Information density functional theory: A quantum approach to intent

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Abstract

Trust from the perspective of traditional social theory is a function of the cooperation promoted across a system of multiple human or artificial agents, assuring that conflict ends with a consensus of the facts drawn from reality, *R*. Overlooked is the downside of cooperation (e.g., invisibility of corruption, terrorist sleeper cells), and the reduction in computational power from the costs to communicate with an increasing number, *N*, of agents cooperating in an interaction, making the traditional model impractical for a large system of computational agents to solve difficult problems. In contrast to logical positivist models, quantizing the pro-con positions in decision-making may produce a robust model of argumentation that increases in computational power with *N*. Previously, optimum solutions of ill-defined problems, *idp*'s, were found to occur when incommensurable beliefs interacting before neutral decision makers generated sufficient emotion to process information, *I*, but insufficient to impair the interaction, unexpectedly producing more trust compared to cooperation. We extend this model to the first information density functional theory (IDFT) of groups.

Introduction

Emerging information indicates that when terrorist factions fully cooperate with outgroups across the social fabric, especially with a society's institutional representatives, they can operate with impunity virtually unnoticed, making it difficult to detect the signal of adversarial groups intent on violence. Intent inference research with humans has largely been unsuccessful, including with scientists trained to draw inferences (Axsom & Lawless, 1992); it has only worked in the laboratory under conditions structured to make salient individual choices and behavioral commitments (Eagly & Chaiken, 1993). No better example of the failure exists than the inability to apply these and other laboratory findings to decisions made in the field (Klein, 1997). The problem has been attributed to the lack of an effective theory of group formation, group dynamics, and a reliance on aggregated observations of individual agents as the primary measure of group processes (Levine & Moreland, 1998), even though the shift from individual to group perspectives has long been considered the major unsolved problem in social psychology (Allport, 1962). For these reasons, the recognition has grown that theory predicated on the individual rational perspective, like game theory, is unsuitable for studying problems associated with cooperation (e.g., asymmetric *I*; Stiglitz, 2002), contrasts between individuals and groups (Luce & Raiffa, 1967), or even determining why groups exist or their function (Lawless & Castelao, 2001), let alone providing a theoretical structure for computational group dynamics.

Table 1: Some of the strengths and weaknesses of game theory.

Strengths	Weaknesses
Rational model of the interaction (event trees, conditional probabilities)	Emotion is not integral to the model
Mathematical logic of interdependence	Uncertainty is modeled sequentially, not interdependently (i.e., observation uncertainty is independent of action uncertainty; Von Neumann & Morgenstern, 1953, pp. 147-8)
Mixed motives of conflict and cooperation	Argumentation, incommensurability, and diversity have zero social value (e.g., Nash, 1950)
Mathematical equilibria (e.g., Axelrod, 1984)	Static configurations and equilibria force information processing (*dI/dt*) to occur "extra-rationally" (i.e., contingent on others)
Quantitative utility of expected outcomes	Arbitrary utilities for cooperation and competition lead to explanation versus prediction, overstating the value of cooperation (e.g., Shearer & Gould, 1999; Axelrod, 1984)
Learning is predicated on rewards and punishments (traditional Social Learning Theory--SLT)	SLT occurs outside of awareness, devaluing rational problem solving skills
Models lead to clear predictions	No lab (Kelley, 1992) or field validation (Jones, 1998)
First models of group behavior	Shifts between individual to group utility or ingroup to outgroup utility cannot be studied
Generalizable	Conclusions are normative (Gmytrasiewicz, 2002)

Rational theorists counter that models of the interaction from game theory have provided a successful test bed for military maneuvers, including nuclear war and terrorism (e.g., Woo, 2002). One of the benefits of game theory is that it allows an event tree to be constructed with conditional probabilities that follow the planning steps in a military engagement, or the interdependent steps and contingencies that a terrorist might follow to attack a target. However, the probabilities for each of these steps are often estimated by experts, rendering a value little different from expert planning. For strengths and weaknesses of rational theory, specifically game theory, see Table 1. Regarding agent based models (ABM's), while traditional social learning theory, such as reward reinforcement, affords the means for machine learning (Bankes, 2002), this learning is "extra-rational" or outside of agent awareness, devaluing mindful problem solving (Lawless, 2002).

In past research, we have shown that the benefits associated with competitive, market economies and liberal democracies include modern science, sophisticated technology, better health, and less corruption (Lawless & Castelao, 2001). These benefits are so pervasive compared to those from other forms of decision-making (e.g., democracies do not suffer from famine, and are less likely to make war on each other; in Sen, 1999 and Wendt, 1999, respectively), the question arises why democratic debate is not used more widely to solve problems. One answer in Plato's *Republic* is now the traditional belief that the best individual reasoning is superior to the turmoil in a democracy (Benardete, 2002), a justification common to command economies (e.g., U.S. steel protectionism in 2002; bureaucracies; and dictatorships; see Hayek, 1944), supported by the illusion that turmoil in democracy precludes trust (Worchel, 1999).

Traditionalists believe that the best societies avoid turmoil and improve trust with reward reinforcement instead of competition, exemplified, according to Skinner (1978), by Communist China in the 1950's at a time, although he was unaware, millions of Chineese had died from famine (Chang, 2001). These beliefs are predicated on devaluing competitive turmoil, but which we have found is interdependent with better living standards, science, and health. As an example of interdependent turmoil at the national level, the most competitive airline today, Southwest Airlines, has a market value nearly twice that of all the airlines larger than it combined (i.e., American, United, Delta, Northwest, Continental, and US Airways), yet its price leadership (7.5 cents per mile in 2002) has benefited all consumers by reducing the average cost of 18 cents per mile flown in 1989 to 12 cents in 2001 (ATA, 2002); in August, 2002, Southwest Airlines further reduced its average fare by 25%, forcing several major airlines already suffering from significant losses to further reduce their fares. As an example of interdependence at the international level, competitive nations attract international investors by constructing conditions favorable to investment (low taxes, labor, and pension costs), increasing the value of their currency and reducing corruption by promoting transparency (e.g., Germany's high costs have weakened the euro at the same time that its corruption index has worsened; Lawless & Castelao, 2001). Clearly, intent can be easily inferred under competitive turmoil and not under cooperation. A possible reason comes from Wendt (1999, p. 360), who concluded that, paradoxically, intent inferencing occurs not under cooperation but when differences are respected.

To overcome the weaknesses with traditional models anticipated by Von Neumann & Morgenstern (1953, pp. 147-8) requires an interdependence between uncertainty in action I, Δa (where $I = -\sum p(x) \log_2 p(x)$, and I flow = $a = \Delta I/\Delta t$), and I uncertainty, ΔI, to give

$$\Delta a \Delta I \geq c \qquad (1)$$

According to Equation (1), as $\Delta a \rightarrow 0$, $\Delta I \rightarrow \infty$, implying that as skills are maximized, observations by self-observers become unbounded (since c is unknown, boundary conditions are used; in the inverse case, as $\Delta I \rightarrow 0$, $\Delta a \rightarrow \infty$; see Lawless et al., 2000). To optimally process I as prelude to choosing the best action under uncertainty, I is generated from orthogonal differences (argumentation; dialectic) between groups, like Republicans and Democrats on the last presidential election, that can then be used to solve problems (Lawless & Schwartz, 2002). Argument clarifies intent. Arguments also generate tension and emotional responding, but if managed to preclude conflict, convert I into knowledge, K (Lawless, 2001). Our findings above agree that, compared to consensus processes, emotions generated in decision makers if managed are associated with better decisions, more trust, and less conflict at local and national levels (to review trust, see Wendt, 1999).

Conversely, to obscure intent, since tension leads to an acute awareness of its source, maximum deception occurs when deceivers act cooperatively to minimize disagreement with opponents, effectively remaining unseen by reducing emotional responses to their presence or politics. To maintain power by deception, dictators or terrorists must block or hide I flow.

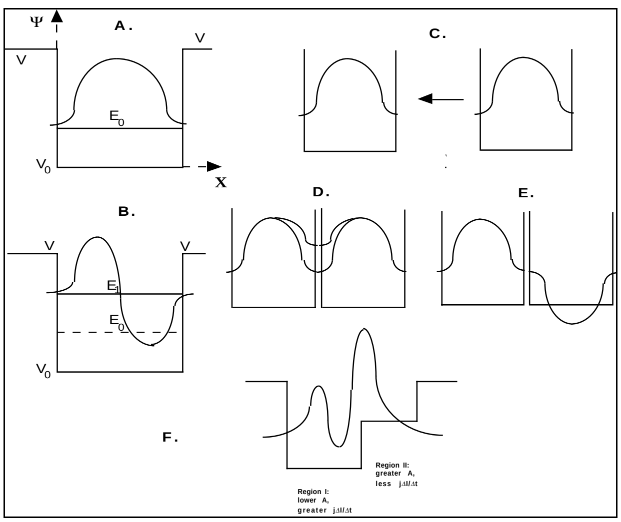
The social interaction is an entangled state that processes I, but once severed renders accounts as individual histories that cannot recreate the interaction (from Zeilinger, 1999), explaining the lack of validity with self-reports (Eagly & Chaiken, 1993), making the intent of deceitful adversaries all the more uncertain. One approach to detecting intent is to study a group's reactance to change. If personality, j, is a stable response to information change or reactance (Brehm, 1966), analogous to "mass", Equation (1) can be revised to time, Δt, and energy uncertainty, ΔE (Lawless et al., 2000):

$$\Delta a \Delta I = \Delta (\Delta I/\Delta t) \bullet \Delta t/\Delta t \bullet \Delta I =$$

$$= j \bullet \Delta\ (\Delta I/\Delta t)^2 \bullet \Delta t = \Delta t \Delta E \geq c \qquad (2)$$

Equation (2) predicts that as time uncertainty goes to zero, E becomes unbounded (e.g., big courtroom cases, science, or urban renewal projects); inversely, when ΔE goes to zero, time becomes unbounded (e.g., at the low E expenditures around resonance, voice boxes easily operate for a lifetime). Quantizing the interaction results in E wells localized around ideas or beliefs as set points, accounting for the stable reactance to social change we defined as information inertia, j (Figure 1.A; for a review of set point theory, see Diener in Lawless, 2001). As increasing E levels approach set points (Figure 1.B), emotions increase, forcing a return to stability (e.g., an "insult" provokes an automatic response from an agent as its set points are engaged, or a group when its "laws" are broken).

Figure 1. From the Schrodinger equations, a square-well representation of I (where $I = f(x)$; from Latane, 1981) is bounded when $E < V$, with V the emotional potential E associated with a belief. As E pumped into a belief attempts to redefine its meaning, V acts as a barrier, producing stability. 1.A. Ground state E_0 generates a probability (ψ) wave concave down or up from the same equation, with $|\psi|^2$locating I (for $\Delta I/\Delta t$, see Lawless & Castelao, 2001). 1.B. First activation level is at E_1. 1.C. I from two separated square wells brought together superimposes into a joint ground state (1.D) or the first excited level (1.E), approximated with a Schrodinger-like equation of both wells. 1.F. Compared to novices, the deeper square wells of experts model denser I flow yet display smaller amplitudes to external observers (see Landers, in Lawless & Schwartz, 2002).



Axtell (2002) rightly questions the application of quantum theory to the social interaction based on the orders of magnitude separating the atomic and social levels. But his belief that application supervenes validation is a test that game theory has never passed (see Table 1). Several reasons exist to use the quantum model. The brain acts as a quantum information processor, converting photons hitting the retina into usable information (French & Taylor, 1978). Unlike the continuous model of traditional signal detection theory (i.e., ROC curves), the Bèkèsy-Stevens quanta model is based on detecting discrete stimulus differences from background for one physical dimension such as E or frequency, ω, producing a linear relationship between threshold and saturation (viz., a 2:1 detection variability gives a range of about 2-4 dB in intensity or frequency around the 60 dB of ordinary conversation; for a review, see Luce, 1963, 1997). Also the dichotomous choices in social decision making have been quantized (e.g., Eisert et al., 1999). And the implication that the left side of Equation 2 always exceeds the right has been established; e.g., based on the Penrose-Hameroff model (Hagan et al., 2002), if I from across the brain can be modeled as a single unit (i.e., Figures 1.D and 1.E), and if c is Planck's constant, h, then $\Delta E \Delta t = \Delta(h\ \omega/2\pi)\Delta t \geq h/2\pi$ reduces to $\Delta\omega\Delta t \geq 1$. Choosing ω as gamma waves associated with object awareness of about 40 Hz gives Δt of 25 ms, a reasonable minimum in that Crick and Koch (1998) have concluded awareness occurs between 200 to 500 ms, even though responses to stimuli occur outside of awareness in a much shorter interval.

Information Density Functional Theory-IDFT

IDFT approximates the function of I density and discrete E effects in an organization of adding or removing members. A group forms or reforms by entangling I from an aggregation of individuals to solve an ill-defined problem, *idp* (Ambrose, 2001), like designing a complex weapon. The chief characteristic of an *idp* is that K concepts do not correspond to objects or actions in R. Once solved, however, an *idp* becomes a well-defined problem, *wdp*, characterized by a correspondence between K, skills and R (Sallach, 2002), such as the set of interactions a closely knit team experiences to build a house (cooperation implies low I density, maximum K, and E ground state). In the solution of *wdp*'s, individuals function in roles bonded into a stable network oriented by a shared emotional potential E field; e.g., stock options were designed but failed to align the interests of management and stockholders (Hall & Knox, 2002).

The potential E surface (E^{PES}) represents the function, hierarchy and geo-cultural differences across a group, organization, or society (Sallach, 2002).

$$E^{PES}(x,y) = min_{z,R\text{-}org}\ E^{TOT}(x,y,z,R_{org}) \qquad (3)$$

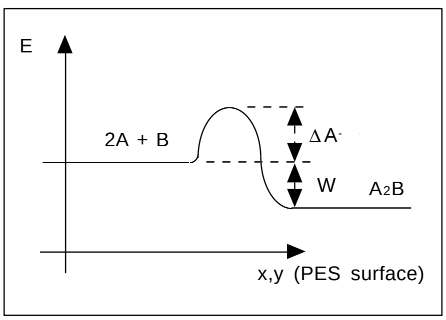
A potential recruit moves across the E surface of an organization, R_{org}, where E^{TOT} is the ground state and PES the minimum total E along the z coordinate of the organizational configuration, including its hierarchy, until reaching a minima (stability or metastability). The growth rate (nucleation) of an organization fits a pattern, with different processes, P, like diffusing or adsorbing recruits, given by:

$$\Gamma_P = n_A n_B\, a\, \sigma_{AB} \exp(-\Delta A / k_B T). \quad (4)$$

where n_A and n_B are the numbers of recruits and leaders interacting; $a = \Delta I/\Delta t$; σ_{AB} is the cross-section (the probability an interaction produces usable E, ΔA, is an area determined by the vocal frequency of indoctrinators, ω, and recruits, ω_0, increasing rapidly as language "matches" increase or differences decrease; i.e., $f(\omega^4/(\omega^2-\omega_0^2)^2)$); $exp(\bullet)$ is the probability of sufficient free E, ΔA, for the activity to go forward; k_B is Boltzman's constant; and T is temperature, where $T = \partial E/\partial I$ (see Lawless, 2001). Equation (4) indicates that the more ΔA required for an activity, the less likely it occurs; that friendship is optimal for those who listen to synchronize with each other, similar to a state of resonance between harmonic oscillators; and that terrorists cooperate to increase their cross-section to preclude warning observers about their hidden intent. But why does a group stick together?

Once a bond forms between two members, A and B, the ground E state of the group is less than the aggregate ground state of its members, the difference being the binding E, W. The E required to reverse the process and break apart the group becomes $\Delta A + W$ (Figure 2).

Figure 2. The binding E to form a group or break it up. Shown here, two followers (2A) bind together with each other and then to one leader (B) to form a group (A_2B).



W is calculated from the configuration of barriers and nearest and next-nearest neighbors. Assuming that two recruits (A) bind to one another and to one leader (B), the Hamiltonian consists of a site contribution, H_0, and an interaction term, H_{int}, giving

$$H_0 = E_b^A \sum_k n_k + E_b^B \sum_k m_k + V^{A-B} \sum_k n_k m_k \quad (5)$$

where k as a role site, n_k, is either 0 or 1 if k is empty or filled, m_k is the same for leader sites, V is an interaction parameter, and

$$H_{int} = 1/2 V_{1n}^A \sum_{k,a} n_k n_{k+a} + 1/2 V_{2n}^B \sum_{k,b} n_k n_{k+b} + 1/2 V_{1n}^B \sum_{k,a} m_k m_{k+a} + 1/2 V_{2n}^B \sum_{k,b} m_k m_{k+b} + 1/3\, V_{trio}^B \sum_{k,a,a'} m_k m_{k+a} m_{k+a'} + \ldots \quad (6)$$

Here $k + a$ and $k + b$ denote nearest and next nearest sites.

As an aggregate of individuals with independent sets of beliefs first interact, arousal is likely (Figure 1.E) from audience effects (Zajonc, 1998), potential threats, or belief incommensurability, but these effects eventually reduce to the ground state for stable interactions that serve the group (Figures 1.D, 2), forming interdependent emotional fields that orient shared cognition (K) and skills (roles) to correspond with R from constructive interference (e.g., Zlot et al., 2002). Barriers in the joint emotional field channel beliefs and skills to interlock with roles and R. New shared cognitive and skill fields can be constructed mindfully (e.g., jointly selecting new terrorist targets or camps) or not (learning by acculturation, or indoctrination); regardless, the goal is to "unfreeze" prior constructions and skills (Lewin, 1951) to change and stabilize new set points over time, the amount of effort (training) determining well-depth (Figure 1.F). Effort expended to convert I into K, and to recruit, indoctrinate, and train new members departs from resonance ($\Delta E > 0$), where conservation of E applies.

The processes above (Equations 3-6) can be used to model a heterogeneous group. Stresses resulting from a mismatch between an organization and new members can instead model a terrorist sleeper cell in a society. As a heterogeneous island nucleates on the surface of a society, the tension on it to be absorbed by the society relaxes the larger the island grows, creating a distance between the society and the island's leaders, the release of E becoming a driving force in the island to build a hierarchy of leaders less like those in the society.

Consider that Osama bin Laden's reactance to the forces arrayed against him led him to build an organization to exploit a rhetoric rich in historical allusion (resonance), gaining power to attract recruits for a new Muslim jihad from peasants and other classes struggling to live under autocrats (Esposito, 1999). "Educators" indoctrinated (unfreezing) the recruits with stories about Westerners who co-opted Muslim lands and resources over the last century, attacked Muslims in the Philippines, Chechnya, Kashmir and elsewhere, and instigated United Nations sanctions that malnourished Muslim children.

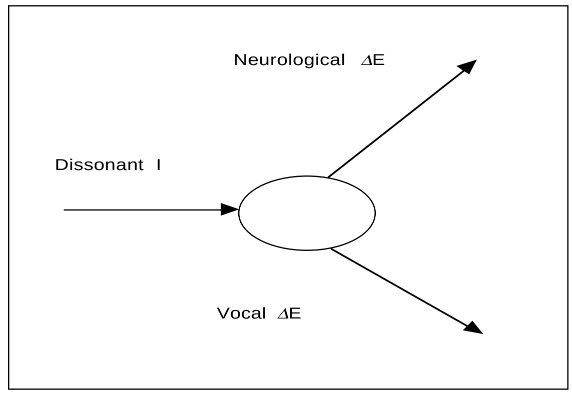
Whether real or perceived, these stories of injustice traced through a history of Islam framed as liberation theologies with overtones of democratic ideals and freedom. In the early years of Islam, education in philosophy, medicine and architecture thrived, but over the past one hundred and fifty years, education has stagnated and in some places become subservient to radical educators who blame Jews, Israelis or Zionists to foment dissension and aggrandize power. Like the Wahhabi educators in authoritarian Saudi Arabia who recruit from Arab masses, indoctrinate them in the desire to "recover" land and resources "lost" to the West and "the Jews", the object was to train recruits to become virulently anti-Western ideologues. As these groups grew, candidates were further selected to train at al Qaeda camps to form sleeper cells composed of well-trained terrorists kept subservient to bin Laden and his leaders by sets of barriers and channels of high potential E.

Joining a group promotes the survival of individuals by reducing *E* expenditures in exchange for membership: social loafing (Latane, 1981); audience effects enhance skills (Zajonc, 1998); greater interaction density promotes health (House et al., 1988); and protecting belief systems (Rosenblatt et al., 1990). In exchange, a group exploits the *E* and skills it collects (Ambrose, 2001), forming a structure around a network of interactions between roles bonded to each other (Sallach, 2002). Generally at the lowest *E* state, interaction exchanges —voice, visuals, products, and money— between agents cycle *I* back and forth in interactions coordinated by common *K* (Wendt, 1999). Among the groups that gain more *E* than it costs to survive (Coase, 1937), some gain sufficient free energy, ΔA, to grow in size, experience and wealth, deepening *E* wells to process more *I* (Figure 1.F), while others merge to offset competitive weaknesses (e.g., Hutchinson Whampoa's bid to merge with Kruidvat in 2002 to sell wireless handsets over Kruidvat's retail network).

Most interactions within a stable organization serve to fulfill a mission, defend a worldview, or acculturate members, but interactions to solve *idp*'s are different. These interactions temporarily shift members from roles, modeled by Equations 1-2, bringing into play factions (underdetermined *R*), neutrals and decision making, where Δt is the time for the system to evolve to an orthogonal state to reach a decision (Aharonov & Bohm, 1961). For optimal decisions, dissonance (argumentation) between polar opposite views processes *I* uncertainty into *K* (e.g., political, legal, and scientific dissonance usually precede optimal decisions; in Lawless & Castelao, 2001). Identifying the optimum solution to an *idp* is analogous to signal detection, the time (Δt) to detect and adopt a solution lasting until the solution signal is separated from social noise; e.g., air-to-air combat, environmental cleanup, environmental disaster recovery, or weather prediction (Lawless, 2002; Lawless & Castelao, 2001).

While cults and terrorists may form regular groups, because their intents if known would be rejected by society, they can only operate by hiding their intents. Cults exhibit increased secrecy (i.e., more cooperation) before a test event to reduce social anxiety from their presence, but should they fail, less secrecy to advertise for members and new *E* sources (Festinger et al., 1956). Similarly, groups with adversarial intents husband *E* by exploiting asymmetric *I* under the guise of being cooperative. But if social dissonance is required to solve an *idp* (Lawless & Castelao, 2001), it is hypothesized that when dissident factions react to dissonance under thresholds lowered by frustration, violence becomes more likely than problem solving at individual (e.g., criminal drug behavior) and social levels (e.g., terrorist suicide bombings). Thus, counterintuitively, one way to test the potential for violence is to stress the system that includes these groups to determine their engagement in social decision making, the extent of their marginalization, or their rapidity for emotional responding (Lawless, 2001). However, given the unreliability of self-reports (measurement collapses the interaction into individual histories that cannot recreate it), a new approach must be initiated to measure physiological *E* states, such as vocal energy changes, to contrast normal and dissonant states (see Figure 3).

Figure 3: Picard's liquid model of emotion suggests that social perturbations caused by dissonant *I* produce a spectrum of emotional responses. Significant vocal *E* changes from normal to angry speech have been confirmed (Lawless, 2001).



Conclusion

At this early stage of development, the primary advantage from using IDFT is the possibility of extending an analytical model that already simulates the conjugate aspects of decision making to one that also simulates organizational growth; e.g., after finding Γ, *then* $1/\Gamma \Rightarrow \Delta t$, and, if *c* is known, ΔE. There are other advantages to IDFT: it accounts for differences between an aggregation and a group constituted of the same individuals (e.g., common *K* is subsumed by collective *K*; in Wendt, 1999); it explains why traditional models based on the individual perspective of rationality fail (e.g., self-reports; in Levine & Moreland, 1998), or why ABM's cannot be validated (Bankes, 2002); and, more importantly, IDFT suggests new approaches to study the interaction. If language is the assignment of meaning to physical vibrations between human oscillators (speech from vocal sounds), and if the primary tool of social science is the self-report, then, in response to Axtell's concerns, it suggests many opportunities for interdisciplinary collaborations that could lead to new tests of falsification by contrasting single versus social *E* states with neuro-physiological-psychological data (self-reports, voice, qEEG's, fMRI's, EMG's, Lie Detectors, etc.) to determine whether as predicted during decision-making for *idp*'s and *wdp*'s that ground and excited states can be distinguished, whether intent inferencing under competition is easier to discern, and whether cooperation enhances deception.

Cooperation is not without value. But the traditional perspective of cooperation, constructed without laboratory, field or analytical validation, is normative, not scientific. We can see, however, first with the conjugate uncertainty relations and now with IDFT, that during negotiations as foreseen by Nash and others but only when driven by competitive forces, cooperation has the broad potential to shape and harness competition to solve *idp*'s and build organizations.

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