Unravelling the Complexity of Teams via a Thermodynamics Perspective

W.F. Lawless, Math & Psychology, Paine College, 1235 15th Street, Augusta, GA 30901; w.lawless@me.com

Ira S. Moskowitz & Ranjeev Mittu, Information Management & Decision Architectures Branch, Code 5580, Naval Research Laboratory, Washington, DC 20375; ira.moskowitz@nrl.navy.mil, ranjeev.mittu@nrl.navy.mil

Abstract:

In its simplest terms, teams and firms operate thermodynamically far from equilibrium, requiring sufficient free energy to offset the entropy produced as a byproduct of their activities (Nicolis & Prigogine, 1989). If social reality was rational, a model of team thermodynamics would have been discovered and validated decades ago. However, teams are interdependent systems (Conant, 1976), and interdependence creates observational uncertainty and incompleteness which manifests as potentially irrational behaviors.

Multitasking (MT) is an unsolved but key theoretical problem for organizing teams, organizations and systems, including computational teams of multi-autonomous agents. But because MT involves interdependence between the members of a team, until now it has been too difficult to conceptualize and adequately address. Exceptional and talented humans intuit most of the organizational decisions that need to be made to self-organize a business or organization, except possibly when faced with the challenge of decision making in the context of big data. But transferring that knowledge to another generation, to business students, or to partners has proved difficult. Even in the case of big data where interdependence can increase uncertainty and incompleteness, unless scientists can construct valid mathematical models of teams and firms that produce predictable results or constrain them, computational teams of multi-agents will always be ineffective, inefficient, conceptually incomplete, or all three.

While individuals multitask (MT) poorly (Wickens, 1992), multitasking is the function of groups as they pool skills to accomplish goals they are unable to accomplish as independent individuals (e.g., Ambrose, 2001). But MT creates a state of interdependence that has been conceptually intractable (Ahdieh, 2009). Worse, for rational models of teams, using information flow theory, Conant (1976) concluded that interdependence is a constraint on organizational performance. Kenny et al. (1998) calculated that statistically including the effects of interdependence causes overly confident experimental results; and unable to resolve the persistent gap he had found between preferences before, and the choices made when, games were played. Speculating that the gap could not be closed, Kelly (1992) abandoned game theory in experimental social psychology. Never has anyone else closed this gap, nor do we in this paper; instead, we account for the gap to exploit it. We note that in (Moskowitz et. al., 2014) Conant's ideas on interdependence are modified and extended in an information theoretic approach to come up with the idea of "Team Efficiency". This is a normalization of certain key concepts from Shannon. Furthermore, Moskowitz et al. (2014) develop a Second Law of Team Dynamics. Additionally, Moskowitz et al. model team knowledge flow via epidemiological models from Network Science.

Many of the claims advanced by game theory have not been validated (e.g., those for cooperation and competition in the Prisoners Dilemma Game; in Schweitzer et al., 2009), likely because its models cannot be designed to match reality, conceded by two of its strongest supporters (e.g., Rand & Nowak, 2013). Despite this disconnect with reality, Rand and Nowak (p. 413) conclude that cooperation produces the superior social good, a conclusion widely accepted by social scientists, including by Bell et al. (2012) in their recent review of human teamwork, but wherein they had little to say about interdependence. Within the computational multi-robot community, no one appears to be close to addressing the problems caused by interdependence on self-reported questionnaires (e.g., Schaefer, 2014); e.g., in a 30-year meta-analysis, Baumeister et al. (2005) found only a negligible correlation between self-reported self-esteem in college or at work. We claim that observations and self-reports are insufficient as guides to the principles of organization. How does a team form mathematically, how does it recognize structural perfection, and what does it do after formation?

Briefly, from Ambrose (2001), teams form to solve the problems that an arbitrary collection of individuals performing the same actions are ineffective at solving, including through multi-tasking in competitive or hostile environments (Lawless et al., 2013). Firms form to produce a profit (Coase, 1937); generalizing, teams or firms stabilize when they produce more benefits than costs (Coase, 1960).

In contrast to the conclusions drawn from rational models, especially game theory, the results from games have, by and large, overvalued, misunderstood and misapplied the notion of cooperation, contradicting Adam Smith's (1776) conclusions about the value of competition. Axelrod (1982, p. 7-8), for example, concluded that competition reduced the social good. This poor outcome can be avoided, Axelrod argued, only when sufficient punishment exists to discourage competition. Taking Axelrod's advice to its logical extreme, we should not be

surprised to see brutality used as a technique to govern non-free societies by making their subjects more cooperative (e.g., Naji, 2004; Naji uses the term savagery).

We disagree with Axelrod and game theorists. Interdependence creates alternate perspectives; free speech allows adherents to compete for their beliefs (e.g., Justice Holmes, 1919) or policy (Justice Ginsburg, 2011). By comparing night-time satellite photos to see the social well-being in competitive South Korea compared to its lack (North Korea very dark at night) under the enforced cooperation demanded by the leaders of North Korea (Lawless, 2014, slide 10), our theory has led us to conclude that interdependence is a valuable resource that societies facing competitive pressures exploit with MT to self-organize teams, to solve intractable problems, to reduce corruption, and to make better decisions; in comparison, dictatorial regimes suppress alternative interpretations (Lawless et al., 2013). The key ingredient is in using interdependence to construct centers of competition, which we have borrowed from Nash and relabeled as Nash equilibria (NE), like Google and Apple, or Democrats and Republicans. NE generate the information that societies exploit to better organize themselves, be it for competition among politicians, sports teams, businesses, or entertainment.

We go much deeper to understand why game theorists, with their inferior models of reality, take strong exception to their conclusions about competition by justifying its value to free societies. We believe the reason that most scientists are unable to readily "see" the root of the MT problem and the path to its solution is that human behavior operates in a physical reality socially reconstructed as an illusion of a rational world (Adelson, 2000). That is, the brain has a sensorimotor system independent of vision (Rees et al., 1997), the two working together interdependently to create what appears to be a “rational” world that is actually bistable (Lawless et al., 2013), meaning that as an individual focuses on improving one aspect of itself, say action (skills), its observational uncertainty increases. Zell’s (2013) meta-analysis supports our hypothesis: He found that the relationship between 22 self-reported scales of ability with actual ability to be moderate at best. Similarly, Bloom et al. (2007) found only a poor association between the views of the managers of businesses and the actual performance of their businesses.

For our presentation, we will review the problems with current social models plus our mathematical model of a team. Further, we continue to extend and develop a new theory of teams based on the interdependence between team members that allows us to sketch conceptually and mathematically how the tools of least entropy production now and, maximum entropy production in the future, may be deployed in a nonlinear model of teams and firms as metrics of their performance.

References:

Adelson, E. H. (2000). Lightness perceptions and lightness illusions. The new cognitive sciences, 2nd Ed. M. Gazzaniga. MIT Press.

Ahdieh, R.G. (2009), Beyond individualism and economics, retrieved 12/5/09 from ssrn.com/abstract=1518836.

Ambrose, S.H. (2001), Paleolithic technology and human evolution, Science, 291, 1748-53.

Axelrod, R. (1984). The evolution of cooperation. NY, Basic.

Baumeister, R. F., Campbell, J.D., Krueger, J.I., & Vohs, K.D. (2005, Jan). Exploding the self-esteem myth. *Scientific American*.

Bloom, N., Dorgan, S., Dowdy, J., & Van Reenen, J. (2007). "Management practice and productivity." Quarterly Journal of Economics **122(4)**: 1351-1408.

Coase, R. (1937). "The nature of the firm." Economica **4**: 386.

Coase, R. (1960). "The problem of social costs." Journal of Law and Economics **3**: 1-44.

Conant, R. C. (1976). "Laws of information which govern systems." IEEE Transaction on Systems, Man and Cybernetics 6: 240-255.

Kelley, H. H. "Lewin, situations, and interdependence." Journal of Social Issues **47**: 211-233 (1992).

Kenny, D. A., Kashy, D.A., & Bolger, N. (1998). Data analyses in social psychology. Handbook of Social Psychology. D. T. Gilbert, Fiske, S.T. & Lindzey, G. . Boston, MA, McGraw-Hill. 4th Ed., Vol. 1: pp. 233-65.

Lawless, W. F., Llinas, James, Mittu, Ranjeev, Sofge, Don, Sibley, Ciara, Coyne, Joseph, & Russell, Stephen (2013). "Robust Intelligence (RI) under uncertainty: Mathematical and conceptual foundations of autonomous hybrid (human-machine-robot) teams, organizations and systems." Structure & Dynamics **6(2)**, from www.escholarship.org/uc/item/83b1t1zk.

Lawless, W.F (2014, 8/8), “The physics of interdependence inherent in signal detection theory”, Proceedings, SciTS 2014 (Science of Teams Science), Austin, TX, 8/6-8/2014, p. 43.

Moskowitz, I.S. Lawless, W.F., Mittu, R.M., S. Russell, & Hyden, P. (2014), A Network Science Approach to Entropy and Training, PREPRINT.

Naji, A.B. (2004), The management of savagery. http://azelin.files.wordpress.com/2010/08/abu-bakr-naji-the-management-of-savagery-the-most-critical-stage-through-which-the-umma-will-pass.pdf

Rand, D.G. & Nowak, M.A. (2013), Human cooperation, *Cognitive Sciences*, *17*(8): 413-425.

Rees, G., Frackowiak, R., & Frith, C. (1997). Two modulatory effects of attention that mediate object categorization in human cortex., *Science*, *275*, 835-8.

Schaefer, K. (2014, 8/20), Trust: An important concept for Army Unmanned Systems Applications, Presentation 1st NSWCDD Unmanned Systems Integration Workshop & Technical Exchange Meeting, Dahlgren, VA.

Schweitzer, F., Fagiolo, G., Sornette, D., Vega-Redondo, F., Vespignani, A., & White, D.R. (2009). "Economic networks: The new challenges." Science **325**: 422-425.

Smith, Adam (1977) [1776]. *An Inquiry into the Nature and Causes of the Wealth of Nations*. University of Chicago Press.

Wickens, C. D. (1992). Engineering psychology and human performance (second edition), Merrill.

Zell, E. (2013), "Self-Insight of Ability", Paper presented at SSSP, Augusta, GA.