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The entangled nature of interdependence. Bistability, irreproducibility and uncertainty

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HIGHLIGHTS

- The fundamental limits of worldviews constrained by checks and balances organize social systems around competition better than authoritarians.
- Quantum-like models based on interdependence reinforce the value of free market and liberal republican processes.
- Metrics based on quantum-like models of teams may reduce human error.
- Our model of interdependence has discovered several novel solutions for perfect team performance, dismal team performance and relative team performance.
- We determined the size of teams, heretofore, an open problem.

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ABSTRACT

With models focused on individuals in research that often fails to be reproduced, social science has been unable to generalize theory into a mathematical physics of social reality to advance the science of teams. For example, Shannon's information theory and the social sciences, including economics, assume that individual observation of behavior records the actual behaviors that have occurred, including self-reports of behavior. In the social sciences this phenomenon allows social scientists to assume that self-reported behavior is actual behavior, justifying strictly cognitive models (but if true, self-deceiving behaviors would not exist). Many economists consider interpersonal comparisons meaningless. We claim that this focus on individuals is unsupported by the evidence, including the laboratory games agreeing with religious beliefs that cooperation provides for the best social good. At the heart of these rational, but false models, interdependence is seen as a constraint (information theory) or experimental confound (cognitive models) that must be overcome to confirm models based on individuals. But, we argue, social scientists have come to believe they understand interdependence when they do not. By replacing independent individuals with interdependent ones in quantum-like models, we have found that only a competition among teams establishes social reality; that the aggregation of neutral individuals determines the team that best captures reality; and that the best performing teams maximize their search of the environment for solutions to the problems they were designed to solve, while poorer performers seek better strategies, teammates (e.g., mergers) or to jettison weaker teammates. With our quantum-like model of interdependence, we solve an open problem to show that redundant members impede team interdependence and performance justifying our conclusion that interdependence is a resource free humans intuitively exploit to promote social welfare.

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1. Introduction to interdependence

To develop a theory of teams requires us to move beyond simply understanding interdependence to modeling it as a phenomenon.[1] We propose to advance the theory of teams with a quantum-like model of interdependence. Why use a quantum-like model for

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[1] To this end, we have co-organized several AAAI (Assoc. for the Adv. of Artificial Intelligence) symposia on interdependence at Stanford (e.g., accepted for 2017 (forthcoming): "Context: Why it's important, what it means, can it be computed, and how?"; in 2014, for the intersection of robust intelligence and trust, see http://www.aaai.org/Symposia/Spring/sss14symposia.php#ss05; in 2015, for foundations of autonomy, see http://www.aaai.org/Symposia/Spring/sss15symposia.php#ss03).

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teams? Per Wendt (2015), "it offers the potential for revealing new social phenomena" (p. 34), which we demonstrate by determining the size of teams, an open problem (Cooke & Hilton, 2015, p. 13).

Interdependence is important for complex problems; e.g., Llinas (2014, pp. 1, 6) issued a

> call for action among the fusion, cognitive, decision-making, and computer-science communities to muster a cooperative initiative to examine and develop [the] …metrics involved in measuring and evaluating process interdependencies …[otherwise] modern decision support systems …will remain disconnected and suboptimal going forward.

A study of interdependence might also help modern society minimize mistakes by teams (Mittu, Taylor, Sofge, & Lawless, 2016), like when a German copilot, Libutz, killed 150 aboard his Germanwings commercial aircraft in 2015; when a Japanese tour boat was sunk by the USS Greeneville in 2001; or when an Amtrak train was derailed by its distracted engineer in 2015, killing eight and injuring nearly 200. With a general model of teams, society may become more confident that a metric of teams can safeguard those at risk in critical situations.[2]

We will argue that interdependence is much more than the mutual dependence common to social science (Jones, 1998, pp. 29–30) or the mutual information in information theory (signals; Conant, 1976). Interdependent states are bistable, entangling speakers and listeners so that once interrupted produce a loss of information from both the perspective of the speaker and listener; e.g., teachers are uncertain whether their message has been understood by students, while students are uncertain whether they have understood the message sent.

We begin with an overarching thesis on teams, followed by a brief literature review including an ethnographic approach (newspapers)[3]; game theory's model of interdependence; what we have discovered with our quantum-like models; an extension of our model in the field to determine team size; a discussion of our results; and future plans. If quantum-like effects exist in the social world, we have concluded that they are expressed as interdependence (Wang & Busemeyer, 2016, p. 147). If true, although interdependence is difficult to grasp, we should see its effects at multiple social levels. We were not the first to propose this idea. After discovering that measurement at the atomic level of one factor complementary to another affected both, known as the measurement problem, Bohr (1955) proposed that measuring a social factor complementary with another generalized the measurement problem.

Much has been written over the years about interdependence (e.g., Lewin, 1951; Von Neumann & Morgenstern, 1953), often aimed at social choice (Luce & Raiffa, 1967); e.g., Hardin (2003) has found strategic choice too complex to be apprehended, which may be why the true nature of interdependence has been hidden from scientists. Most laboratory studies with interdependence as the focus result in "bewildering complexities" (Jones, 1998, p. 33), leaving mathematicians or physicists lost at sea. While we draw a parallel between interdependence as a phenomenon and quantum theory in its level of difficulty, we agree with McNeill (1981), "Human society is, however, more complicated than atoms and molecules …". Even still, despite great success with the quantum theory, after more than a century since its discovery, the meaning of quantum theory remains as controversial as in 1927 (Krips, 2013). The reverse appears to be true for the social sciences; although meaning seems to flow easily from social science, we agree with Hardin (2003, p. 3) that the meaning so derived can be indeterminate, the result of a convergence process by individuals (Adelson, 2000) and social systems that excludes contradictory evidence (Darley & Gross, 2000). Moreover, for decades, while validation had seemed to be straightforward in the social sciences, replication is an issue today (Nosek, 2015).

Why is interdependence important? From Wendt (2015): "humans live in highly interdependent societies (p. 150) …[where they form] organized, structured totalities in which parts and whole are dynamically interdependent …" (p. 134). Most scientists attacking the problem of interdependence focus on it from an individual's perspective; e.g., in classical science, Darwin and Einstein relied on the work of others for their extraordinary advances, yet the common belief exists that an individual is sufficient to advance science and overcome the resistance of peers (e.g., Kurzweil, 2013, p. 23–24). Focusing on the individual ignores how humans interdependently determine social reality. Instead of quantum-like cognitive models focused on the individual (e.g., Wang & Busemeyer, 2016), we have found that studying the effects of teams observing and in action on the field solving problems which individuals working alone cannot solve has wide social application (Ahdieh, 2009). If quantum-like effects occur among humans, we speculate that the effects on teams might be more easily displayed than at the level of the individual (Lawless & Sofge, 2016b).

2. Thesis. Interdependence: Bistability, irreproducibility, uncertainty

If interactions process information (Cooke & Hilton, 2015, Ch. 3, p. 6); if humans are cognitively capable of interacting with others; if the cognitive capacity of interactants is sufficient to process the information arising during interaction; but, unlike classical social science, if interaction creates bistable information in that the information to act (e.g., giving a lecture) is different from the information observed (e.g., listening to a lecture), uncertainty is created from alternative interpretations of social reality. Interactions occur in states of dynamic interdependence (the turn-taking exchange of bistability between interactants) to create a measurement problem for participants and observers that accounts for the incompleteness associated with self-reports. We hypothesize that for insiders in a state of dynamic interdependence, ceteris paribus, cognition is sufficient to process the information emitted during an interaction, but insufficient to capture information about the interaction, the cause of irreproducibility; for observers outside of an interaction (e.g., a scientist, playwright, marriage counselor), dynamic information is inaccessible. If interdependent information in the interaction is bistable and when extracted is incomplete, irreproducible and uncertain, our assumption conceptually constrains teams. To grasp the social reality associated with an issue under uncertainty, interdependence spontaneously creates a debate among observers to reduce uncertainty, entangling undecided observers with both sides of an argument until deciding, interfering with the creation of knowledge, contradicting social scientists who believe they understand interdependence when they cannot.

3. Research and literature review and discoveries with interdependence

Interdependence results in bistability; incompleteness; and uncertainty (Lawless & Sofge, 2016b), organizing this paper: Under bistability we place the measurement problem, game

[2] For AAAI Spring 2016 Symposium at Stanford, we studied intelligent systems to reduce human error; see https://www.aaai.org/Symposia/Spring/sss16symposia.php#ss01.

[3] http://www.bmj.com/content/337/bmj.a1035; http://aei.pitt.edu/67200/1/CES_OFWP_12.pdf.

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