Quantum-like interdependence "squeezes" structural entropy, system advantages over command decision-making, AI, and social science

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Abstract: - Our research finds that the 1:1 relationship between cognitive beliefs and actions is an illusion. Whether for games, concepts, preferences, rational choices, eyewitness accounts, self-reported pain, 1:1 relationships cannot generalize beyond reinforcement for humans or generative-AI (gen-AI), a lower form of learning, explaining the failure of biases to evolve, the impediment to predict, and the inability to account for higher-level reasoning (e.g., innovation). The problem with 1:1 is that observations of social interaction produce independent and identically distributed (i.i.d.) or separable data (i.e., like the frames of a video), which cannot reconstruct the interaction. Interdependent systems are entering the market (e.g., heart-lung machines). Until now, however, AI has been unable to replace humans, likely because AI uses i.i.d. data derived from symmetry breaking, preventing Gen-AI from modeling the essential aspects of interdependent teams. Solving this problem is critical to advance the science of human-AI-machine-robot teams. Failing to account for interdependence, classical models of teams do not generalize well, if at all, nor do their models predict advantages. As a brief review of our research into a theory of interdependence, we conclude that humans have two cognitive systems, which puzzled Simon and Kahneman, one being cognition and the other interdependent, hidden and embodied cognition. We have contributed to the science of teams with our theory of measuring the entropy produced by teams (viz., "squeezing" structural entropy is characteristic of the best teams). In support, our quantum-like model of interdependence in teams generalizes (e.g., how a team can execute covert actions such as espionage; how to find and exploit vulnerabilities in a team), explains why self-organized advantages are impeded under command decision-making (viz., authoritarianism impedes interdependence), and suggests a future study for the elusive connection between mind and reality, with Einstein's struggle over a decade to discover his concept of how mass and energy act like gravity to affect spacetime to be explored as an exemplar of reducing cognitive dissonance. We close by proposing control by mutual tuning of interference across a system is our plan for future research.

Key-Words: - Interdependence; quantum-like uncertainty; human-machine teams; coupled interference; control; Command decision making

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1 Introduction

In this brief review, cognitive science assumes a 1:1 relationship between beliefs and actions, whether for games [1], concepts [2], preferences [3], rational choices [4], eyewitness accounts [5], or self-reported pain [6], generalizing to the use of reinforcement for generative-AI (gen-AI), a lower form of learning, echoing the failure of biases [7] to evolve, the inability to predict [8] (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) and Planck that physics evolves one funeral at a time [9]. Two problems: reinforcement was invented by Skinner who proclaimed that individual freedom was of little value [10]; and the observations of social interaction result in i.i.d. data [11] which is separable and cannot reconstruct the interaction (e.g., like the static frames of a movie to give an illusion of reality; in [12]). Existential fear has been raised by the use of Gen-AI (e.g., [13],[14]). Presently, however, Gen-AI uses i.i.d. data in its tensor models [15], preventing Gen-AI from modeling interdependent systems. Solving this problem of interdependence is critical to the advance of human-AI-machine teams; it may also alleviate some of the fear about Gen-AI models [12].

Before reviewing our findings to advance the science of teams, we consider a problem that plagues all dynamic teams: Measuring a dynamic team produces i.i.d. data [11] which neither supports the recreation of what was viewed (viz., like the frames of a movie, i.i.d. data at best provides an illusion of what has been captured). This improves our assessment of Nash's game result [16], but not our negative appraisal of Axelrod's [17]. For a team of interacting agents, the i.i.d. data collected not only cannot recreate whatever has been collected, but also since it cannot hold tension [18], accident reports while helpful [19] are not definitive [20], making predictions difficult and innovation less understandable. We address both problems below.

2 Findings

A selection of our findings relevant to this report (cf. full review at [21], including social networks [22]):

Using game theory with feedback to model interdependence, the author's dissertation replicated Nash's equilibrium [16] of countering (i.e., competition) and Axelrod's [17] result for cooperation, but with no way to distinguish between or combine them. In the conclusion for this review, minimum redundancy combines these results.

Human-machine teams need mathematics to fully function, but the 2015 National Academies of Sciences report proposed no mathematics [23]. The reason has now been reckoned by us as i.i.d. data [18], forcing us to a theoretical approach. Theoretically, if interdependence is a resource [21], anything that reduces it performs at a lower level. Thus, we hypothesized that increased redundancy would harm performance, supported by our finding with the largest oil companies in world; e.g., Exxon and Sinopec are equivalent producers, but Sinopec has 8 times as many workers, contradicting social network theorists [22]). Replicated with top militaries in the world, in addition, we found a significant correlation with redundancy and corruption (reviewed in [12], [20]). However, our i.i.d. data model suggested the existence of hidden data, made more difficult to unravel as team redundancy decreased, suggesting this equation:

$$S = \lim_{Structure \to unit} \ln(Structure) = 0 \quad (1)$$

This extraordinary result has been supported: The structural effects of interdependence are hidden (viz., given structural entropy production, or SEP, then $\Delta SEP \to min$, where "Delta" represents uncertainty), embodied information, supported by the National Academy of Sciences [23] reporting that interaction contributions cannot be disentangled (cf. p. 341, [24]).

This success led to an uncertainty relationship in team interactions; i.e., "squeezing" uncertainty in a team's structure (e.g., choosing capable candidates for roles that fit together reduces structural entropy production, or ΔSEP, and amplifies a team's productivity; i.e., increasing maximum entropy production, or ΔMEP). For example, the most powerful hurricanes have the tightest structures [12]. In contrast, top-down command decision-making (CDM) teams are composed of separable, non-interdependent units, providing disadvantages for authoritarian-based teams (but no disadvantages for their leaders who can become wealthy and powerful, as in China or Cuba, but while countering [16] fears of gen-AI, see [13],[14],[25]) versus the advantages offered to freely interdependent teams home-based in democracies [12],[26]:

$$\Delta SEP * \Delta MEP \geq 1 \quad (2)$$

This equation exposes a difference between separable systems (viz., CDM, especially under authoritarian control, but any separable system; e.g., gen-AI).

Our first generalization ($\Delta SEP \to \infty$): Considering action in the mind with i.i.d. data alone could explain why games do not capture the reality modeled [27] (reviewed by [28]: “reinforcement learning methods in real-world, large-scale multiagent problems … are currently unsolvable.”) For example, from repeated prisoner dilemma games, Axelrod [17] claimed: "the pursuit of self-interest by each [participant] leads to a poor outcome for all," avoided, he continued, when sufficient punishment discourages competition. Contradicting Axelrod and Skinner, Cassidy [29] counters that the free market: "is soulless, exploitative, inequitable, unstable, and destructive, yet also all-conquering and overwhelming."

Supporting Cassidy, we have found that forced cooperation, including consensus-seeking [30], produces the poorest outcomes for national defense [31] or nuclear waste cleanup [32], but that maximum interdependence produces the best outcomes during competition ($\Delta MEP \to max$) while surprisingly maximizing cooperation [31].

For our second generalization, we found that randomness infuses social affairs [33],[34] in the search for fitness, characterized by reduced structural entropy production ($\Delta SEP \to min$) and increased performance of an interdependent whole ($\Delta MEP \to max$; in [35]), described by assembly theorists as complexity [36],[37], and by us as a resource for innovation [12].

With our third generalization, we found that interdependence transmits additive or destructive interference across all forms of life [20]. For a team, impeding interdependence produces destructive outcomes (i.e., $\Delta SEP \rightarrow max$, e.g., corruption, thievery, vulnerability; in [31]), whereas exploiting interference produces competitive advantages (i.e., $\Delta MEP \rightarrow max$; e.g., innovation, cooperation, evolution; in [20]).

Our fourth generalization dealth with orthogonality. The education of Air Force combat fighter pilots had no effect on performance, while training did [39]. The opposite effect was found for education in Middle Eastern African Countries (MENA) and patent productivity, led by Israel (reviewed in [12]). We apply these two results to explain the validation crisis [2],[38] represented by the ongoing failure of social psychological concepts (e.g., the invalidity of self-esteem [39], implicit racism [40], priming [41], honesty [42], ego-depletion [43]). The failure of education (air-combat pilots) versus the success of education (patents) may be explained by an orthogonality between classical cognitive concepts (C) and the behavior (B) they are meant to represent (e.g., the dot product of vectors C and B goes to zero: $\bar{C} \cdot \bar{B} = 0$). To merge concepts and physical reality, as Einstein did during his great struggle to derive general relativity, requires effort [44].

Our next generalization was with Schrödinger's equation and the uncertainty relations for time, as teams "squeeze" time uncertainty, the tradeoff causes energy use to increase proportionally (i.e., given $\Delta t \cdot \Delta E \geq 1$, as $\Delta t \rightarrow min$, $\Delta E \rightarrow max$), a quickening of time in the interaction; e.g., support comes from the *Wall Street Journal* [45]: "High-speed traders often seek to capture fleeting differences between prices of related assets, making quick response times critical."

Next, if Noether's theorem [46] on symmetry generalizes to larger structure-performance tradeoffs ($\Delta SEP \leftrightarrow \Delta MEP$), we conclude that productivity increases as N increases but only if N remains interdependent, matching the findings of Cummings [26]. To fit the results found so far, we estimate the cost for CDM (authoritarian or consensus-seeking rules, both which block decisions that need be disfavored by only one agent) with the next equation:

$$Power\ (P) = z \frac{\sum_i^n teamwork}{\delta t} \quad (3)$$

where $z = r/k$. For freely organized teams, r ranges from 1 to 2 or more, but r is reduced for authoritarian or consensus-ruled teams (see examples in Table 1 below). For home-based authoritarian teams, r becomes:

$$\frac{1}{r} = \sum_i^n \frac{1}{n} \quad (4)$$

For k,

$$k = \frac{SEP(target\ team)}{SEP(average\ competitors)} \quad (5)$$

Table 1: Examples of estimated calculations to model findings in the literature:

Example	r	k	z=r/k	Evidence
Consensus-seeking	3	1/2	2/3	DOE's Hanford CAB: No HLW tanks closed of 177 tanks v. SRS 8/51; in [32]
Authoritar-ian	3	1	1/3	Equivalent agents, no interdependence; e.g., redundancy in Sinopec v. Exxon; in [31]
Freely self-organized	2	1/4	8	SpaceX's Dragon spacecraft v. Boeing's Starliner; in [20]

Our fifth generalization concluded that spies rely on deception to execute spying activities or even espionage. Before committing an act of spying or espionage, whether with covert channels or in the open, the actions they want to take include minimizing their presence until their deeds are done (i.e., $\Delta SEP \rightarrow min$). An example is Aldrich Ames, hired by the Central Intelligence Agency agent but convicted of espionage for Russia in 1994 [47]. His actions led to the deaths of numerous American assets.

3 Conclusions

To summarize, it appears that humans have two cognitive systems, which Simon [48] failed to capture and Kahneman [49] had begun to address, one being cognition and the other hidden and embodied [50]. Failing to account for interdependence, classical models of teams generalize poorly, nor do their models predict advantages. In contrast, we have contributed to the science of teams with our theory of the entropy produced interdependently between a team's structure and its productivity. The result, a quantum-like model of teams based on interdependence, generalizes and models self-organized advantages not foreseeable under command decision-making (viz., authoritarianism; i.e., $\Delta SEP \rightarrow max$, $\Delta MEP \rightarrow min$, or both), and may help to 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 time create spacetime (e.g., for the struggle to overcome, see [44]).

Before ending our review, we consider a sample from the short history of interdependence applied to machines. First, the F-16 fighter jet caused a loss of consciousness (LOC) in fighter pilots who lost awareness after excessive high-speed maneuvers that produced the experience of G-effects sufficient to cause a pilot to pass out, known as G-LOC. When G-LOC occurs in the F-16's pilot, the plane takes over to give the pilot time to recover [51]. Second, an interdependent production of new laser materials has been operational for a couple of years [52]. Many other interdependent mechanical systems have arisen, including self-driving cars and taxis. But these are all reactive systems, designed to execute well-established protocols. However, these machines are neither self-aware of their reality or actions, and, unlike human heroes, cannot be quizzed about the actions they took to save a life. To know why an action took place, say a fatality like Uber's pedestrian fatality in 2018, investigators pour over all of the (i.i.d.) evidence available, test their findings, and issue a public report [19].

In conclusion, interdependence in freely organized teams operates on structures interdependently like entanglement to promote adaptability, resilience, innovation, and more. But when teams are measured, only i.i.d. data is produced, which, by definition, cannot reproduced what has been observed (e.g., like the static frames of a movie or video that, at best, produce an illusion of reality [53], illustrating a key operation of the brain to enjoy illusions [54]; nor does i.i.d. data support tension [18]). Innovation explains the value of a culture that supports interdependence [55], a threat to authoritarians, but also why autocrats must steal innovations to keep abreast [56],[20]. AI is presently creating existential fear [13],[14], offset, we argue, by the advantages of freedom [12].

Contradicting Skinner's reinforcement theory [10] and its interpretation by Axelrod [17], maximum cooperation occurs and works best in minimally redundant teams during maximum competition against other teams, our contribution here.

4 Future Research

Nash's C-C countering choices between competitors creates an equilibrium [16] that models free choice, resolved by majority rule, checks and balances, and action in the U.S. In contrast, forced cooperation reduces information or produces stalemate [32]; e.g., consensus rule used in the European Union [30]; National Academy of Sciences; and China.

For our future research, we focus on how to control teams composed of any combination of humans, machines, AI, and robots. Random effects routinely occur in the social, political and business worlds (e.g., with business mergers, see [57]), including with teams. Compared to authoritarian regimes which use punishment [10],[17], dampening interdependence, we speculate that control works best with self-organized teams, and that control for superior teams arises from interdependently coupled quantum-like harmonic oscillators [12] freely organized to use the entropy produced by a team's structure and its maximum performance. When coupled interdependently as one, we speculate that the entropy generated in the mind of a team's leader is bidirectionally coupled to teammates like harmonic oscillators, all at low structural entropy producing high performance entropy across a freely operating team inside of a supportive culture [58], a structure within a system.

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