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Entropy of teamwork: Multitasking and Effectiveness

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Abstract: Traditional social models discount the theoretical value of interdependence, the defining characteristic of social behavior, in favor of cooperation, a shift to least entropy production (LEP). But, theoretically, teams organized like distributed processors overlook the interdependence in multitasking. As a simple example of interdependence, foraging deer overgraze in forests free of predators. In our model, interdependence entails uncertainty, tradeoffs, and teamwork. Unlike individuals, the ability of teams to multitask reflects a quantum-like entanglement that suggests the application of maximum entropy production (MEP) to problems that improve social welfare. Our model supports findings in the literature that evolution in nature is driven by the MEP from intelligent choices. Exploiting interdependence improves team intelligence; forced cooperation dis-organizes it; e.g., if local cooperation improves teamwork, widespread forced cooperation under autocracies reduces social intelligence. In our model, competition between teams self-organizes outsiders willing to sort through the noise for signals of the choices that improve social welfare (e.g., juries in courtrooms). Social systems organized around competition (checks and balances) better control a society than autocracies due to their inefficiency in sizing teams to solve problems. Overall, we predict, the density of MEP directed at solving problems in a society able to freely self-organize its labor and capital is denser.

Keywords: interdependence; maximum entropy production; teams; multitasking;

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1. Introduction

Beset by the lack of replicating important social science research (e.g., in psychology [1]; in economics [18]) reduces the generalizations that social science has to improve society that are not normative. Compounding the failure to replicate, discounting the value of interdependence, the defining characteristic of social behavior, most of social science is focused on the individual, including economics [2] and the law [3]. In fact, social psychologists recommend that interdependence be removed or avoided (e.g., social psychology, in [21]; information theory, in [22]). While game theory incorporates interdependent choices [24], it negates its value with toy problems [27] designed to overstate the value of social cooperation [4], an atheoretical result that models least entropy production (LEP). And yet, the most basic tool of traditional social science, the self-reported observations by individuals, has left social scientists unable to comprehend how to resolve their inability to find sizable correlations between self-reports and behavior [23]. Despite this uncertainty with the replication and meaning of its basic data, social scientists strongly believe that cooperation is superior to competition, but some of them at least admit that "the evolution of the human mind is a profound mystery" (e.g., p 8999, [19]).

Traditionally, teams have been organized around a division of labor, like distributed processing where a job is divided into *n* processors [5], overlooking the large benefits derived from exploiting interdependence with multitasking [11]. Individuals are poor at multitasking [26], the function of teams; e.g., like the independent roles for the players cooperating together to form a baseball team. Heretofore, interdependence has long been an unsolved theoretical complexity; e.g., Von Neumann and Morgenstern feared that if Bohr was correct about the interdependence between action and observation, it would make a rational model of the interaction "inconceivable" (p. 148, [24]). More importantly, by basing our model on interdependence, we calculate that the reduction in the degrees of freedom (*dof*) for the individuals who constitute a team is similar to quantum entanglement.

In our model, the perfect team is composed of independent agents working interdependently; by exploiting interdependence, the reduction in *dof* helps the team to generate LEP from internal cooperation among teammates to maintain structure, the small expenditures of energy on structure allowing a team to maximize entropy production (MEP) on the problems the teams was formed to address, thereby driving social evolution. In fact, "evolution (progress) in Nature demonstrates … maximization of the entropy production ([6], p. 1152). This is further brought home with the recent work on Entropic Intelligence [7] to stress that the most intelligent choices follow curves that maximize entropy (where $\boldsymbol{F}$ is the entropic force; T the reservoir temperature; $S(\boldsymbol{X})$ the entropy associated with macrostate $\boldsymbol{X}$; and $\boldsymbol{X_0}$ the present macrostate):

$$F(\boldsymbol{X}_0) = T\nabla_{\boldsymbol{X}} S(\boldsymbol{X})|_{\boldsymbol{X}_0} \quad (1)$$

The key to understanding equation (1) is that the search for the paths to the macrostate $\boldsymbol{X}$ that are most likely to maximize MEP must avoid "excluded" volumes (p. 168702-1, [7]). Non-equilibrium systems, such as the intelligence displayed by human and machine teams (i.e., hybrid teams) and higher organizations of teams, measured by productivity, have a bias for instantaneous MEP [20] at each instant in time across all possible paths through configuration spaces that seek to avoid "excluded" volumes [7]. That this information is dynamically revealed [16] suggests a role for intelligent observers in instantly seeking the path to the microstate at each instant that is most likely to promote MEP [7]. Should this state be recognizable and determinable [10] leaves open two questions: "How?" and "How to avoid excluded volumes?"

We have also applied our model to understand the dis-organization from social systems that widely enforce cooperation in a fashion that reduces intergroup competition, in effect increasing the size of "excluded" volumes: gangs; authoritarians (e.g., China); and large bureaucracies (e.g., the U.S. Department of Energy, or DOE). Increasing the size of excluded volumes occurs when teams are fragmented by enforced consensus decision rules [17]. For example, instead of using MEP to address its problems, present-day China is creating uncertainty that impedes a random search for MEP as it, instead, expends energy to tear apart its self-organized social structures, thereby reducing its social intelligence and social welfare [9]. Autocracies work by decreasing intergroup competition; e.g., in politics; in the law; and in environmental practices. While competition leads to centers of self-organization able to generate MEP [14], open competition also generates the instability and uncertainty that have long offended socialists [13]. Why is competition necessary?

To answer this question with our model, we envision that the frisson from competition attracts the onlookers (e.g., neutral voters in a political campaign; jury members in the courtroom; computer users seeking new hardware) who are willing to sort through the noise to find the signal for the options, paths and choices that better provide the resources needed by a society to improve its social welfare [14]. The surprise with our approach is that social systems organized around competition (checks and balances) are better able to control the many elements of a society than authoritarian regimes (e.g., on the inability of China to control the lower-level managers of its economy, see [12]).

2. Results and Discussion

By being inefficient in optimizing the size of teams able to solve a problem they deem important, authoritarian regimes are unable to reach the levels of MEP comparable to free-market economies e.g., authoritarian decision-makers prefer consensus decisions, otherwise known as minority control [17].

As an example of consensus decision making from the EU [28]:

> 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." (p. 29, [28])

As another example, DOE-WIPP data for DOE's Citizen Advisory Boards (CAB) following majority-rule (MR) versus consensus-rule (CR) decision-making indicated that teamwork and compromise between factions was more prevalent under MR while teams were more fragmented under CR [17]. Specifically, we found that four of five MR-CABs accepted the recommendations of DOE's scientists regarding the operation of WIPP's transuranic waste repository compared to three of four CR-CABs that rejected the same advice. This result indicates that majority rule teams are more highly interdependent than consensus ruled teams.

Similarly, recent research indicates that the best teams of scientists are highly interdependent [8].

3. Experimental Section

Hypothesis: The open systems that create and separate information from noise (higher T) better determine macrostate$\{\mathbf{X}\}$ paths than the closed systems which obfuscate information (lower T) by increasing the size of its “excluded” volumes [14]. The driving force for social evolution ([14] [19]), more likely in democracies than autocracies, competition between groups [10] forces teams to survive by becoming effective and then efficient. Democracies with healthy checks and balances not only generate noise but the solutions to problems; under majority rule (MR), opposing viewpoints are more likely to lead to a solution, suggesting that opposed teams are fighting through the combination of noise and information to find the signal for the information that indicates an better path forward. In contrast, the fragmentation from consensus rules (CR) increases the degrees of freedom of a team, leading to less success [17]; e.g., that autocracies censor public discourse leads to the misallocation of team resources.

Authoritarian regimes are unable to reach the levels of MEP comparable to free-market economies by being inefficient in optimizing the size of teams able to solve a problem they deem important; e.g., Sinopec oil company uses about 548 thousand employees to produce about 4.4 million barrels of oil per day whereas Exxon uses about 82 thousand employees to produce about 5.3 million barrels of oil per day [14].

Autocracies, surprisingly, are also ineffective at gaining widespread social cooperation with the law by not adhering to the value of the checks and balances afforded with the law; thus, autocracies are less effective at gaining the same level of cooperation than democracies which operate with more effective checks and balances [14]. Less effective with matters of the law increases team fragmentation and internal competition.

As an example, Indonesia is the 105th freest country in 2015 [30]. The following example exemplifies the inability of Indonesia with its environmental affairs [26]:

Indonesia is preparing [its] Navy ships to evacuate citizens suffering from a toxic haze that has spread throughout the region and grounded flights as far away as the Philippines and Thailand.

As another example, the military productivity of Iran, an autocratic theocracy, is less effective than the military productivity of Israel, a constitutional democracy [29].

The central planning by autocracies leads to resource misallocation, increasing entropy but not entropy focused as MEP, thereby increasing waste far more than societies governed by free-markets. Central planning also reduces the competition that drives innovation [31]. For example, Europe is turning against biotech science [32].

4. Conclusions

From our work-in-progress, we conclude that Authoritarian regimes are unable to reach the levels of MEP comparable to free-market economies by being inefficient in optimizing the size of teams able to solve a problem that has been deemed important.

Unlike rational decision-making (lower T), the key to causal entropy forces is to search for and to find a point (higher T) of instability [7] common to decision making by those human groups free to explore the configuration space for solutions, and where choices have the potential to head in maximum manifold directions at any instant in order to solve the problem faced by a team. This instability is more likely to occur with decision making in democracies than in autocracies.

Applying equation (1) to hybrid teams of humans, machines and robots, our model exploits interdependence to improve teams, their decisions, and, by generalizing, social intelligence [8]. Finally, we expect to find in future research that the density of MEP directed at solving problems in a society able to freely self-organize its labor and capital is denser.

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Author Contributions

Both authors contributed to this research.

Conflicts of Interest

The authors declare no conflict of interest.

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