Review

Review: “Squeezing” Quantum-like Interdependence Outweighs AI Risks, Cognitive Science Limits, Yet Its Duality Promotes Random Choices, Generalizations and Advantages that Advance Science

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Review: "Squeezing" Quantum-like Interdependence Outweighs AI Risks, Cognitive Science Limits, Yet Its Duality Promotes Random Choices, Generalizations and Advantages that Advance Science

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Abstract

In this review article, we introduce the problem of team interaction, cover the mathematics, results, discussion, conclusions, and a path forward. To begin, cognitive science assumes a 1:1 relationship between beliefs and actions, whether with games, concepts, preferences, rational choices, eyewitness accounts, or self-reported pain. Unfortunately, it generalizes to reinforcement for generative-AI (gen-AI), a lower form of learning which can not account for higher-level cognition, the resistance of biases to be rectified, the inability to predict successfully without updated information, and supports Planck's lament that physics evolves one funeral at a time. The problem with 1:1 beliefs-to-reality is that observations of social interaction only produce separable independent and identically distributed (i.i.d.) data, which, by definition, cannot reconstruct the interactions observed. Presently, Gen-AI uses separable i.i.d. data, preventing Gen-AI models from replicating interdependent human systems. Failing to account for interdependence, classical models of teams do not generalize, nor do their models predict advantages. Solving this problem is critical to advancing the science of teams arbitrarily composed of human-AI-machine-robot members. In contrast, based on interdependence, choosing how to "squeeze" uncertainty in our quantum-like (Q-L) model of teams, generalizes (e.g., vulnerability, espionage, time-energy tradeoffs), models self-organization's ability to provide advantages (e.g., innovation) not possible under command decision-making (viz., authoritarianism), and may solve the hard-to-find connection between mind and reality. Our results suggest that humans have dual cognitive systems, one being cognition and the other embodied, but hidden, interdependence, which Simon was unable to capture and Kahneman had begun to address, our exemplar being Einstein's decade-long struggle to construct his concept of general relativity. In the future, we propose that coupled tuning "squeezes" interdependent information to produce the advantages we have found over CDM and current AI risks.

Keywords: interdependence; quantum like uncertainty; quasi-time crystal; human-machine-Gen AI-robot teams; hidden information; coupled physical-cognitive interference; squeezed states; tunable advantages

1. Introduction

In this review of our research on interdependence, we report that evidence does not support the assumption in cognitive science of a 1:1 relationship between beliefs and actions, whether for games [1], concepts [2], preferences [3], rational choices [4], eyewitness accounts [5], suicidal ideation [6], or self-reported pain [7],[1] generalizing to the use of reinforcement for generative-AI (gen-AI), a lower form of learning unable to account for the failure of biases to rectify [8], the inability to predict [9],

[1] Editors, Mayo Clinic Press, retrieved 12/15/2025 from https://mcpress.mayoclinic.org/opioids/how-chronic-pain-works

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[2] and makes it difficult to understand Planck's claim that physics evolves one funeral at a time [10]. The problem of 1:1 is that observations of social interaction result in i.i.d. [11] non-factorable data [12], which combined cannot reconstruct the interaction [13]. Presently, Gen-AI uses i.i.d. data from symmetry breaking [14], impeding Gen-AI from fully modeling interdependent systems.

We have concluded in the past [13] that adding interdependence to artificial teammates is critical to the advance of human-AI-robot-machine teams. In this regard, there has been some progress; e.g., the F-16 fighter jet will take over after its pilot loses consciousness from a high-G maneuver [15,16]; partly interdependent machines have been used to produce new laser materials [17]; and SpaceX's Starship booster was recovered by its 'chop-sticks' machine for the first time in 2024 [18]. But each of these cases involved physical reactions, not the paired physical-intellectual interactions (χ) we argue are necessary to fulfill our goal to advance the science of human-machine teams [13].

In pursuit of our goal, we have several objectives in this article: First, to counter the public fear campaign being waged in *Science*. For example, human crowds can outperform experts given sufficient time; however, Schroeder's team in *Science* [19] tells us that AI swarms may be able to swiftly generate a synthetic consensus, thereby creating an illusion of majority agreement, falsely nudging public discourse invisibly over time, creating engineered realities designed to keep groups apart, and further poisoning the epistemic substrate of AI. The result, supposedly, is the loss of trust and silence in the face of this onslaught. But not to worry; instead of time-honored public debate, elite "scientists" have proposed that an "AI Influence Observatory" composed of "scientists" can counter the threat (e.g., [19]; see also [20,21]).

Second, to correct the failure of cognitive science to recognize the value of interdependence, we argue herein for the recognition of a separate and embodied system of cognition. For example, unable to measure the thinking of a large number of individuals fishing for food, Schwakowski and colleagues [22,23] use "Spatial feature weights combined with bandwidth parameters ... [allowed authors to] extrapolate individuals' mental representations of the resource distributions" (p. 8), indicating that the authors, as "scientists," have only imputed what individuals were thinking based on physical actions.

Third, our results will challenge reinforcement theory, also known as operant conditioning, which originated with B.F. Skinner (p. 9, in [24]). Skinner believed in scientific determinism, but not in freedom:

> "A scientific conception of behavior dictates one practice, a philosophy of personal freedom another."

Axelrod (pp. 7-8 [25]) not only agreed with Skinner, but also based on the Prisoner Dilemma Games he oversaw, he came to believe about competition that:

> "the pursuit of self-interest by each [player] leads to a poor outcome for all ..."

To overcome this outcome, Axelrod concluded that punishment should be used to discourage competition.

In what follows, we make a distinction between interdependence among scientists and their methods, and interdependence in a team. The first is procedural (e.g., "epistemic interdependence requires integrating experimental data and biological expertise from molecular biology with computational and mathematical expertise and methods from computer science, applied mathematics, and engineering," in [26]), the second phenomenological.

1.1. the Effects of Interdependence

For the phenomena of interdependence, in that it has long been considered unmanageable in the laboratory [27], in our research, we have focused on three of its effects: Bistability; measurement problem; and non-separable information.

[2] Tetlock collected the best forecasters from around the world to predict incorrectly that in 2016, Brexit would not occur, and Trump would not become president.

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First, bistability is illustrated by Carroll [28] who concluded that when prey in a forest do not fear the presence of predators, they overgraze and harm the forest. Building on this idea is an HIV prevention study reported in Science [29]:

> "The women reported using PrEP 90% of the time, and their unused returns seemed to validate that figure. But when the researchers later analyzed blood levels of drugs in the women, they found that no more than 30% had evidence of anti-HIV drugs in their body at any study visit. "There was a profound discordance between what they told us, what they brought back, and what we measured," infectious disease specialist Jeanne Marrazzo said."

For humans confronted by a bistable illusion, we know from Eagleman (p. 923, in [30]) that: "… the visual system chooses only a single interpretation at a time, never a mixture." That is why we have long known that teams can multitask, but a single human cannot [31].

Second, to unravel the measurement problem, we begin with the first fatality of a pedestrian by an Uber driver. In 2018, a three-way interaction occurred between three *independent* agents [32]: a pedestrian, an Uber car and its human operator. The pedestrian walked into a street but not in the pedestrian walkway. The Uber car struggled to classify the pedestrian 6 seconds before impact, selected the emergency brakes 1.3 seconds ahead of impact but they were not operational. Unaware until too late, possibly distracted, the human operator engaged the brakes 1 second after impact. As another example, shortly after 13 American service members had been killed, a U.S. Department of Defense (DoD) drone strike in Afghanistan killed 10 civilians, a tragic mistake; the investigation [33] found that the Americans were in an emotional state, and that their decision to strike should have been challenged. The DoD example suggests that interdependence can be dampened, including by emotion, to promote only one sided arguments, illustrated by the severe repression occurring daily in North Korea [34]. And Gazzaniga's [35] finding that the two halves of split-brain patients perceiving reality differently supports the view that the brain consists of specialized regions cooperatively linked interdependently into a unified whole [36].

Third, non-separable information is illustrated by conflict, an all-too-common experience among humans, but determining who is right is difficult, causing many states to have "no-fault" divorces.[3] Long-running business conflicts cause an impact on profits; e.g., the fight between CBS and Viacom from 2016-2018 [37] cost significant amounts of money to settle, in the process exposing secrets that changed lives. Missteps can also happen, illustrated by the decision to split apart by the partners of Ernst & Young in 2023, who after spending a year and $600 million in preparation for retirement by many of its partners, failed to split apart a planned breakup of the partnership instead leading to anger [38]. But non-separable information underscores the value of debate when facing uncertainty.

2. Mathematics

In this review, hypotheses will be indented and in bold, associated with an equation(s), then the results reviewed in Section 3. At times, we represent interdependence with the symbol χ. We start with the inability to study interdependence in the laboratory, which led us to pursue a theoretical approach [39]. Assuming that interdependence is a resource [27], that assumption led to the first hypothesis:

Hypothesis 1A: Increasing redundancy in a team weakens its performance.

The results for hypotheses are reported in Section 3; assuming support [40,41] led us to Equation 1.

2.1. Squeezing Quantum-like Interdependence

We assume that the difficulty experienced with interdependence in the laboratory reported by Jones [27] was due to a loss of information. We consider the entropy produced by a team's structure to be SEP, and the entropy produced by a team's performance to be MEP. For a tradeoff in uncertainty to occur among intelligent agents, the team must be able to become a unit, which only happens when the degrees of freedom for a team shift to becoming a unit:

[3] No-fault divorce is reviewed at https://www.justia.com/family/divorce/the-divorce-process

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Hypothesis (H) 1B: As a team's structure improves, its loss of entropy (information) is modeled when the team's degrees of freedom shift to a unit structure.

$$S = entropy = log_{Team's\ structural\ dof \to 1} SEP = 0. \tag{1}$$

For the commutator of two operators, A, B, having equal eigenfunctions (p.256, in [42]), then $[A, B] = AB - BA = 0$; but when these two operators do not commute, we stipulate that they are interdependent. For the uncertainty relations in a team, we treat the structure of a team and its performance as interdependent uncertainties, allowing for the two to be represented in an uncertainty relationship tradeoff:

$$\begin{aligned} [A, B] = AB - BA = C \\ \implies [SEP, MEP] = SEP * MEP - MEP * SEP = C \end{aligned} \tag{2}$$

Thus, for the uncertainty relationships in a team, we predict:

$$\Delta SEP * \Delta MEP \geq C. \tag{3}$$

As an example of Equation 3, Walker [43] reviewed the 1950-56 Hungarian soccer team consisting of ordinary individuals who achieved a greatness that could not be explained then or now. We assume that this soccer team's magical transformation was due to a focus on orchestrating its members into a team greater than its more talented opponents. If correct:

H2A: From Equation 3, for a team at maximum interdependence, as its structural entropy (information) decreases, its performance increases, its whole becomes greater than the sum of its parts, but its loss of structural (SEP) information promotes random effects.

H2B. Equation 3 implies the two variables are conjugate (quantum mechanics), complementary (quantum-like) or orthogonal (independent).

Assuming Equation 3 is able to model energy-entropy tradeoffs in human-machine teams, we begin to consider how we might generalize it. Our first thought was to try boundaries, vulnerabilities, espionage, and corruption. The key is to consider how a team might exploit low structural entropy.

H2C. Boundaries around teams impede external communications with a team, preventing vulnerabilities from destructive interference.

H2D. Vulnerability in a team is exposed by an increase in ΔSEP, ΔMEP or both.

H2E. Espionage is conducted while keeping ΔSEP at a minimum during enaction.

H2F. Corruption exploits vulnerability.

The downside of a great team is its loss of structural information about cause and effect, i.e., about what makes a team great; this loss suggests random effects.

2.1.1. Generalization 1: Power

If Equation 3A is correct, a team performing at its highest capability has an advantage over lower performing teams, but it is also losing information on why it is performing well. If a team needs more power, how is that accomplished?

H3: For a team with power, P, from teamwork by n teammates in time increment δt with z resonance, ceteris paribus, it increases power by adding a teammate:

$$Power = P_{n+1} = \Sigma_{i=1}^{N+1} \frac{teamwork}{z * \delta t} \geq P_n \tag{4}$$

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In Equation 4, z is unknown, but in a state of interdependence, it is context dependent, reflects cultural resistance to new situations (e.g., especially in authoritarian regimes when a team's goal generates political interference), the insights from internal and external fragmentation (e.g., by consensus seeking, in [44]), the solution of the problem being addressed by a team, the effects of the advantages afforded to a team, etc. From this, we expect comparative advantages [45] for teams in coherent states of interdependence that aggregate.

H4A: Interdependence under freedom motivates innovation and evolution, producing a comparative advantage. 4B. The more competitive a situation, the more cooperative must become its teammates, destructive interference reduced by teammates in orthogonal roles.

2.1.2. Generalization 2: Squeezing Time-Energy Tradeoffs

Given potential energy, T, and kinetic energy, V, the Hamiltonian for a quantum-like system becomes $H = T + V$. If we treat time as a duration and not an operator, we can derive a heuristic. With Schrödinger's equation [42], $i\hbar\frac{d|\psi(t)\rangle}{dt} = H|\psi(t)\rangle$ and $\hbar = 1$, then:

$$[H,t]|\psi\rangle = Ht|\psi\rangle - tH|\psi\rangle \tag{5}$$

$$i\frac{d}{dt}(Ht - tH) = i\frac{d}{dt}(t|\psi\rangle) - it\frac{d}{dt}|\psi\rangle \tag{6}$$

$$= i|\psi\rangle + it\frac{d}{dt}|\psi\rangle - it\frac{d}{dt}|\psi\rangle \tag{7}$$

$$= 1 * i|\psi\rangle = i|\psi\rangle. \tag{8}$$

Thus, $[H,t] = i$ and

$$\Delta E \Delta t \geq C. \tag{9}$$

H5A: As time duration is squeezed by a team, its energy consumption increases.

H5B: As ΔE is squeezed, time duration becomes uncertain.

2.2. Debate

In the past (e.g., see [14]), we began with a model of teams consisting of members with m_i for mass, x_i as the state of the output of team member i at time t; coupling strength, k_i; damping coefficient, γ_i; and driving force, F (which we set to zero), giving:

$$m_i\frac{d^2x_i}{dt^2} + \gamma_i\frac{dx_i}{dt} + k_ix_i = F = 0 \tag{10}$$

However, since our ultimate aim is to model teams in a debate as prelude to a decision, instead, we choose an RLC circuit with a resistor (R), inductor (L), and capacitor (C), connected in series. As an oscillator, RLC circuits are used for tuning to find a narrow frequency range among ambient radio waves. For our case, the electric-like circuit forms a harmonic oscillator that we use to model information flow. Then the resistor, reflecting an audience, increases the decay or damping of information oscillations.

For our classical model, we let induction represent the energy increasingly stored from countering arguments of any kind [46], capacitance to resist potential changes from one side of an argument to set the stage for an alternating argument; and resistance to impede information flow, emotional displays, and to dissipate energy, increasing with audience size, questions, or importance of the decision to be debated. The result gives us an oscillating inductor-like ($V = L\frac{dI}{dt}$, I for the flow of information regarding an issue), a debate's capacitor-likeness ($I = C\frac{dV}{dt}$), and an audience's resistor-likeness ($R = \frac{F}{I}$) model.

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This background gives us:

$$L\frac{di}{dt} + Ri + \frac{1}{c}\int_0^t i\,dt + v_{c0} = E. \tag{11}$$

Differentiating with respect to time gives:

$$L\frac{d^2i}{dt^2} + R\frac{di}{dt} + \frac{1}{C}i = 0 \tag{12}$$

To seek an exponential solution, if we let $I = I_0e^{st}$, we get

$$Ls^2I_0e^{st} + RsI_0e^{st} + \frac{1}{C}I_0e^{st} = E. \tag{13}$$

Looking for the characteristic solution at $E, t = 0$ and $L, R, C = 1$ gives:

$$Ls + R + \frac{1}{Cs} = 0 \tag{14}$$

$$s^2 + s + 1 = 0 \tag{15}$$

$$s_{1,2} = \frac{-R \pm \sqrt{R^2 - 4L/C}}{2L}. \tag{16}$$

For our model, we first use R=0, L=C=1, to get $s_{1,2} = \pm i$ for debates without an audience; and for compromise (see [47] and [48]), we use R=2, L=C=1, to get $s_{3,4} = -1$ (see Figure 1).

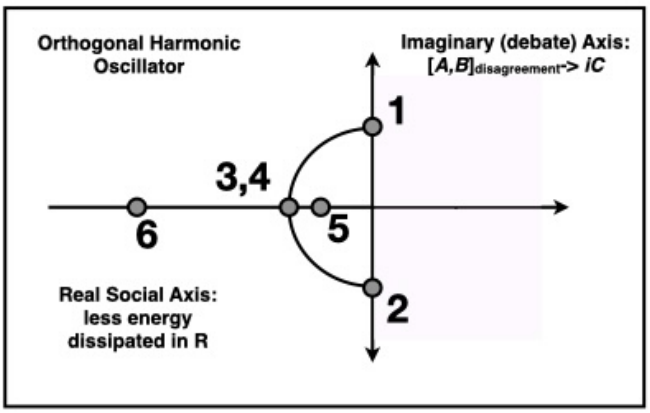

Figure 1. The image represents points 1 and 2 with $s = \pm i$ for no audience (i.e., no resistance: $R = 0, L = C = 1$), points 3,4 reflecting a compromise ($s_{3,4} = -1$ for $R = 2, L = C = 1$), and from point 5 to 6 for the outcomes of arguments of decreasing energy and time from R (i.e., decreasing energy on the x axis moving to the left, increasing to the right; roots in the right half plane reflect increasing time and energy, not natural frequencies of dissipative circuits.)

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Assuming Figure 1 and Equation 16 reflect a simplified version of a debate leads to the following:

H6: Debate within and between teams is often the purpose of within group discussions and debates, like the Department of Energy's (DOE) Citizens Advisory Boards (CABs) designed to provide DOE with advice about the remediation of DOE's mismanagement of its military nuclear wastes created from the early days of nuclear weapons research, the production of nuclear weapons, and continuing through today. For majority rule CABs, we predict recommendations for the acceleration of cleanup, i.e., the closure of highly radioactive High-Level Waste (HLW) tanks; for consensus-seeking CABs, we predict no or few calls for action; i.e., no calls to close HLW tanks.

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3. Review of the Results and Generalizations

We begin our review of the results of the hypotheses we have proposed in Section 2. First, redundancy in a team impacts the interdependence in that team:

> **Results H1A. Redundancy**: We studied the top oil firms in the world to find that the top oil firms home-based in democracies had significantly fewer workers than those home-based in authoritarian countries [40]. For example, Exxon and Sinopec produced about the same amount of oil at that time, but Exxon with 61,000 employees[4], and Sinopec with 374,791.[5] We replicated that study to find not only a similar effect with the top militaries in the world, but also as an explanation that more corruption was associated with militaries home based in countries under authoritarian rule (i.e., command decision-making, or CDM), a possible explanation for the redundancy and source of corruption [41].

Interdependence transmits additive or destructive interference across all forms of life [27]. However, when a team works well, its constructive intrerference is not evident.

> **Results Eq. 1 and H1B. Squeezing quantum-like interdependence produces hidden information**: The causal effects of interdependence are hidden, embodied information, leading the National Academy of Sciences [49] to report that interaction causality cannot be disentangled (also p. 341, [50]).

Uncertainty in team interaction exists; "squeezing" uncertainty in a team's structure (choosing capable candidates for roles that fit together reduces structural entropy production, or SEP), thereby amplifying a team's productivity (increasing maximum entropy production, or MEP); e.g, the most powerful hurricanes have the tightest structures [51]. In contrast, top-down command decision-making (CDM) teams are composed of separable, non-interdependent units, offering no advantage over interdependent teams; e.g., a possible means to manage gen-AI (see [52]).

For a team, impeding interdependence produces destructive outcomes (e.g., corruption, espionage, vulnerability; in [41]), whereas exploiting interference produces competitive advantages (see Hypothesis 4 below).

> **Results H2A**: In his study of 500 of scientific teams, Cummings [53] found that the best teams were highly interdependent. On the other hand, mergers are designed to reduce competition in consolidating markets, to improve competitiveness in advancing markets with the newest ideas or technology [54], but the study of merger outcomes by Christensen's team found that mergers were successful about 50% of the time [55], supporting randomness.

But if structural information is being lost from the best teams, it may be that a disconnect is occurring between information for cognitive claims and behavior (accounting for the replication crisis alarm raised by [2]).

> **Results H2B. Squeezing quantum-like interdependence exposes orthogonality in cognitive systems**. Support for the existence of an orthogonality between cognition and interdependent behavior is found with the crisis today in cognitive science from the failure to validate concepts. First, we set the stage by commenting on what the American Psychological Association believed in 1995 [56]: Self-esteem is the gold standard of mental health indicated by good results with academics and work. We used ChatGPT to provide a typical correlational matrix for self-esteem today. It reported that high self-esteem is significantly correlated with low levels of depression (r=-.54, p,.05), low levels of suicidal ideation (r=-.50, p<.05), and significantly good mental health (r=.50, p<.05). In the literature, self-esteem and academics are related (e.g., see [57]), however, Baumeister and his team [58] found the concept of self-esteem's relationship to academics and work to be invalid in 2005; in turn, his own leading

[4] https://corporate.exxonmobil.com/who-we-are#Ourpurpose
[5] https://www.forbes.com/companies/sinopec

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theory of ego depletion was found to be invalid in 2016. On the other hand, prediction is hard; e.g., consider the number of changes in predictions made daily with Polymarket[6] or Kalshi[7], setting the stage for a look-backwards at Tetlock's team in 2015 that in 2016, with his hand-picked "superforcasters," that predicted the United Kingdom would not breakaway from the European Union (i.e., Brexit) nor would Trump become President; both predictions failed.

See Table 1 below.

Table 1. Classical Social Science's concept failures goes beyond replication failures: 1 Validity (in the table); and, 2.Its lack of Generalizability (in the text).

Leading theory	Leading theorists	Theory invalidated by
Self-esteem	Diener (1984); hailed by APA (1987) as "important to success"	Baumeister et al., 2005
Ego-depletion	Beaumeister and Vohs, 2007	Hagger et al., 2016
Implicit attitudes theory (implicit racism)	Greenwald et al., 1998	Blanton et al. (Tetlock's team), 2009; also, NIH 2021)
Superforecasters predicted Trump not to be elected and Brexit not to pass	Tetlock and Gardner, 2015	Brexit passed and Trump got elected
Ethics	*"How we enable the unethical and how to stop"*, Princeton U. Press, 2022	Bazerman, 2022
Honesty (2012), PNAS	Lisa, Ariely, Bazerman et al., 2012; the honesty scale	Fabricated data led PNAS (2021) to retract article on "honesty."
"Implicit" effects	Bargh et al. (1996)	Kahneman blog post; Lunebeck (2025)

In support of Table 1, In 2015, Nosek [2] raised the lack of concept validity to the level of a replication crisis in cognitive science. Further, the lack of success at reducing bias [8], such as implicit racism, was dispiriting; e.g., the National Institutes of Health's on implicit racism, concluded that there was "scant scientific evidence" to support the existence of the phenomena.[8] Hoping to rectify the crisis with more carefully collected data, Nosek proposed a major article to *Nature* in 2024, only to have it retracted by *Nature* [59].(For recent news about replications, see Nature News [60]) and one of its three articles [61]).

Having established orthogonality as a plausible alternative for the cognitive crisis, in support of Equation 1, we generally consider the crisis to be data that supports the existence of an orthogonality between cognitive claims and behavior [51]. This support allowed us to generalize to boundaries, vulnerability, espionage and corruption.

Results of H2C. Boundaries around the strongest teams are stronger than boundaries around weaker teams [39]. Boundaries prevent vulnerabilities from destructive interference with a team's training, practice, planning, etc.[62].

H2D. Vulnerabilities in a team can be exposed during an attack when structural entropy increases or performance entropy decreases from an attack at a specific point; e.g., a cyber-attack that works (e.g., Stuxnet, in [63]); an attack by an underdog team against a better

[6] https://polymarket.com
[7] https://kalshi.com
[8] NIH (2021) Scientific Workforce Diversity Seminar Series (SWDSS) Seminar Proceedings: "Is Implicit Bias Training Effective?" retrieved 3/15/2023 from https://diversity.nih.gov/sites/coswd/files/images/

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opponent that works (e.g., the surprising soccer team, in [43]); also an attack against a business, a school or a hospital.

H2E. Espionage or deception depend on reducing structural entropy from one's presence to avoid being attacked by a predator in the field [28], or a foreign agent pretending to be a member of a team by pretending to be a good teammate; e.g., Alrich Ames [64], an American CIA officer convicted in 1994 for conducting espionage for the Soviet Union, which compromised many CIA human assets.

H2F. Corruption: "Totalitarianism is sustained by each person's willingness to lie." [65,66]. Undergirding authoritarianism is corruption, reflected by redundancy, stealing innovations,[9] and corruption by and in government (e.g., China and Saudi Arabia, respectively in [68,69]).

But how common is interdependence? Jones [27] claims that it infuses all of life; we add even when it is repressed [13]; further, we argue that it promotes randomness, for which a free people self-organizes better than those under aurhoritarianism. However, some teams are great [43], and formerly great teams like Boeing lose their way [6,14], but why?

Results H3: While z is unknown, its effects magnify or diminish a team's power; e.g., contrast the results of the awards by NASA to SpaceX (viz., in 2024, the first catch of a rocket after its return to earth of by SpaceX's Starship rocket Flight 5, in [18]) versus Boeing post completion of the International Space Station ([70], which almost saw the loss of Boeing's Starliner and crew headed to the ISS; reviewed in [14]). From news accounts about Boeing [71], "the crew indicated that the Boeing Starliner spacecraft experienced multiple, cascading thruster failures during its June 2024 docking attempt with the International Space Station (ISS). The problems brought the mission close to catastrophe ..."

Great teams out perform weaker teams [39], as in marriage [72] and business [73].

Results H4A. Advantages: In the news in the summer of 2024 [74,75], the kill ratios of Hamas soldiers to Israel Defense Forces and Russians to Ukrainian soldiers was reported to be about 10:1, leading us to explore four conflict zones, Israel-Iran, Taiwan-China, Ukraine-Russia and South Korea-North Korea. Using Kullback-Leibler diffusion with freedom as the standard, we found that the freer countries were superior for GDP/capita, Environmental Protection Index and Corruption Perceptions Index [6,14]. Also, de León and colleagues (p. 170, in [76]) reported that an interdependence between humans and technology led to their "co-evolution". Couple that with the finding that CDM countries impede interdependence to favor the few over the many, as in China's medical establishment [77].

Orthogonality should reduce interference in teams, promoting advantages.

Results H4B: One of the advantages of orthogonal roles is that interference disappears; e.g., developed during the French Revolution [78]: "In the kitchen brigade system, a military-like hierarchy creates a line of command. Each team member has a specific role that they fulfill with utmost precision. The system creates order and maximizes productivity." Another advantage is patent productivity. We studied patent productivity in 2019 among Middle Eastern North African (MENA) countries using UN data [79], replicated in 2022 [80], to find that the more freedom in a MENA country, the more educated its citizens and the more patents produced. However, this result contradicts what we found in 2000 [81], that for USAF combat fighter pilots, education had no relationship to performance in air-to-air combat, which we attribute to orthogonality between intellects (patents) and behavior (air combat) [6,14].

[9] From an interview by the Wall Street Journal's staff [67], General M. Hayden, the former Central Intelligence Agency (CIA) and National Security Administration (NSA) chief, stated that the Chinese stole millions of records from federal employees for the innovativeness that has so far eluded China. He told his Chinese counterparts: "You can't get your game to the next level by just stealing our stuff. You're going to have to innovate."

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Next, we generalize Equation 3 to time-energy uncertainty, Equation 9.

> **Results H5A**: Using UN data,[10] as time uncertainty is squeezed [14], we found that the average time it took to start a business in a nation was significantly and inversely related to that nation's GDP/capita (r = -.75, $p < .05$); significantly and inversely related to a nations ability to innovate (r = -.66, p <.05); significantly and inversely related to the perception of corruption in a nation (r = -.71, p < .05); inversely related but not significantly to freedom in a country (r = -.23, p > .05); and strongly but not significantly related to the energy consumed per capita in a nation (r = .53, $p > .05$).

What evidence supports squeezing the energy for time relationship that can be related to human and human-machine teams?

> **Results H5B**: Cohen, 1995 (p. 45, in [82]) had found in signal theory with transformations between Fourier pairs, that a "narrow waveform yields a wide spectrum, and a wide waveform yields a narrow spectrum and that both the time waveform and frequency spectrum cannot be made arbitrarily small simultaneously." In human teams [83], "Team flow occurs when a group functions in a high task engagement to achieve a goal, commonly seen in performance and sports." Further, [84], team flow supposedly occurs for "experiences during which individuals are fully involved in the present moment." These experiences are similar to the low-energy-high time uncertainty for the time crystal [85].

Interdependence as a resource that conveys constructive and destructive interference should have a large effect during debates, where strength of arguments and weaknesses or vulnerabilities become exposed.

> **Results H6. Debate**. Nash's C-C choices between competitors creates an equilibrium [46] that models the spontaneity that occurs with free choice; e.g., majority rule in the U.S. In contrast, consensus seeking or forced cooperation produces stalemate [44]; e.g., consensus rule in the European Union [86]; National Academy of Sciences [21,87]; China [88].[11]

4. Discussions

We began our research program with the assumption that interdependence is a resource. But the lack of information about team structure in the literature [27,49] led us to consider what would happen to that resource in a state of interdependence if additional, but unneeded, members were added to a team, leading to the hypothesis that redundancy would interfere with team performance.

> **Discussion H1A. Redundancy**: Social network theory [89] predicts that redundancy improves social dynamics, likely the reason why redundancy was not further explored, and why we were able to easily contradict social network theory [89]. Redundancy impedes the phenomenon of interdependence, its flow of constructive and destructive interference, and, consequently, the performance of teams.

Equations 1 and 2 promote randomness, which infuses social interactions [90,91] in the search for fitness, characterized by reduced structural entropy production and increased performance of an interdependent whole [39], described by assembly theorists as complexity [92,93] and us as a byproduct [51].

The loss of information in the interaction predicted by Equations 1 and 2, in agreement with by the National Academy of Sciences [49], supports the claim that interdependence is quantum like. This loss makes it difficult to copy teams or even to repeat performances by the top teams similar to the no-cloning rule in quantum mechanics [94].

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[10] The UN's business startup data base, since discontinued.

[11] From [88], China's "Integrated Joint Operations Platform" is "one of the most sinister components of China's surveillance state, managing what has been described as a genocide against the Uighurs. The IJOP combines multiple systems of repression – location, messages, contacts, social media and other data from phones, together with information from checkpoints, cameras and biometric records. It then flags "suspicious" individuals for detention and forced labor."

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> **Discussion H1B**: The loss of information. The causal effects of interdependence are hidden [50], and assumed to be embodied information [95], leading the National Academy of Sciences [49] to report that causal attributions in the interaction cannot be disentangled ([49]; also see Busemeyer and Bruza, p. 341, [50]).

Interdependence transmits additive or destructive interference across all forms of life [27]. For a team, exploiting interdependence can produce destructive outcomes (e.g., corruption, vulnerability; espionage; in [41]). This suggests that managing structural uncertainty in a team can lead to an advantage:

> **Discussion H2A. Squeezing quantum-like interdependence**: Uncertainty in team interaction exists; "squeezing" uncertainty in a team's structure (choosing capable candidates for roles that fit together reduces structural entropy production, or SEP) amplifies a team's productivity (increasing maximum entropy production, or MEP); e.g, the most powerful hurricanes have the tightest structures [51]. In contrast, top-down command decision-making (CDM) teams are composed of separable, non-interdependent units, offering no advantage over interdependent teams; e.g., gen-AI (see [52]).

Cognitive science has not solved the problem of consciousness; e.g., integrated information theory [96]; assembly theory [92]. Cognitive science also has not solved the significant role of the physical environment in human thinking, which is embedded in and extended into the world; nor the role of embodied cognition [97]. Conveying an aspect of cognitive science, Thagard [98] has held that humans display a particular kind of intelligent behavior based on mental rules, procedures for using these rules to search a space of possible solutions, and procedures for generating new rules to produce the behavior observed. Oppositely, Skinner [24], the behaviorist, has imputed cognition from behavior. Thus, cognitivists and behaviorists both ignore the interdependence between cognition and behavior, impeding an advance of team science. Similarly, Simon [99] attempted but failed to capture the decisions experts made with his theory of bounded rationality; and Chomsky's [100] theory of language holds that innate rules govern human behavior. But cognitive scientists, Simon, Chomsky, and behaviorists have not addressed the contribution of interdependence to human thought and action, leaving them unable to explain the invalidity of concepts, a prelude to our discovery of orthogonality.

> **Discussion H2B**: The education of Air Force combat fighter pilots had no effect on performance, while training did [40]. The opposite effect was found for education in Middle Eastern African Countries (MENA) and patent productivity, led by Israel [80]. These two results from the crisis [2,59] ongoing from the invalidity of social psychological concepts (e.g., self-esteem [58], implicit racism [101], priming [102], honesty [103], ego-depletion [104]) may be explained by an orthogonality between classical concepts and the behavior they are meant to represent. The results of Table 1 and the advantages afforded by interdependence can be explained by an orthogonal interdependence between cognition and behavior, contributing to the randomness in social interactions. For the physical skills required for air combat, an education is superfluous; but in the production of patents, education of knowledge about the field is paramount. That is, air combat is physical and reliant on navigating interdependent states in 3-dimensional physical reality, patent productivity is cognitive and navigates the interdependence among intellectual states regarding innovation and knowledge.

The inability to overcome the limitations in validating concepts tells us that even if cognitive concepts are real and correlate with other cognitive concepts (e.g., self-esteem and academics; but see Baumeister and colleagues, 2005 [58]), they do not capture physical reality; instead, they capture what is *believed* to be reality. To capture reality, cognition comes to match reality only through struggle; e.g., Einstein's struggle with general relativity [105], somewhat similar to overcoming any form of resistance to change [106]. The inability to find concepts such as Einstein's general relativity [6] have prevented social sciences from finding a platform from which to construct a science that generalizes to new findings, new theory and new discoveries. However, instead, we propose that the lack of concept validity,

 doi:10.20944/preprints202604.0946.v1

namely, Nosek's crisis [2], is evidence of the phenomena of interdependent duality between cognition and behavior existing in plain view.

Similarly, games do not capture the reality modeled [107];[12] If games worked, dating sites would be more successful than about 20% [109], and simulated war games would lead to better predictions; e.g., General Eisenhower [110] said that "Plans are worthless, but planning is everything." In our own research, we found that training had a significant effect on who was successful as a fighter pilot in air combat, whereas an education of air combat training had no effect on the performance of air-combat pilots [81].

We return to theory to generalize interdependence to other phenomena linked by structural entropy production (SEP): Boundaries, vulnerability, espionage, and corruption. Boundaries reduce noise, exposure to vulnerability, help to manage espionage and to control corruption.

> **Boundaries H2C:** Boundaries prevent destructive interference affecting the operations of a team's training, practice, planning, etc. ([39]: "a strong team is one where its "boundaries are stronger than any inner boundaries" (p. 319); from Germany [111], "Germany has lost power; it's politics keep it divided between the boundaries of East and West;" and [112], "healthy boundaries are critical for effective conflict resolution, collaboration, avoiding unnecessary conflict, and creating truly good outcomes for ourselves and others").
>
> **Vulnerability H2D:** Vulnerability is commonly a target in an opponent, characterized by a loss of structural entropy or a reduction of maximum entropy or both [80]; e.g., the forced merger of UBS bank to buy its faile rival Credit Suisse at the request of the Swiss government [113], a merger that has been successful; e.g., a cyber-attack works to expose a vulnerability (e.g., Stuxnet, in [63]) that a team must address to prevent failure; an attack by an underdog team against another that works, whether in sports (e.g., soccer, in [43]) or an attack against a vulnerable operation such as a school or business.
>
> **Espionage H2E:** Aldrich Ames [64] successfully operated in the CIA during which he exposed numerous CIA assets over a number of years before he was caught, tried and convicted.
>
> **Corruption H2E:** authoritarians operate by replacing free speech and free choice by lying [65]: "Totalitarianism is sustained by each person's willingness to lie." Yet corruption in China has been an obsession of Chinese leader Xi's concern for some time: Xi's "Campaign snares over 500,000 low-level state personnel ... affecting ordinary citizens", in [68].

As an example of finding vulnerabilities in software, Moskowitz and his team [114] have explored the mathematical capture of geometric changes in system dynamics to reveal software performance vulnerabilities.

> "Detecting anomalous software behavior before it causes failure or security compromise is a central challenge and large information gap in modern computing, and in dealing with generative AI risks and benefits within Human-Machine Teams."

If an interdependent team is at minimum structural entropy, SEP, and maximum productivity, MEP, how does it gain more power?

> **Discussion H3. Power**: Applying Noether's theorem on symmetry generalizes $SEP - MEP$ to support the finding by Cummings [53] with teams, we conclude that productivity increases only if $P_n \rightarrow P_{n+1}$ and if the team remains fully interdependent [14] and freely self-organized.

Exploiting interference produces competitive advantages (e.g., innovation, cooperation, evolution; in [14,76]).

> **Discussion H4A. Advantages**: In reading news accounts of the wars between Israel and Iran in 2025 [74] and Ukraine and Russia in 2024 [75], the kill ratio for Hamas to Israel's Defense Forces was about 10:1 and similarly for Russia's military to Ukraine's military, suggesting

[12] Suleymanov's review [108]: "reinforcement learning methods in real-world, large-scale multiagent problems ... are currently unsolvable."

 doi:10.20944/preprints202604.0946.v1

an advantage for freely organized military teams versus those forced to cooperate. Using Kullback-Leibler diffusion against the standard of freedom, we [6,14] found clear advantages across four zones of conflict: Israel (4th) over Iran (5th); Taiwan (1st) over China (tied for 6th); South Korea (2nd) over North Korea (8th); and Ukraine (3rd) over Russia (tied for 6th).

From repeated prisoner dilemma games, Axelrod [25] claimed: "the pursuit of self-interest by each [participant] leads to a poor outcome for all," avoided, he continued, when sufficient punishment discourages competition. But our results contradict Axelrod, indicating the advantages of self-organization during states of freedom versus punishment with CDM.

Discussion H4B. Cooperation-competition: The only way for low-redundancy teams to succeed competitively is to have maximum cooperation among its teammates, supported by Adam Smith's discovery of the value in the division of labor [115]. From von Mises [116] and Hayek [117]: the turn from self-organized capitalism is to turn to the forced cooperation of socialism, slavery, and serfdom.

Cassidy [118] also counters Axelrod by commenting that while the free market:

"is soulless, exploitative, inequitable, unstable, and destructive, yet also all-conquering and overwhelming."

Supporting Cassidy, we found that forced cooperation, including consensus-seeking [86], produces the poorest outcomes for national defense [6] or nuclear waste cleanup [44], but that interdependence produces the best outcomes while maximizing cooperation to offset the lack of redundancy [6].

Squeezing time requires more and more energy [6], in agreement with Cohen. To reiterate, in 1995, Cohen (p. 45, in [82]) found in signal theory for transformations between Fourier pairs, that a "narrow waveform yields a wide spectrum, and a wide waveform yields a narrow spectrum and that both the time waveform and frequency spectrum cannot be made arbitrarily small simultaneously."

Discussion H5A. Time-Energy: With Schrödinger's equation, we recreated the uncertainty relations to find that as teams "squeeze" time uncertainty, the tradeoff causes their energy use to increase proportionally; e.g., in support, the *Wall Street Journal* [119]: "High-speed traders often seek to capture fleeting differences between prices of related assets, making quick response times critical."

Reversing to Energy-Time should produce a reduced sense of time in the interaction that suggests a similarity with quasi-time crystals (e.g., [83]).

Discussion H5B: There is support for the proposition that as energy uncertainty is squeezed, i.e., $\Delta E \rightarrow 0$, that time flow occurs, like a time crystal [85]. From Shehata and colleagues [83], "Team flow occurs when a group functions in a high task engagement to achieve a goal, commonly seen in performance and sports." This flow provides a "reduced sense of time" [84].

For debate, the Department of Energy required the use of consensus-seeking rules in its guidelines [120] for its Citizens Advisory Boards (CABs). The CABs were constructed to advise DOE on the cleanup of its nuclear waste mismanagement from the early days of producing nuclear weapons. However, DOE allowed CABs to adopt majority rules; notably DOE Hanford used consensus-seeking rules and DOE Savannah River Site (SRS) used majority rules, setting up a natural field experiment between the two largest DOE sites. The broad result is that DOE-SRS accelerated its cleanup, DOE-Hanford did not, best illustrated in 1997 by DOE-SRS closing not only the first two of its 51 highly radioactive waste tanks (HLW), but today reaching a total closed of eight HLW tanks [44];[13] whereas DOE-Hanford has not closed any of its 177 HLW tanks.

[13] At DOE-Savannah River Site, the HLW tanks range in size from 750,000 gallons to 1.3 million.

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Discussion H6. Debate: For Equation 15, we predict that no audience is modeled by points 1&2 in Figure 1. The power, P, equation for majority rules, Equation 4, needs to be changed for consensus seeking or authoritarian rule by reducing the effect of teamwork:

$$Teamwork = \sum \frac{1}{w_i} = \frac{1}{w_1} + ... \frac{1}{w_n} \tag{17}$$

For example, for agents with contribution weights of 1,2,3, then $\frac{1}{w_i} = 1/1 + 1/2 + 1/3 = 6/6 \implies w = 1$. In support of Equation 17, one of the leaders of the DOE-Hanford Board said that consensus-seeking blocks action, seconded by the European Union in its White Report (2001, p. 29, in [86]):

> "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."

In contrast, where free speech governs, points 3,4 and 5 in Figure 1 suggest that the winning argument comes from a decision advantage (DA).

Previously, we modeled the oscillations in a debate (Figure 1) with a simple LRC-like electrical circuit that oscillates back and forth, with the audience providing resistance, causing the oscillations to stop when a decision was made; in this LRC-like model, beliefs are modeled as being a part of imaginary space, driving the oscillation of information for the benefit of the audience. Based on the rotations that occur as a debate's representatives argue for and against a decision, the oscillations back and forth are represented by a "torque", τ, in the minds of the audience that drives their processing of the information, allowing us to model decision advantage, DA, as:

$$DA = \tau_A / \tau_B. \tag{18}$$

DA means that one team, team A, was quicker than another team, team B, in driving the oscillations back and forth between competitors during a debate; that team A's grasp of the complex issues was more forceful; or that team A's perception of the eventual solution was held with more conviction than the other; etc.

By DA, Equation 18 has support in literature and field. From office of the Director of National Intelligence in 2015 (pp. 6–9, in [121]), a "strategic advantage is the ability to rapidly and accurately anticipate and adapt to complex challenges ... the key to intelligence-driven victories may not be the collection of objective 'truth' so much as the gaining of an information edge or competitive advantage over an adversary ... one prerequisite for decision advantage is global awareness: the ability to develop, digest, and manipulate vast and disparate data streams about the world as it is today. Another requirement is strategic foresight: the ability to probe existing conditions and use the responses to consider alternative hypotheses and scenarios, and determine linkages and possibilities."

The purpose of a decision advantage in combat is to "exploit vulnerabilities" (see p. 7 in [122]). Speed and quality decisions are important in business, too [123].

5. Conclusions

First, reality is not 1:1. Second, cognitive concepts do not generalize to valid concepts, but theorizing about the phenomenon of interdependence does [13]. Interdependence is a resource. It is difficult to manage in the laboratory, but it gives decision advantages (DA) to self-organized teams able to work with it. Unlike CDM, freely organized teams performing tasks are able to mange the uncertainty and randomness of interdependence [27] to advance technology and society [76]. An infinite number of signals from society and the market place must be aggregated and managed by CDM, an infeasible proposition but an explanation for how authoritarian countries send their citizens on the road to serfdom [117].

Our goal is to meld cognition and interdependence, an elusive goal based on i.i.d. data [11]. Language is primarily a tool to communicate [124], but it does not capture all of reality, behavior or communication [125], nor is it necessary to be able to think [126]. Wittgenstein [127] came to believe

 doi:10.20944/preprints202604.0946.v1

that language can not map the structure of reality; e.g., "Water!" can be expressed as an exclamation, an order, a request, or an answer to a question. The meaning of the word depends on the language game in which it is used. Another way Wittgenstein makes the point is that the word "water" has no meaning apart from its use within a language game. One might use the word as an order to have someone else bring you a glass of water. But it can also be used to warn someone that the water has been poisoned. "Fire!" has many interpretations, all context dependent: An order to fire a weapon; the sudden discovery of fire; a request to start a fire; the start of a race; the danger of a fire.

Our argument is that this valid information flowing in an interaction is being conveyed by interdependence. States of interdependence can be wrong; ask any pilot learning to fly in instrument conditions, where pilots must learn to not trust their perceptions but instead their instruments for instrument flight rules (IFR) when entering instrument meteorological conditions (IMC), i.e., when the horizon becomes indistinct for a pilot and the terrain appears to be featureless [128].

Third, measuring interdependent states produces i.i.d. data that, by definition, cannot recreate an observed interaction [11]. That is possibly why Jones [27] felt that the interaction in the laboratory was "bewildering" and unmanageable.

Then what is to be done? The predicted loss of information in the interaction also underscores what Lewin said that [39]: "nothing is so practical as a good theory". Theory led us to discover that redundancy interferes with a team's performance [40] and to randomness from the lack of success with mergers [90]. Interestingly, the loss of information is a product of an excellent structure for a team; in contrast, the lure of becoming an authoritarian is the one-sided benefits that accrue, for example, with health care [77], "There are actually two systems in China—one for the elites, and another for everyone else. The elite system is excellent. The public system is rudimentary, underfunded, and riddled with corruption, with much of the funding that moves through bureaucratic channels siphoned off by officials at various levels before it ever reaches patients." Thus, without complete control, authoritarianism cannot survive without stopping freedom, why they use punishment to prevent the flow of interdependence to prevent the existence of hidden information [129].

The loss of information from interdependence implies quantum-like superposition or entanglement. But, in agreement with the claim by the National Academy of Sciences [49], a look inside of an interaction is not permitted, making it quantum like; from Zeilinger regarding superposition [130]:

> "It is sufficient to destroy the interference pattern, if the path information is accessible in principle from the experiment or even if it is dispersed in the environment and beyond any technical possibility to be recovered, but in principle still "out there". The absence of any such information is the essential criterion for quantum interference to appear."

Interdependence transmits additive or destructive interference across all forms of life [27]. For a team, impeding interdependence produces destructive outcomes (e.g., vulnerability, espionage, corruption; in [41]), whereas exploiting interference produces competitive advantages (e.g., innovation, cooperation, evolution; in [14]). And our quantum-like model of interdependence links with the quantum processes now being shown to manage energy in biological systems [131], an effect we have shown occurs with interdependence at the team level.

Interdependence builds an uncertainty relationship between dependent parts of a whole, agreeing with Davies [132] that living matter needs physics. In fact, we have stated in the past that the best operated team is similar in many aspects to a hurricane: The tighter the structure of a hurricane, the more powerful it becomes [51]. We have included in our review an explanation of the advantages that come from operating teams in free choice team structures, home based in free countries, leading to Cassidy's [118] comment that despite the negative aspects of capitalism, the free market economy is "all-conquering and overwhelming."

As Lincoln [133] spoke about freedom in his first public speech almost two centuries ago, given before the Young Men's Lyceum in Springfield, Illinois,

> "What dangers are we to face in a future faced by armies of robots commanded by authoritarians? ... Upon these let the proud fabric of freedom rest, as the rock of its basis; and as truly

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> as has been said of the only greater institution, "the gates of hell shall not prevail against it."" "From whence shall we expect the approach of danger?" asked Lincoln. "Shall some trans-Atlantic military giant step the earth and crush us at a blow? Never. All the armies of Europe, Asia and Africa combined . . . could not by force take a drink from the Ohio, or make a track on the Blue Ridge, in a trial of a thousand years. . . . If destruction be our lot, we must ourselves be its author and finisher. As a nation of freemen, we must live through all time, or die by suicide."

Regarding debate, Kuhn [134] argued about the "essential tension between competition and cooperation" is necessary for evolution to occur; de León and colleagues [76] claimed that evolution is enhanced by the interdependence between society and technology; we add that with minimum redundancy in a team performing in a highly competitive situation between two teams, maximum cooperation is demanded [6].

For debate, Nash [46] provided the solution of the first games with his proof that countering an opponent's every move establishes an equilibrium. We take Nash one step further by speculating that polarization from countering steps is spontaneous, allowing opposing sides facing uncertainty, if capable and able, to find sources of energy to sponsor their position, a spontaneous effect that authoritarians expend energy to tamp down. When two sides of a debate or argument are equal, compromise becomes possible [48].

In pursuit of our goal, we had several objectives in this article: First, to counter the public fear campaign being waged in *Science*. But what we have found is that i.i.d. data is separable, as are AI systems, suggesting that interdependence provides the means to defeat AI should it become malicious.

Second, to correct the failure of cognitive science to recognize the value of interdependence, we argued herein for the recognition of a separate and embodied system of cognition. That system is interdependence.

Third, our results have challenged reinforcement theory, also known as operant conditioning, which originated with B.F. Skinner (p. 9, in [24]). Our results have directly contradicted Skinner's assessment of freedom.

To summarize, it appears that humans have two cognitive systems, which Simon [135] failed to capture and Kahneman [136] had begun to address, one being cognition and the other hidden and embodied [137]. Failing to account for interdependence, classical models of teams do not generalize to valid concepts, nor do their models predict valid advantages. In contrast, our quantum-like model of teams, based on interdependence, generalizes to valid concepts, models self-organized advantages not available under command decision-making (viz., authoritarianism), and may solve the elusive connection between mind and reality, suggesting as an exemplar Einstein's struggle over a decade with his concept of how mass and energy act like gravity to affect spacetime. Einstein's struggle reflects effort justification [138], itself a generalizable phenomenon.

In 1935, Dirac [139] declared the end of classical physics. Our research with interdependence leads us to the same conclusion for classical team science, which is limited by not addressing interdependence as a phenomenon.

In sum, we were the first to see that theory is currently the only means to address i.i.d. data [11] collected from the interaction; to use theory to see the effects of redundancy on teamwork; to see the advantage of majority rule on action versus the stifling effect of consensus-seeking, a key element in authoritarianism; but not the first to see the decision advantage (DA) of quicker decision making in countering a debating point [122], interpretation or decision [121].

In Table 2, a brief list of the hypotheses and results are provided for convenience.

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Table 2. Summary table of hypotheses, results and references.

Hypothesis	Claim	Supported	Examples: (citations)
1A	Redundancy reduces χ	Supported	Lawless [40] Exxon versus Sinopec
1B	Squeezing ΔSEP loses I	Supported	NAS, 2022, p. 12 [49]
2A	Squeeze ΔSEP for MEP	Supported	Cummings [53] study of science teams; Lewin [39]
2.B	Orthogonality	Supported	Concept crisis [2]; patents vs. air combat [80,81]
2.C	Boundaries	Supported	Shannon information [62]; Lewin [39]
2.D	Vulnerability	Supported	Stuxnet [63]; Credit Suisse Merger [113]
2.E	Espionage	Supported	Aldrich Ames [64]
2.F	Corruption	Supported	China's Xi's anti-corruption drive [68]
3	Teams max χ	Supported	Cummings [53]: $P_{N+1} > P_N$
4A	Comparative advantages	Supported	Lawless [6]; innovation in Cassidy [118]; evolution and technology [76]
4B	Innovation	Supported	MENA countries, led by Israel [80]; Under competition, cooperation maximizes [6]
5A	Squeezing Δt	Supported	As $\Delta t \to 0$, E increases [14]; Cohen [82]
5B	Squeezing ΔE	Not fully	Low E in team flow; time crystal [83–85],
6	Debate CR v MR	Supported	MR accelerates, CR impedes [44]

6. Future Research

1. In the future, we propose that tuning coupled physical-cognitive interference "squeezes" interdependent information to produce the advantages we have found over CDM and current gen-AI risks. We plan to propose a coupled quantum-like harmonic oscillator.
2. The emotion challenge: Cognitive science neglects the important role of emotions in human-machine teams. We expect to find that emotion drains available energy from a team, reducing rationality [4], increasing ΔSEP and reducing ΔMEP. However, from a larger perspective, emotion may help to set the stage for social change (see Figure 2), raising the question of how much emotion is too much?[14] A stable social equilibrium is the ability to withstand change, especially from the disruptions caused by innovation [141]. A social equilibrium can be impressed by force; e.g., under authoritarianism. But force, whether for seeking a consensus [44,86] or by threat of punishment to achieve cooperation [25], produces inferior results, especially the changes brought about by innovation [142] among Middle Eastern North African (MENA) countries. Mokyr [141] believes that the political fragmentation and market competition formed a free "market for ideas" to explain how the Industrial Revolution arose in Europe but not China, despite similar levels of technology and intellectual activity, while the period of the Enlightenment in China was controlled by its rulers.
3. Quantum biology [131] implies that life searches for efficiency. Living in large cities is associated with longevity, an advantage possibly due to access to health care. Alternatively, large cities represent large concentrations of energy, and gravity is stronger nearer to the earth's surface than to mountains, slowing time [143], a possible contribution.
4. Hamilton type learning becomes important in the attempt to model opposing teams, businesses, institutions, etc.
5. The Overton window is an intriguing concept that we hope to explore further [144]. "The most common misconception is that lawmakers themselves are in the business of shifting the Overton

[14] For example, Jefferson [140], in a letter dated November 13, 1787, to the son-in-law of John Adams, wrote: "the tree of liberty must be refreshed from time to time with the blood of patriots and tyrants."

 doi:10.20944/preprints202604.0946.v1

window. That is absolutely false. Lawmakers are actually in the business of detecting where the window is, and then moving to be in accordance with it."

6. Speculation: Rovelli [143] wrote that gravity causes time to slow. There is evidence that longevity increases around highly intense areas. We want to explore whether a relationship exists between them (e.g., [145]).
7. Reinforcement is a weak approach to learning. We predict for future research a study of effort justification between cognitive concepts and physical reality. For example, Aronson's team found that harder initiation into societies made for greater liking and appreciation of them [146].

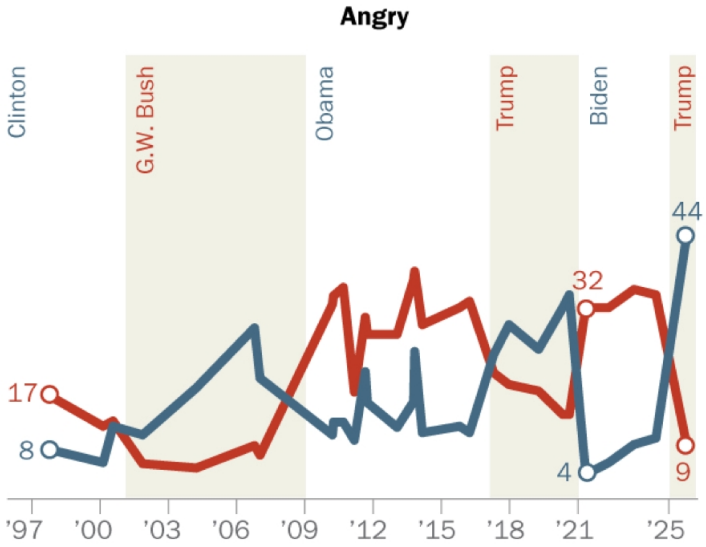

Figure 2. Question wording is, "Some people say they are basically content with the federal government, others say they are frustrated and others say they are angry. Which of these best describes how you feel?" Source (with permission granted by the author): Survey of U.S. adults conducted Sept. 22-28, 2025. Trend data: Pew Research Center's American Trends Panel (2020-25), Pew Research Center phone surveys (2019 and earlier).

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Abbreviations

The following abbreviations are used in this manuscript:

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CAB	DOE's Citizens Advisory Boards
CDM	Command Decision-Making
DA	Decision Advantage
DOE	Department of Energy
HLW	High-Level Waste tanks
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
SEP	Structural Entropy Production
MEP	Maximum Entropy Production

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