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The Symmetry of Interdependence in Human-AI Teams and the Limits of Classical Team Science

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Abstract: In our quantum-like model of interdependence for human-human, human-AI, and human-machine teams, we apply Dirac's quantum claims that dependency is symmetry, that dependency is a loss of degrees of freedom (*dof*), and, consequently, a loss of information occurs among a team's dependent parts. As we have noted in prior research, the best teams are highly interdependent, putting symmetry in play. Every human activity produces entropy. Mathematically, first, we hypothesize that a highly interdependent team (organization, system) in a state of symmetry can trade the entropy generated by the team's structure, producing least entropy production (LEP), few *dof*, and, thus virtually no internal information to independent observers; and, second, the result allows more of the expenditures of a team's available energy to be directed at its productivity, reaching maximum entropy production (MEP), another form of conservation involving tradeoffs between a team's structure and performance. However, the problem with a state of interdependence is the lack of information it generates, creating an intractable problem for classical social science and a science of teams. To overcome, we provide indirect, but convergent, measures of the advantages of conserving interdependence in teams. In future research, generalizing, when servicing the trade-offs of the available energy to a team, we propose that claims from a team balanced by counterclaims made by a competing team are an example of the symmetry connected to the conservation of interdependence in a system or society, a measure of the freedom agents have to make decisions in their best interest, where every claim among free agents is countered, and where every decision is an example of symmetry breaking.

Keywords: symmetry; symmetry breaking; interdependence; human-machine teams; entropy

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1. Introduction

Noether's theorem [1] predicts that conserved quantities are derived from symmetries found in the laws of nature. For example, time translation symmetry gives conservation of energy; space translation symmetry gives conservation of momentum; and rotation symmetry gives conservation of angular momentum. As we plan to apply symmetry to the classical social science of teams, Noether's theorem and Dirac together call for the end of determinancy in classical social science.

We apply Noether's idea to teams to address team function. To do so, we take liberties with the complex flow of energy through a team at any instant: we avoid a focus on getting energy into a team, on dividing it among team members to perform their jobs, and on concerns about each team-member's state (e.g., we assume that at the moment of interest, each member is able to do its job; namely, each member is well-trained, competent, fully operational, etc.). We assume that those issues have been resolved elsewhere. We also ignore losses due to friction, etc.

Instead, we assume that the energy available to a team can be expended on the team's structure, its performance, or both, creating a tradeoff. We consider the problem of tradeoffs in a team in a state of interdependence; the advantages to a team while being in a state of interdependence; the disadvantages of information losses while in a state of interdependence, how to maintain interdependence (indirect control), and ancillary questions that may arise but be addressed by the findings of this study. In particular, with AI (machine learning, automatons, etc.), one claim today is that AI is potentially dangerous (e.g., Bengio et al., 2024 [18]). Are the advantages afforded by interdependence in human-machine teams able to offset these threats?

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For a science of human-machine or human-AI teams, mathematics is necessary. To capture the phenomena of teams mathematically, the substance of our argument directly accounts for the limits of team science, social science, collective logic, and generative AI. In future research, we sketch team decision-making; debate and competition between teams; and compromise between choices offered to two teams versus majority rule (symmetry breaking) or consensus-seeking rules (minority control rule).

1.1. Background of the Problem

We borrow Dirac's (p. 15, in[2]) idea of a superposition intermediate between two or more states to focus on the confounds that naturally obscure from science the interactions inside of teams. From Dirac, symmetry between dependent states indicates superposition; and that degrees of freedom indicate independence. But in Dirac's view, superposition and interference at the quantum level combine to create states unlike anything in classical physics. Generalizing to human teams to explain the failures we will later review in depth, in the interactions over time for a team experiencing additive and destructive interference, choosing to join or leave a team (a high *dof* state), and knowing whether an agent's skills fit or not cannot be predicted before hand; after joining, members of the team are changing rapidly between actor-observer roles, especially when problems arise, the interference promoting, abridging, shifting their interactions between support or not of a team's decision, all the while the dependencies [19] between interacting elements are obscured from an independent agent's view.

Our goal is the mathematics of interdependence. With this mathematics, we have been able to generalize to new findings [62]. As an example of generalizing interdependence, inside of a machine's team, if one machine's process, *A*, is dependent on another machine's process, *B*, and machine *B's* process is dependent on a third machine's process, *C*, and the results are dependent on *A*, *B* and *C*, non-verbal interdependence performs its team's coordination activities well (e.g., chem-labs are interdependently developing new laser materials, in [26]), but does so by ignoring cognitive beliefs about the situation, context, or world at large. Thus, we recognize that generalizing interdependence to include both behavior and language for human-machine teams presently poses a series of challenges with more questions than answers.

For example, the goal to achieve interdependent cognition and behavior is not as far along (viz., where teammates both speak and react physically to each other); e.g., from the *Wall Street Journal* [27], robots cannot yet manage themselves or other robots:

> "Some traditional warehouse roles have proved too difficult for Amazon to fully automate ... Humans [but not robots] can easily look into a storage container packed full of goods, identify a particular item and know how to pick it up and handle it ..."

The problem with machines and robotics is that while they are becoming more capable, they are not yet competent with interdependent language and behavior for teams because classical social science has failed to produce a mathematical theory of interdependence that integrates both [28]. Thus, for data collection, we focus on human-human systems. But to what end?

Manipulating states of interdependence in a team of humans is considered too difficult to manage in the laboratory (Jones, 1998, p. 33; in [25]).

A contributing factor to this problem of cognitive social science is that classical social science has not been able to establish a valid process to construct and test the reproducibility of concepts. As examples of scales that have been found to be invalid, the claims made for self-esteem could not be reproduced in 2005 [4]; implicit racism in 2009 [5]; ego-depletion in 2016 [6]; and the honesty scale in 2021 [7]. The reproducibility crisis was identified formally in 2015 [29], leading to a plan to strengthen the tests for conceptual scales by, among other things, the preregistration of measures and analyses supporting claims before a reproducibility experiment was run. However, the plan itself was retracted after the editors of *Nature* lost confidence based on criticisms raised about the results then being produced [30].

The problem of replication remains. From *Psychology Today* [8]:

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> "The vibrations of the "replication crisis" continue to be felt throughout the social sciences, and particularly within psychology. ... [but] Rather than effectively scrutinize this foundation, it has been more convenient for stakeholders in the field to push the narrative that it was founded on scientific rigor."

These problems with cognitive science suggest a loss of information within the interaction, acting like quantum superposition [28]. However, the opposite occurs with behaviorism (e.g., [31]). From a different perspective but with the same result, logic applied to collective decision-making while operating in the open has also failed [32]. These problems with social science, logic and the Academy all support the conclusions earlier drawn by Jones [25].

Furthermore, compounding the problems of social science, logic and the conclusions drawn by Jones [25], the National Academy of Sciences [33] reported that to unravel interdependent effects may not be possible:

> The "performance of a team is not decomposable to, or an aggregation of, individual performances ..."

These problems with cognitive science, we suggest, can be explained by a loss of information within the interaction, acting like superposition [28].

2. Mathematics

To capture the lack of knowledge about the interaction, we note Schrödinger [21] was the first to describe the phenomenon of quantum entanglement as one state dependent on another, where creating "a whole does not necessarily include the best possible knowledge of all its parts," a loss of information among the interacting parts of a team that depend on each other (in our case, teammates). At the quantum level, confirming Schrödinger and Dirac, according to Zeilinger [22], we cannot know what occurs inside of a state of superposition. For the same situation in a team, we model it with subadditivity.

To convey the information about subadditivity from classical systems, we use Shannon entropy, H, for two discrete, independent random variables, X, Y, where $H(X, Y)$ is their joint entropy:

$$H(X,Y) \leq H(X) + H(Y). \tag{1}$$

Equation (1) models statistical independence. Classical systems are composed of independent parts. As an example of independence, should a car's part break down on a road trip, replace the part and continue on the trip. Another example is when two phones not in use. If one phone breaks and is replaced by another and then used, the users are oblivious to its replacement. Shannon's contribution is the interdependence, $I(X, Y)$, between two phones in communication:

$$I(X,Y) = H(X) + H(Y) - H(X,Y) \tag{2}$$

The parts of a phone are *separable*. A phone can be disassembled, and reassembled. It is a classical system.

Measurement theory in classical mechanics differs from quantum mechanics because measuring a classical element of a compound object has no effect on the other elements of the combined object when they are independent of each other. In a review of the science of entanglement posted for the three Nobel Physics Laureates in 2022,[1]

> "That a pure quantum state is entangled means that it is not separable ... being separable means that the wave function can be written as
>
> $$\psi(x,y) = \psi_1(x)\psi_2(y) \;\; ..." \tag{3}$$

[1] https://www.nobelprize.org/uploads/2023/10/advanced-physicsprize2022-4.pdf

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The National Academy of Sciences (see p. 12, in [33]) reported that the

> "performance of a team is not decomposable to, or an aggregation of, individual performances."

However, classical social science that models independent parts cannot reproduce the effect reported by the Academy, that is, the dependent interactions among the members of a team are irreproducible (e.g., in group dynamics, Lewin concluded that a whole is greater than the sum of its parts; in [39]; similarly, for Systems Engineering, see [40])). For synergy, when a team's members are interdependent, we next use subadditivity to model a whole that has become greater than the sum of its parts.

For dependent quantum systems and, we assume, quantum-like systems, with H now as the Hamiltonian of the system (considering only its total available energy), with ρ as the density matrix, and with ρ^{AB} as the density matrix of a bipartite system where $\rho^{AB} \epsilon\ D(H_A \otimes H_B)$, and entropy, S, then ([41]):

$$S(\rho^{AB}) \leq S(\rho^A) + S(\rho^B). \tag{4}$$

Equality governs *iff* $\rho^{AB} = \rho^A \otimes \rho^B$; then

$$S(\rho^{AB}) = S(\rho^A \otimes \rho^B). \tag{5}$$

If the parts of a team are separable or factorable and can be represented by a tensor, then the equality in Equations (4) and (5) govern. However, if the parts are not factorable [23], the joint entropy vanishes in the quantum case. To model the Academy's claim, we make the same assumption for the quantum-like case of a team to find the joint entropy of an interdependent bipartite system, i.e.,

$$S(\rho^{AB}) = 0. \tag{6}$$

Equation (6) not only models what the Academy reported, amounting to a loss of identifiable information from the interaction, but it also means that, generalizing, we cannot know the effect of adding a new member to a team until the entropy, S, changes (increases, indicating a poorly fitting choice; or decreases, indicating that a new member fits with existing teammates; in [20]). If the result is a good fit among teammates, then interdependence reduces the subadditivity of entropy to zero in the limit.

How can we use Equation (6) to model a team? First, we represent the members of a team with N degrees of freedom (dof), where H_A is the classical information produced by the whole, and H_{a_n} is the information from each of the whole's parts. If the team is a group of disconnected, uncoordinated, separated, independent participants, then:

$$H_A = \sum_{dof=1}^{N} H(a_N) = H(X_1) + H(X_2) ... + H(X_N). \tag{7}$$

There are two problems with Equation (7): First, it does not explain the effect of Equation (6). Second, it affords no advantage to teams; i.e., there is no synergy, no aggregation of power from teamwork. But if when a team comes together, its degrees of freedom among the interacting parts of its whole are reduced (viz., as it unifies into a "team"), that reduces its information in accord with Equation (6). Second, there is a finite amount of free energy available to a team to operate. If the team is disunited, it wastes its free energy on policing the team's structure (e.g., divorce disrupts a family's life; spin-offs disrupt life in an organization). However, if the team's structure is unified and stable, its free energy becomes available to the team to become more productive than the sum of its members, able to accomplish a mission, and capable of serving a function; in that case, we represent the whole, A, as the structure of a team. When team members controlling the team are able to build and maintain the structure as a unified, cohesive, and stable whole, the entropy, S, produced by its structure, $LEP_{Structure-A}$, decreases, allowing the team to shift proportionately some (an unstable team

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structure) or most (a stable team structure) of its available free energy from keeping its team together to the team's productivity, increasing the power of a team. For that to happen, structural entropy production must reduce, in the limit becoming:

$$S_A = \lim_{dof \to 1} \log(LEP_{Structure-A}) = 0. \quad (8)$$

Equation (8) explains how Equation (6) happens. The loss of degrees of freedom in a team's structure precludes the information from being available to "decompose" the "performance of a team ..." [33]. It also implies that the less energy expended by a team to maintain its structural coherence, the less heat it generates in emotional responding and the more energy is available to make the team productive (adapted from Rovelli, 2016; in [42]).

2.1. The Mathematics of Measurement Theory

We turn to the foundations of metrics. Charles Sanders Pierce began the school of pragmatism. He wanted to know this about reality [16], "What do we know and how do we know that we know it?" William James, a leading pragmatist, stated that "The ultimate test for us of what a truth means is indeed the conduct that it dictates or inspires" ([17]).

The classical social science of teams assumes that social reality consists of independent pieces of information based on the number of agents being observed, or *dof* (Equation (7)); and assumes that information can be linked to form social structures to produce recoverable information. But that does not happen; instead, as we have already documented, in the attempts to validate them, social concepts fail instead. Worse, generalization to new theory and new findings do not occur.

This assumption led us to conclude that Belief A when completing a self-reported questionnaire and Action B described in the questionnaire can be orthogonal to each other:

$$(Belief\ A) * (Action\ B) = A * B = |A||B| \cos 90^0 = 0 \quad (9)$$

We used this equation to represent the case in a study of US Air Force pilots who were being educated in the classroom about the skills needed for air combat maneuvering, to find that the correlation between their education of air-to-air combat and their actual skills in air-combat was zero, unlike air-combat training, which was significant (reviewed in [20]).

The measurement problem: Based on our arguments above, the evidence and Equation (6), we conclude that the measurement of a state of interdependence disrupts that state, producing Shannon information, known as independent and identically distributed random data (i.e., i.i.d. data; in [35]). To buttress our assumptions, and of greater importance, the Shannon information captured from any social or team interaction is i.i.d. data that, by definition, cannot reproduce the original state of interdependence (see also [57]).

That is why measuring a quantum system affects the system measured. And, we argue, that is true with quantum-like individuals, teams and organizations, resulting in two non-commutative observables that cannot be measured exactly simultaneously. If we assume the existence of two matrix operators, **A** and **B**, that are incommensurable, non-commutative but also interdependent with each other, and with C as a constant, then

$$[\mathbf{A},\mathbf{B}] = \mathbf{AB} - \mathbf{BC} \geq C. \quad (10)$$

Given Equation (10) and given a team in a state of interdependence when its interactions among teammates remain coherent, modeled by Equations 6 and 8, we assume that the available energy saved while coherent can be applied to a team's productivity, where the maximum available free energy saved from a team's structure and applied to a team's productivity produces maximum entropy (MEP), then:

$$\Delta LEP * \Delta MEP \geq 1 \quad (11)$$

Equation (11) represents our equation of the power gained by forming a group of individuals into a unified team: The more unified the team (i.e., as $LEP \to 0$), the more powerful it becomes (i.e., $MEP \to \infty$). Furthermore, maintaining a unified state of interdependence provides indirect control.

2.2. Method: Building Convergence I. Case Studies

As part of our method, we build towards a convergence of results with a case study of two organizations; past hypotheses that have worked; and a new hypothesis generalized from our past results for this article.

Case studies. We test Equation (11) in a case study. Control requires the intelligence inherent in a team's interactions to make the adjustments on the fly in real time that maintain the coherence among a team's teammates by maximizing the team's interdependence, allowing the team to maximize its performance, no matter its size [24], which we identify by its production of MEP, or by competing with another team to expose a vulnerability in the competitor's team structure.

An example of an organizational success and a failure. We begin the study of convergence with a case study of two organizations, a highly successful SpaceX (i.e., with the highest MEP) and a dysfunctional Boeing (with the highest LEP). Recently, a NASA engineer recalled visiting SpaceX to find its atmosphere feeling "like a frenzied graduate school, where all of the employees were being pulled in different directions," seconding what Cummings [24] had found for the most productive science teams. In contrast, the visiting engineer had also found that Boeing was struggling to keep its Starliner on schedule.

Based on this case study, by dampening or preventing interdependence, a mature organization, like Boeing, can lose its way or falter, making it unable to compete with a much younger organization, like SpaceX. After the Space Shuttle retired, NASA chose Boeing to develop a "commercial crew" transportation system named "Starliner" to reach the Space Station and its competitor, SpaceX, for a significantly lesser amount. SpaceX won the race with its Dragon capsule; Boeing lost [44]:

> "With Boeing's Starliner spacecraft ... we know the extent of the loss, both in time and money. Dragon first carried people to the space station nearly four years ago. In that span, the Crew Dragon vehicle has flown thirteen public and private missions to orbit. Because of this success, Dragon will end up flying 14 operational missions to the station for NASA, earning a tidy fee each time, compared to just six for Starliner."

In sum, first for convergence, we have reviewed a case study comparing Boeing unfavorably with SpaceX, indicating that Boeing is mature and unable to adjust, and SpaceX is young and motivated; we suspect that part of maturity for an older organization is an unwillingness to change, an indication that interdependence is being suppressed. Second, we have reviewed the failure of concepts from classical social science. Third, we next consider indirect evidence, including the difference between consensus-seeking and majority rule.

What we have argued in this article is that there are three key justifications for combining interdependence and symmetry: Classical social science has failed to make predictions and to generalize; the Nation Academy of Sciences concludes that analyzing the individual contributions of teammates in teams is infeasible; and the collection of i.i.d. data cannot recreate interdependent states. We have also posed a possible fourth justification with our case study.

2.3. Method. Convergence II

Our goal is to derive a theory of integrated cognition-behavior that addresses all risks posed by AI to humans.

2.3.1. Method. Hypotheses Supported: Triangulation

1. Claim 1: The self-reported questionnaires reported above (i.e., self-esteem; implicit racism; ego-depletion; honesty) capture belief data orthogonal to behavioral data, leading to poor correlations reflected by invalid concepts. Interestingly, the conceptual questionnaires produce data that is

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significantly cross-correlated among the questionnaire data, but just not with physical behavioral data, which we claim is orthogonal to the cognitive data. Supported by the literature (reviewed in the Editorial by Lawless et al., 2023 [43]; see also the Editorial by Lawless and Moskowitz, 2025 [62]; and their most recent Editorial, in [62]).

2. Claim 2: The data collected post-interactions is i.i.d. data which, by definition, cannot capture interdependent events. Supported by the National Academy of Sciences (p. 12, [33]).
3. Claim 3: Interdependence ends direct determinancy in classical social science for the decisions made by teams facing uncertainty or for teams making major changes in their plans. For example, when successful, organizational mergers build, among other things, new organizations with a series of teams by making them mutually dependent upon each other, the dependence reducing the production of entropy by the newly merged structure's arrangement and, consequently, the information derivable from it when successful (estimated at 50% by [45]), thereby replacing the need for knowledge of how to acquire a new team's member with random selection in a trial and error process instead of with logic [20], which does not work [32]. While we need trial and error to build coherent teams, even though we cannot know what is occurring inside, if the structure remains coherent, its products are better and can be measured in the output, our new hypothesis.
4. Claim 4: By reducing information with fewer *dof*, entanglement at the quantum level provides a mathematical model of a merger that, we argue, acts as a quantum-like model of interdependence at the team or organizational level. Interdependence is a resource that promotes human development [57]; competition; reduces corruption; provides the tools to discover vulnerability in an organization [20]; and increases freedom. Partly supported by the SpaceX-Boeing case study.

2.4. New Hypothesis: Interdependence Is a Resource

The assembly theory of alien life [34] avoids the complications of the hidden operation of interdependence by counting results of successful assemblies, the greater the number of assemblies, the more likely that the complexities of interdependence are involved. Building on assembly theory's idea of observable effects, by focusing on the observable results of interdependence in a team, we have hypothesized that interdependence in managing the flow of entropy is key: By producing a low entropy in a team's structure (LEP), the team can maximize its performance by producing maximum entropy (MEP) in its output [20].

This last step allows us to hypothesize that central or command decision-makers (CDM; e.g., authoritarians, kings, gang leaders) place their teams, organizations or nations at a decision disadvantage by oppressing interdependence and replacing it with logic, inherent in minority control ([20]), thereby preventing information symmetry within and between teams, the quantum-like resource used by sufficiently free humans to organize themselves at varying social levels, where the "essential tension" [56] from interdependence improves social function by providing a decision advantage to fully interdependent teams [24].

To test our hypothesis, we begin with estimates of kill ratios of Russian soldiers to Ukrainian solders in Ukraine, and Hamas to Israeli Defense Forces (IDF) in the Gaza strip. Then we focus on eight nations in highly competitive situations, either in outright conflict on nearing conflict (Iran; Israel; China; Taiwan; North Korea; South Korea; Russia; Ukraine). In addition to these eight, we add four others in milder forms of conflict (Costa Rico and Haiti; USA and Cuba).[2] Finally, we consider evidence of the top most innovative firms and companies in the world.

3. Results

The kill ratios of Russian soldiers to Ukrainian soldiers was estimated at 220,000 to 43,000 [46], a ratio of about 5.17:1; and a range of Hamas soldiers killed to IDF soldiers estimated at between 17-18,000 [47], ranging downward to a lower estimate of 8,500 ([48]), providing ratios of about 43.28-20.99:1.

[2] We plan to provide to the Editor a supplemental file of the data used to make these additional calculations.

Next, we construct a model of country data to attempt to account for these kill ratios. In Table 1, we tabulate the United Nations' Human Development Index data (HDI);[3] a country's gross domestic product per capita from the International Monetary Fund (IMF);[4] Transparency International's Corruption Perception Index (CPI);[5] the Global Innovation Index (GII) by the World Intellectual Property Organization (WIPO);[6] and the Fraser Institute's Economic Freedom Index.[7] In Table 1, NA stands for data that was not available.

In Table 2, we calculated the advantages afforded by maintaining the symmetry of interdependence as a beginning by us to estimate the value of this hidden resource. The best advantage afforded by a people to itself is reflected by its collective productivity, or GDP/capita. But HDI and freedom are necessary ingredients for self-organization, followed by a measure of the corruption reduced by the tension wrought by interdependence, interdependence that also produces competition among teams and organizations, and while serving as a resource for innovation (GII)[55]. In Table 3, we used data from Forbes about the most innovative countries in the world, cross-tabulated with the Fraser Institute's determination of "Mostly Free or Mostly Unfree."[8] That allowed us to count the number of companies home-based in free to mostly free, or in mostly unfree to unfree countries (shown in Table 3).

Table 1. Advant. interdep.: Country; HDI; GDP/N; CPI; GII; Freedom.

Number	Country	HDI	GDP/cap	CPI	GII	Freedom
1	Israel	.92	54.4k	62	15	7.4
2	Iran	.78	5.3k	24	64	4.6
3	Ukraine	.73	5.8k	36	60	5.1
4	Russia	.82	15.1k	26	59	5.9
5	Taiwan	NA	34.9k	67	NA	7.7
6	China	.79	13.9k	42	11	6.1
7	S. Korea	.93	37.7k	63	6	7.5
8	N. Korea	NA	NA	17	NA	NA
9	Costa Rico	.81	18.7k	55	70	7.6
10	Haiti	.55	2.4k	17	NA	5.8
11	USA	.93	89.7k	69	3	8.1
12	Cuba	.76	NA	42	NA	NA

Table 2. Calculated Advantages of interdependence from Table 1.

	HDI	GDP/cap	CPI	GII	Freedom
Advant. R1-3-5-7 to R2-4-6-8	1.08	22.32	2.09	1.65	1.25
Advant. R9-11 to R10-12	1.33	22.58	2.1	NA	1.35
Global Ave. Advantage	1.21	22.45	2.10	NA	1.30

For Table 3, using the Fraser Institute's data, we categorized as Free to Mostly Free these countries: Japan; the European Union countries; the United Kingdom; the United States; Canada; Indonesia; and South Korea. We classified these countries as Mostly Unfree to Unfree: Russia; China; Brazil; India.

[3] https://hdr.undp.org/data-center/human-development-index[add hashtag]/indicies/HDI
[4] https://www.imf.org/external/datamapper/NGDPDPC[add at symbol]WEO/OEMDC/ADVEC/WEOWORLD
[5] https://www.transparency.org/en/cpi/2023
[6] https://www.wipo.int/en/web/global-innovation-index
[7] https://efotw.org/[add q mark]geozone=world[add ampersand]page=map[add ampersand]year=2022
[8] https://www.forbes.com/innovative-companies/list/2/[add hashtag]tab:rank

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Table 3. The most innovative companies in the world by Country

Free to Mostly Free Countries	Mostly Unfree to Unfree Countries
86	14

4. Discussion

The process that we have attempted to uncover is a set of choices that produce random outcomes [45]. And yet for a free people, the outcomes are superior to those predetermined by logic under command or central decision makers (CDM). The sum of the advantages in Table 2 is 28.39, with an average of 5.68 (both from Table 2, line 1). The smaller average closely approaches the Ukrainian advantage in combat, and the larger sum approaches the Israeli's IDF advantage.

As stated in claim 3, the end result of mergers is poor on average, no better than 50-50, and yet, with Table 3, supporting our third claim based on theory that a random process occurs for teams facing uncertainty about a new choice that has to be made about their future ([45], the result suggesting that CDM is inferior to self-organized free markets.

In this study, we have attempted to establish the value of symmetry. From the literature about nation states facing uncertainty [49]:

> "the role of symmetry in interdependence and conflict lies in the relationship between a state's exit (opportunity) costs and the costs it is willing to bear in the face of political conflict with another state. Asymmetry with respect to two states' exit costs/threshold relationships can generate bargaining power that constrains the use of force."

We have found that CDM decision-makers often mis-judge and mis-choose more often while using logic rather than trusting the random, self-organized choices made by leaders of teams or organizations in free countries. In agreement, Osborn concluded that [50]

> "China's leadership is concerned about corruption within the PLA's ranks, especially at the lower levels, and to the extent possible wants to remove the individual soldier from the decision-making process in favor of machine-driven guidance. This is in stark contrast to the U.S. Army's way of war, which relies heavily on warfare as an artform ... The U.S. Army sees its Soldiers as its greatest advantage in battle and relies on their intuition, improvisation, and adaptation to lead to victory."

In agreement, the *Wall Street Journal* reported that [13],

> "China's crackdown on corruption within its defense industry could set back its weapons procurement programs, delaying its military modernization, the Pentagon said Wednesday. ... Pentagon assessment says Xi Jinping's crackdown on fraud might delay efforts to turn China's military into a 21st-century force."

Our argument assumes that "words alone do not equal reality," which means that the tools of Generative AI (e.g., tensors for LLMs and machine learning) used to model "reality" are separable (factorable) entities (Equations (4) and (5)) that generate random independent and identically distributed (i.i.d.) data [35], but i.i.d. data by definition cannot recreate whatever social interactions have been captured [20]. Why? Words account for only 7 percent of communication [36]; moreover, we do not need language to think [37]:

> "Language is a defining characteristic of our species, but the function, or functions, that it serves has been debated for centuries. Here we ... argue that in modern humans, language is a tool for communication ... [not] for thinking."

From the literature, regarding the lack of information about states of interdependence, our results buttress the conclusions by Polanyi (1962; in [52]) that a judge's decisions have greater precedence than a judge's written justifications. Polanyi had claimed that tacit knowledge meant that we humans know more than we can say; e.g., some drivers can park a car in a small space each day, but are unable to articulate how their skill is enacted. Polanyi (1962) agreed that Law Courts often follow the precedents set by similar cases decided in the past. In these prior court decisions (precedents), judges recognize that practical wisdom is embodied in decisions rather than opinions about the decisions. Precedents allow for the possibility that judges may be mistaken by the interpretations they offer for their own decisions. The judicial maxim, the 'doctrine of the dictum,' holds that a decision governed by precedent has more value than a judge's justification for the decision (viz., obiter dicta).

Our results also agree with Acemoglu and his fellow Nobel laureates that economic freedoms and the rule of law are important as institutions,[9] but we do not agree entirely. We disagree in the sense that even democratic rule can be abused sufficiently to prevent or impede interdependence, and that a better marker is whether interdependence is being impeded or not.

For example, those who lose in their public battles may become ostracized from society even in a democracy [67]. Instead, by standing up, the person and society will be better able to evolve [55] their situation in a positive manner, and move forward. It also underscores the changes that may occur for the political losers in an election, those able to grasp clues for success from the winners, resulting in the process of turning from what they once believed into a different version for the next political contest; e.g., see Cohn in the *New York Times* [69] for the changes in the political parties that occurred in the 2024 Presidential election; viz., that conservatives in the U.S. represented workers, a constituency formerly represented by liberals.

5. Conclusion: Limits of Classical Team Science

We have made and supported three arguments: That classical social science has failed for individuals (for a review of another concept for individuals that has failed to be validated, see [70]), making it unable to generalize to teams; that information is lost in the interactions due to a loss in *dof* [33]; and that the measurement of team actions (or its individual members) produces i.i.d. data which cannot recreate the state of an interdependence observed.

The best way to control a free people, and by generalization, future autonomous human-human, human-machine, human-AI or machine-machine teams to protect humanity, is to let teams self-organize to the maximum extent possible; i.e., indirect control. The results will be random (i.e., [45]), but, under the "essential tension" [56] afforded by interdependence between self-organized teams, our results support the conclusion that they will be superior to the methods used by CDM leaders.

From Art Sellers, President and GM of Avathon Government Systems, AI's [64]

> true potential will not be in replacing humans with smart machines; rather, it will happen when activities become truly synchronized.

Moreover, Madison's insight, in Federalist No. 51 [53], is that "Ambition must be made to counteract ambition." He believed that was the only way to prevent oppression (of interdependence) by a majority. Similarly, to find the truth in the courtroom, Freer and Purdue [54] concluded that justice is found when the practice of law occurs between equally competent but competing attorneys. In particular, with AI (machine learning, automatons, etc.), one claim today is that AI is potentially dangerous (e.g., Bengio et al., 2024 [18]). However, our findings indicate that the advantages afforded by interdependence in human-machine teams are more able to offset the threats posed to interdependent teams. Our results indicate that autocrats who suppress interdependence may not counter this threat [20]. Furthermore, Cummings [24] reported that the best teams of human scientists worked in states of maximum interdependence, a path forward to generalize from human teams to human-machine teams.

Our conclusion that information during the interaction is hidden also agrees with Adam Smith's "invisible hand" [51]. As a society becomes more specialized, mutual interdependencies arise in free markets guided by an invisible hand of need [51], a much more successful process of organizing a

[9] The [Nobel] Prize in Economic Sciences 2024, https://www.nobelprize.org/prizes/economic-sciences/2024/popular-information/

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society than the logicians of central decision-making. For example, a plumber needs a lawyer, a lawyer needs a doctor, a doctor and a lawyer both need a plumber, each adapting to the market forces and their competitive advantage for the benefit of all, far more successfully than a central decision-maker who depends only on i.i.d. data and logic, thereby transforming cause and effect into an illusion (but for a contrary viewpoint, see [65]).

Our findings contradict the conclusions about the "Squid Game" reported in the *New York Times*. This article indicated that competition is bad, underscoring the common belief of the need to end free choice in politics [59]: "the toll of tribalism: how the push to pit ourselves against one another in a winner-take-all political battle leads to destruction and despair for all." Instead, we conclude that the value of random exploration for success with the best products, the best agents, the best political leaders, etc., greatly outweighs the best choices that CDM leaders can make in advancing technology and society (e.g., [55]).

Regarding symmetry, our findings support the value of self-organization, which includes debate when facing uncertainty, compromise, and majority rules.

In conclusion, interdependence is a resource that provides a significant advantage to agents free to self-organize. Applied to the classical social science of teams, Noether's theorem and Dirac's research, supported by our results, call for the end of classical determinancy.

6. Future Research

First, from the literature, we have addressed the random outcomes associated with team mergers [45]. But what drives mergers? Returning to Noether's time-symmetry formulation that led to the conservation of energy, given a finite amount of available energy to a team (organization, etc.) having achieved a minimum LEP and a maximum MEP for a given n, the only way to increase MEP, as predicted by Cummings (see Cummings, p. 82, in [68]), is to have $n+1$ members in a state of interdependence with minimum *dof*, with the exception that heterogeneity decreases performance, but that decrease can be cured with the experience of teammates working together over time (see Cummings, p. 94, in [68]). If those conditions are met, then a team's power should increase:

$$Power_{n+1} = P_{n+1} = \Sigma(\frac{Work_{n+1}}{\Delta t}) \geq P_n. \tag{12}$$

However, does this increase in power require a supporting increase in available energy, technology, or both (e.g., [55])?

Second, what is it about majority rule that makes it work? When an audience of voters adopts a view point belonging to the majority, does that mean that their belief dependency increases to merge with the majority (see Equation (8))?

Third, our future research should include negative and positive emotion. We have proposed a mathematics of state dependency [38] to model interdependence for human-human, human-AI, or human-machine teams [28]. In our model, emotional distress increases entropy in a team's structure, a trade-off diverting the available energy from a team's maximum entropy production, reducing a team's performance [20]. We proposed that, if emotion is generalized to a model of society with quantum-like coupled harmonic oscillators, it could fulfill Lewin's vision proposed decades ago of an interdependent whole [39] such as a human-machine team, organization or system. There, under the uncertainty caused by free choice (e.g., recall that the failure rate of corporate mergers is about 50%; in [45], exemplified by the recent failure of Walgreens' merger; in [60]), political compromise [61] and innovation might be combined into an index as we have begun in Tables 1-3 that differentiates evolvable, autonomous, and observable self-organized assemblies ([34]; e.g., [62]) of interdependence randomly seeking the positive emotion of "animal spirits" [63]:

> "...if the animal spirits are dimmed and spontaneous optimism falters, leaving us to depend on nothing but a mathematical expectation, enterprise will fade and die."

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Fourth, for these animal spirits to arise, we argue for an "essential tension" [56] between two teams that leads randomly to a competition or debate between the best opponents possible.

Presented in a short manuscript [58], Nash won the Nobel largely based on the first solution to game theory, i.e., that countering each claim by an opponent produces an equilibrium. Equation (10) reflects Nash's [58] idea about the existence of an equilibrium between countering views. Given Equation (10) and given a team in a state of interdependence when its interactions among teammates remain coherent, and when two equally coherent teams compete against each other, if every claim produces a counter claim, a Nash equilibrium has generated a symmetry that lasts until a vote is taken to break it.

Generalizing, when servicing the trade-offs of the available energy to a team, we propose that claims from a team balanced by counterclaims by a competing team are an example of the symmetry connected to the conservation of interdependence in a system or society, a measure of the freedom agents have to make decisions in their best interest, where every claim among free agents is countered, and where every decision by observers (e.g., juries, voters, judges) is an example of symmetry breaking.

Fifth, we also want to explore in future research the value of seeking consensus decisions, which we have found are inferior when a consensus is forced, required or purposively sought [20]. Consensus reports written by the National Academy of Sciences (NAS) discuss the need not only to counter misinformation in science (p. 163, in [14]), but also considers as an option the need for censorship:

> "post-hoc detection of misinformation rather than prevention of (or censorship against) the initial appearance of misinformation ... [but this] corrective advertising ... has primarily focused on providing accurate factual knowledge to consumers as a specific goal for mitigating misinformation ... a goal which does not necessarily address irreversible behavioral effects that may have stemmed from earlier exposure to misinformation."

The consensus report by NAS continues (p. 169, in [14]:

> "As a strategy for reducing exposure to misinformation, deplatforming is controversial, in part because it has often been equated with censorship and raises concerns regarding potential infringements on freedom of speech ..."

Journalists may add to the problem (p. 234, in [14]):

> "Science reporting for the general public may be particularly prone to the unintentional spread of misinformation about science. Several factors can influence this, including journalistic norms (e.g., giving equal weight to both sides of a scientific debate, even when the scientific evidence overwhelmingly points in one direction)..."

Using AI or machine technology to censor speech, however, not only ignores the value of educating the public about a targeted topic, but also does not allow interested other (younger) scientists to learn from public challenges that produce the information generated by full-throated debates instead of hiding information by preventing symmetry breaking.

On the other hand, from the Pew Research Center [15], "Trust [in science] moves slightly higher but remains lower than before the pandemic." Americans are split on whether scientists should be involved in making policy: 51% of Americans are in favor of having scientists to "Take an active role in public policy debates about scientific issues," but 48% want scientists to "Focus on establishing sound scientific facts and stay out of policy debates."

In closing, for our fifth future research project, we believe that Gutmann and Thompson [66] have the better idea when they state that compromise is necessary to govern; campaigning is necessary to remain in office. These incompatible ideas of Gutmann and Thompson help to explain why compromise is, and should be, difficult to achieve. The authors define compromise as: Mutual sacrifice amid willful opposition by both sides. We believe their guidance can be generalized to human-machine teams, but consensus-seeking should not.

For this part of our future research, thus, we want to explore the symmetry not only within teams, but also between two competing teams, not only producing a Nash equilibrium [58], but also the consensus or majority ruled decisions that follow for human-human and human-machine teams. It is our conjecture that majority rules are more likely to lead to symmetry breaking and the production of useful information for the winners, the losers, and for the evolution of technology interdependently with their society [55].

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