contrast to Kenny, and unlike the control of airspaces by dampening the effects of ι (Skormin, 2009), instead, can ι be manufactured and maintained to test its effects on decision-making, organizational performance and control independently of self-reports?

Discussion and Conclusion

Traditional social science has reached a dead end. In response, we have proposed a new theory of social physics centered around field and laboratory evidence based on a fundamental view of social psychology that is bistable but also computational. Nash equilibria produce Social-Psychological Harmonic Oscillators (SPHO) to process information among observers sufficiently free to self-organize. In contrast, autocracies survive by destroying, suppressing or

controlling Nash equilibria;[34,35] interestingly, contemporary social scientists often give what amounts to the same advice in our society to end the existence of Nash equilibria (e.g., Axelrod, 1984; Insko et al, 2005; Rand et al., 2009).

Self-reports cannot recover reality. Even for the oppositely directed experts who drive a Nash equilibrium, their self-interests make them too partisan to fully articulate reality; in contrast, neutrals witness both views of interdependent reality sufficiently to capture its essence, but as novices, they are unable to retain what they have captured (witness that the post-hoc interviews of jury members, as entertaining as they may be, are mostly irrelevant; this point was made succinctly by Polanyi [1974] regarding judges when he concluded that while judicial decisions may become precedents, the justifications for their decisions are mostly ignored by society). What is left is the tool that ordinary humans use daily with intuition to study their opponents by either attacking them (e.g., price wars; courtroom challenges; scientific debates; peer review) or watching them be attacked. As scientists, we need a theory to formalize and improve this process; to extend it to systems and teams of humans, machines, and artificial agents; and to formally study dark social systems (DSS), not only of terrorists, but also of well-known organizations. That is why we have developed social-psychological physics, beginning with the conservation of information.

Limitations. Lastly, while successful, our endeavor has raised more questions than it has answered. Every theory depends on data. But a severe limitation exists in intelligence data for social networks when the data is static. After a real-world event (Lawless, 2009b), comparing what could have been predicted from a database with newly uncovered information tests the validity of the database; e.g., consider what was known about Noordin Mohammed Top prior to recent bombings of two hotels in Indonesia in 17 July 2009 with what has been discovered since by police and military canvases of his involvement. With the sole exception of Noordin, *no other names* in the database matched news accounts, including that of his wife, chief associates, financial backers, etc. The many new faces and elements involved in Noordin's attacks in Jakarta, many with no prior history of violence (ICG, 2009), nullified the predictions based on archived data. Similarly, USAID (2005, p. 10) graphs for 2002 predicted severe factionalism in Colombia, "poor political legitimacy", and collapse, versus good news for Zimbabwe; in

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[34] From Friedman (2010), "I would argue that Command China, in its efforts to suppress, curtail and channel knowledge flows into politically acceptable domains that will indefinitely sustain the control of the Communist Party--i.e., censoring Google--is increasingly at odds with Network China, which is thriving by participating in global knowledge flows. That is what the war over Google is all about: It is a proxy and a symbol for whether the Chinese will be able to freely search and connect wherever their imaginations and creative impulses take them, which is critical for the future of Network China."

[35] From *New York Times* (2010, January 7), "China admits new tainted milk case is older", despite a new Chinese food safety law requiring alerts to consumers in response to public outrage after 300,000 sickened including six dead babies in 2008, undisclosed for a year until now were the arrests of executives in April 2009, "If Shanghai Panda's crime is confirmed, the quality supervision bureaus, both local and national, violated the [new] law … [yet] The government hid the truth from the public and behaved extremely irresponsibly to public safety." Wang Xixin, professor of constitutional law at Peking University (retrieved 1/25/10 from nytimes.com); also from *New York Times* (2010, January 25), "China Province discovered more melamine-tainted milk." "The government said it wouldn't tolerate cover-ups … [However] milk products made by three companies … were … removed from store shelves in the southwestern province of Guizhou … in early 2009 … [regarding] why the announcement was delayed so long … A Guizhou government spokeswoman declined to comment. A spokesman for the province health bureau didn't return a phone call and a person answering his phone denied knowledge of a problem. The companies couldn't be reached." (retrieved 1/25/10 from nytimes.com).

retrospect, however, Zimbabwe was beginning its collapse as a state and Colombia its rise to recovery.[36]

There are several limitations to our research. First, methodological individualism implies no interference from interdependence, but Gaussian distributions also imply a lack of interdependence. How does this affect Fourier pairs of Gaussian distributions, which we assumed reflected interdependent phenomena? Second, interdependence between Gaussian distributions of information is the basis of COI, but does ι transform these Gaussians into power-law distributions (e.g., White, 2007, pp. 20-21)? The rate equation inherent in Figure 3 (cf. footnote 27 on p. 14) provides an example of a power law distribution that fits our model of the tradeoffs characteristic of COI (see Figure 4 below). Third, we have assumed that interdependence and bistability are equivalent, but they are not–more than two sides exist for some stories, more than two cultural interpretations, more than two religious explanations, and so forth. Finally, despite our assertion at the beginning of this paper that the mathematics are straightforward, the question that remains at the end is: could the interdependence of social systems, considered from the perspective of bistability, be one day formally represented and proved?

Figure 4. With notional data, considering only the exponential aspect, *exp (-ΔA/<A>)*, of the rate equation for interactions, Γ, in Footnote 27, where ΔA is the uncertainty in the resources required for an interaction to proceed, *<A>* the average resources available in an organization or system, if the resources required for an interaction increase, Γ decreases; in contrast, if the resources and time available for an interaction increase, Γ increases.
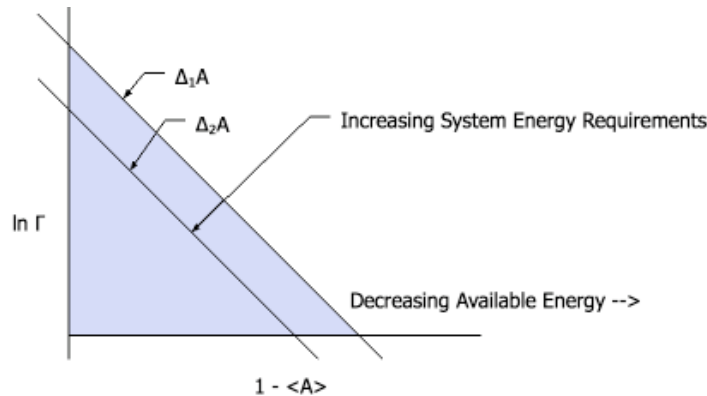
Despite these limitations, we have found answers. Because attention is shifted to focus either on action or observation skills, losing information in the process, our theory of ι, NE, and SPHOs overturns Simon's bounded rationality. But information can also be gained in a way that promotes problem solutions, social evolution and entertainment, too. For instance, we do not fully understand how kinematic mixtures of 2-D information displayed on a movie screen can engage an audience for extended periods in what Sarris (1968) named *mise en scene*. And yet, to illustrate what we have found with our theory, two operators *A* and ***B*** are community interaction matrices that locate social objects ι in social space (shared conceptual space) and are in turn anchored (embedded) geospatially. ι states are non-separable and non-classical; disturbances from measurement collapse ι states into classical information states. Two agents, Einstein and

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[36] CIA World Factbook (2009, 9/2/09); at www.cia.gov.

Bohr, meet in Copenhagen to compete over their interpretation of conjugate variables in quantum mechanics (Pais, 1992), each holding a skill set needed by science that permits these two close friends to debate fiercely while both are aware of their different functions and social standing in science, generating bistable social perspectives that reflect separate social constituencies in two incommensurable world views that profoundly disturbed science and society even in the theater today (e.g., Frayn, 1998). Classical interpretations of quantum–and socially interdependent–realities inescapably produce endless debate that can enlighten, entertain, or degenerate into violence if not moderated by an audience, stopped forcibly, or ended by the physical proof that drives social evolution. Based on physics, this finding alone significantly advances our understanding of human systems and underscores how in a democracy an audience or the larger society cooperates with the protagonists of an NE to control and exploit their competition to solve problems or to entertain itself, but also illustrating how human interpretations of reality drive debate while hiding its tracks, leaving as a residue, only one side of a story.

   Bohr sought eloquent concepts, Einstein mathematical beauty. Putting aside both eloquence and beauty for the rough and tumble in the search for truth, our task remains to determine how the residue from the debate over an ill-defined problem is formed, how emotions center the residue, and how to control the residue formation in the interplay between self and collective processes for computational organizations and systems composed of humans, robots, and machines. Nonetheless, based on our fundamental theory that includes the oscillations from Nash equilibrium, the rotations from social-psychological interdependence, and the audience feedback from processing information (or its lack), we speculate that a new technology will arise to reverse engineer dark social systems.

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Appendix: Glossary of Acronyms and Terms with Examples

ABM (agent-based models; see <u>Tutorial on agent-based modeling and simulation part 2: how to model with agents</u>. Association for Computing Machinery).

ACM (air-combat maneuvering; e.g., www.352ndfightergroup.com/virtual/main.html)

AOL (America Online; cf. www.aol.com).

Bistability: as opposed to a nearly universal agreement of a stable interpretation of a 2-D image or dataset (e.g., the image of the tank in Figure 1A), any two dimensional image or data set that permits two mutually exclusive or incommensurable interpretations (see Figure 1B).

CAB (Citizens Advisory Board or Site-Specific Advisory Board; created by the Department of Energy's Office of Environmental Management for advice on nuclear waste management cleanup, cf. ww.em.doe.gov/stakepages/ssabguidance.aspx).

COI (Conservation of Information; the Fourier pair of a Gaussian distribution forms a constant; e.g., the Heisenberg Uncertainty Principle at the quantum level).

CR (Consensus Rules for decision making; many resources exist: for an online guide, see web.mit.edu/publicdisputes/practice/cbh_ch1.html; for consensus with DOE CABs, see www.energy.gov/safetyhealth/nuclearsafety.htm).

DoD (Department of Defense; cf. www.defense.gov).

DOE (Department of Energy; DOE's Environmental Management oversees nuclear waste management; cf. www.em.doe.gov/Pages/EMHome.aspx).

DSS (dark social systems; systems are "dark" from either highly skilled practices, as when a perfect organization reduces its generation of information; or by expending effort to "darken" an information signature, as with illicit drug gangs or terrorists).

eIRB (electronic Institutional Review Board for electronic approval to perform research on human and animal subjects; cf. irb.jhmi.edu/eIRB).

EU European Union; see europa.eu; for statistics in the EU, see Eurostat at epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home

Fourier transforms and Fourier pairs: The standard deviation for a notional function is calculated, transformed, and the standard deviation for the transform calculated; multiplying the two standard deviations produces a Fourier pair.

Figure 5. In the left hand side, notional Gaussian functions described in the Table below are graphed in color (Red: inner; Green: middle; Black, outer). In the right hand side, Fourier transformations convert the Gaussians (Black, inner; Green, middle; Red, outer).
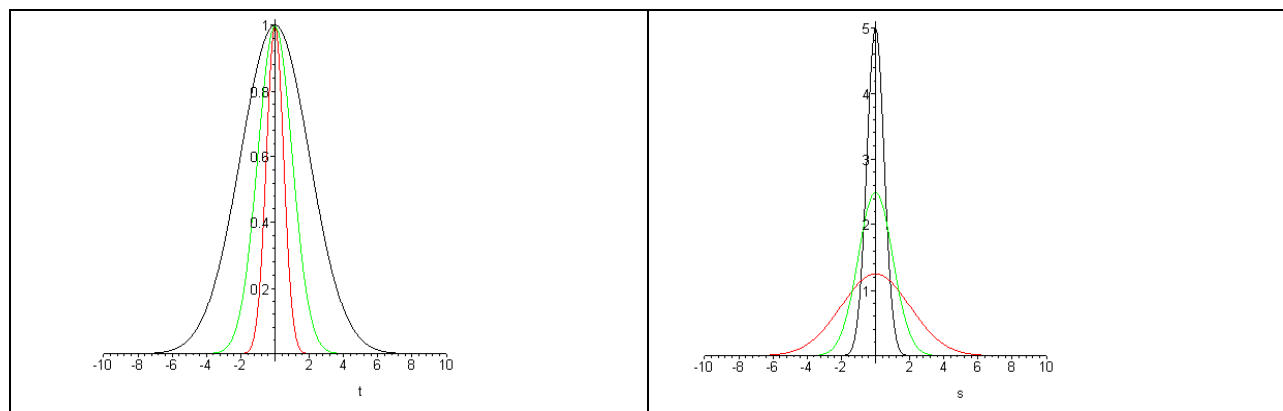
Function	σ_f	Fourier Transform	σ_F	$\sigma_f \sigma_F$
$f(t) = e^{-2t^2}$	0.558	$F(s) = \dfrac{\sqrt{2\pi}}{2} e^{-\frac{1}{8}s^2}$	5.013	2.806
$f(t) = e^{-\frac{1}{2}t^2}$	1.583	$F(s) = \sqrt{2\pi} e^{-\frac{1}{2}s^2}$	2.507	3.969
$f(t) = e^{\frac{-t^2}{8}}$	4.478	$F(s) = 2\sqrt{2\pi} e^{-2s^2}$	1.253	5.612

ι (*iota* for interdependence; cf. wordnetweb.princeton.edu/perl/webwn?s=interdependence).

Lotka-Volterra-like Equations: These coupled non-linear equations were first used to describe predator-prey populations for a fixed set of constants *A* (prey birth rate), *B* (prey death rate by predators), *C* (predator death rate) and *D* (predator birth rate). Given *dR/dt* for the rate of change in the population of prey, say rabbits, *R*, and dF/dt for the rate of change in the population of predators, say foxes, F, then

$$dR/dt = A\,r - B\,r\,f$$

$$dF/dt = -\,C\,f + D\,r\,f$$

Setting the rates to zero to find the critical points gives *r = C/D* and *f = A/B* (i.e., {*x, y*} = {*r, f*}={*C/D, A/B*}). With this equation, we can plot *R* and *F* over time, its limit cycle (*dR/dt* versus *dF/dt*) or estimate those values in Figure 3.

M&A (mergers and acquisitions; e.g., www.cio.com/topic/3194/Mergers_Acquisitions).

MDRC (military Medical Department Research Centers, a fictitious name; their mission is to improve patient care; develop new medical knowledge; and promote education).

MR (Majority Rules; cf. www.rulesonline.com).

N (The frequency or number in a distribution).

NE (Nash equilibria; in game theory, a stable state where participants cannot improve their self-interests based on the choices made by others; e.g., www.gametheory.net).

NRC (Nuclear Regulatory Commission; at www.nrc.gov).

SDT (signal detection theory; cf. MIT classes: Human Factors Engineering, Fall, 2002, Signal Detection Theory and Vigilance).

SNA (social network analysis; e.g., Center for Computational Analysis of Social and Organizational Systems, or CASOS; cf. at www.casos.cs.cmu.edu).

SPHO (Social-Psychological Harmonic Oscillator; for an example of a simple harmonic oscillator, see hypertextbook.com/chaos/41.shtml).

SRS (the DOE Savannah River Site, Aiken, SC; cf. www.srs.gov/general/srs-home.html).

TRU (Transuranic nuclear wastes; cf. www.wipp.energy.gov).

USAF (United States Air Force; cf. www.af.mil/index.asp).

WAMU (Washington Mutual; acquired by J.P. Morgan Chase; cf. www.jpmorganchase.com).

WP (White paper on European governance; cf. ec.europa.eu/governance/white_paper/en.pdf).

WSJ (The Wall Street Journal; cf. online.wsj.com/home-page).