The quantum of social action and the function of emotion in decision-making

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Abstract

The rational model of the interaction, as derived from the individual perspective, has been unable to replicate the emergence of social phenomena. But by focusing on the physics of interaction, the recently developed social quantum uncertainty relations provide a computational model that functions for individual and social decisions. In this model, emotion signals in the interaction bind individuals into social units (to operationalize emotion in this study, the focus is on a system of individual and social groups with few and perhaps not very significant individual properties). This new model indicates that voice is a non-invasive tool that may measure emotion in conflict more reliably than self-reports; that the absence of emotion associated with conflict distinguishes well-defined problems (*wdp*) from ill-defined problems (*idp*); and that tension between cooperation and competition produces the emotional responses necessary to generate and process information to make decisions.

Introduction

Artificial intelligence was characterized initially by the belief that collecting the knowledge of experts would render expert behavior rational (Simon 1992); emotion was added later to make artificial agents more human-like (Newell 1990). But the primary assumption was that information, *I*, intrinsic to the interaction and conveyed by language from the choices selected by agents was sufficient to model the interaction (e.g., Von Neumann and Morgenstern 1953). In these models, emotion (from conflict or cooperation) is configured into the choices faced by agents. But while models like game theory look like interactions, by restricting *I* to numerical exchanges inherent in the choices selected by agents, it became necessary that researchers arbitrarily assign values to choices (e.g., non-cooperation has zero social value; in Nash, 1950). The result is a mathematical model of the interaction from which the social fails to emerge (Jones 1998). We postulate that for the social to emerge requires a model that generates *I* exogenous to interaction (Lawless, Castelao and Abubucker 2001); e.g., signals of emotion.

The rational perspective is relatively straightforward, with uncertainty determined sequentially for the dual roles of observation and behavior (e.g., decision theory; Luce and Raiffa 1967). But a physics of interaction must capture simultaneously the uncertainty in the complementary roles of an agent who "acts" while another agent "observes" the action (Bohr 1955). These simultaneous roles produce discrete conjugate sets of *I* from actions and observations, increasing computational complexity exponentially with the number of participants in an interaction. For example, if emotions have positive and negative valences to reflect agreement or conflict, assuming that each rational decision has a single $\pm$ valence component, $2^N = 2^{100} \approx 1E30$ numbers would be needed for an N of 100 agents to represent a simple decision with vectors, far beyond the computational capacity of present computers (Preskill 2000, p. 8). Thus, rational or logical positivist models become impractical as the number of interactants increase. In contrast, while the social uncertainty theory is speculative, its ability to add a distribution of values by superpositioning suggests that it can model the interaction for any *N* (Lawless and Castelao in press).

Little about the function of emotion is understood except from an individual perspective (Zajonc 1998). We know that emotional states are reactive (Bates, Loyall, and Reilly 1992), motivational (Newell 1990), and pattern forming (dispositional; in Wright et al. 1995). Independent of cognition, emotions control, manage, or select choices (Simon 1992) by influencing thinking (Dyer 1987) and appraisal processes (Chwelos and Oatley 1994). Emotion is a signal of uncertainty (Den Dulk 1999), frustration (Elliot 1993), or deviance from the trajectory toward a goal (Frijda 1988). This deviance produces feedback for the cognitive appraiser to change control inputs (Ortony et al. 1988) as part of a survival response that directs approach or avoidance behaviors in individuals (LeDoux 1996).

But given that rational cognition functions to plan and evaluate behaviors, *B*, emotions enact and facilitate interactions between social organisms (Fiske et al. 1998). According to Zajonc's (1998) review, from an interaction perspective, emotion provides the "sources of energy that society exploits for its own merit" (p. 620). Yet no theory of emotion accounts for social behavior. This problem may arise from the emergent property of emotion (Newell 1990), making it less accessible to measurement, especially with self-reports (Cook 1994). Levine and Moreland (1998) posit that much outside of the individual perspective cannot be captured. Game theorists (Luce and Raiffa 1967) conclude that it may be impossible to construct the social from individual rationality. By definition, the individual perspective is framed or biased by its "worldview" (Linton 1957), making it unrealistic as a model of social behavior (e.g., Arrow 1951).

Yet traditional models of multiple autonomous agent systems (MAS) employ variations of set logic that continue to verify classical De Morgan laws (Tessier et al. 2001). This path remains within well-formed formulas for distributive lattice logical frameworks (*dllf*) that assure classification while avoiding contradiction and tautology. But the conflict found in nature differs from formal logic and its essential feature of contradiction. Given P_1 and P_2 as mutually exclusive propositions, conflict (i.e., $><$) occurs when $P_1 >< P_2 \leftrightarrow P_1 \cap P_2 = 0$. For a *dllf*, this happens for a complemented lattice given $P_1 = \neg P_2$ and $P_1 \cup P_2 = 1$, the difference being that these conditions are not necessary for conflicts in nature. To better represent nature, Tessier and her colleagues (see p. 24-26) propose a model of "conflict-adapted negation" that weakens negation with orthogonal operators in weak lattices to constitute the research path forward. An alternative path follows quantum logic adapted to the mechanisms underlying interaction and the evolution of conflict, with emotion linking individual with social behavior to stabilize the interaction, establish interaction channels, and build social structures (Lawless, Castelao and Abubucker 2001).

Structures standardize cooperative interactions; e.g., greetings, religious rituals, or barter. Interaction requires energy, E; with $k\partial^2E/\partial x^2 \approx c\Delta E$ and k,c as constants, minimum E loss gives:

$$\Delta E \approx 0, \qquad (1)$$

i.e., structures minimize E uncertainty; e.g., technology, like language or money, reduces E consumption (Ambrose 2001). Equation (1) represents resonance (e.g., vocal resonance). Linking individual and social behavior, resonance between interactants occurs under maximum agreement, minimum conflict, and least E expenditures (Lawless and Castelao in press).

Equation (1) can be re-derived from the interaction uncertainty relations and qualitatively from information theory (Lawless, Castelao, and Ballas 2000). For the first re-derivation, assuming that action and observation are controlled by interdependent cognitive systems (Rees et al. 1997), with action, Δa, and observational uncertainty, ΔI, the interdependent uncertainty relations become

$$\Delta a \Delta I \approx c. \qquad (2)$$

Not knowing c, the quantum of social action, a solution requires boundary conditions: e.g., as $\Delta I \to 0$, $\Delta a \to \infty$: The more certain the information derived from an interaction by an individual or group (e.g., ideology), the less I it has about its own actions or those of others (Baumeister 1995). Support came from an experiment with Air Force combat pilots when air combat performance was found not to be associated with scores from a written examination of air combat maneuvers (Lawless, Castelao, and Ballas 2000). Regarding emotion, speakers are less aware than listeners of emotion conveyed (Zajonc 1998, p. 612); correlations between autonomic nervous systems and subjective reports are weak (Zajonc, 1998 p. 612); and Moreland and Zajonc (1977) found that emotion from mere exposure of stimuli does not correlate with self-reports.

The biases in self-reports derive from a function of worldviews to reduce the uncertainty associated with reality, R (Rosenblat et al. 1990). If worldviews are composed of arbitrary (e.g., culture, ritual, or religion) and functional components (e.g., hunting, engineering, medicine) (Ambrose 2001); if worldviews are bistable in the sense that the mind can focus on only one view of R at a time (Cacioppo, Berntson, and Crites 1996); if the expression and measurement of self-interest is guided by culture (Wright 2000); if social influence is inversely related to distance between cultural sources (Latane 1981); and if each worldview, including science, underdetermines R (Feynman 1963), multiple cultures ensue (Bohr 1955).

Consequently, self-reported events become framed by worldviews guided by self-interests. With conflict or competition over scarce resources, these biases can become incommensurable barriers between cultures (ideology); e.g., from a 1999 Public Opinion Strategies Poll, "Republicans, by 45% to 17%, think the Clintonesque movie "Primary Colors" is more truth than fiction; Democrats, 40% to 23% think the opposite".

Reversing boundary conditions for Equation (2) is counterintuitive: as $\Delta I \to \infty$, $\Delta a \to 0$; i.e., the solution to an ill-defined problem (*idp*) occurs by bringing incommensurable viewpoints together before neutral observers to *reduce* the certainty in each belief, contradicting Nash (1950). This prediction occurs surprisingly often: courtroom conflict between adversarial interests, opposing viewpoints in scientific journals, and foils in the theater to illuminate character. From a field study, a comparison of environmental remediation decisions at the Department of Energy's Savannah River Site in South Carolina versus its Hanford Site in Washington, and the Citizen Advisory Boards at both sites (SAB and HAB, respectively), indicated that competition between opposing viewpoints led to better environmental results than cooperation under consensus rules to promote a single worldview (Lawless, Castelao, and Ballas 2000).

Letting a equal the rate of information change, $\Delta I/\Delta t$, and j the inertia of reacting to information change gives the uncertainty relations for energy, E, and time, t:

$$\Delta a \Delta I = \Delta\, (\Delta I/\Delta t) * \Delta I * \Delta t/\Delta t = j * \Delta\, (\Delta I/\Delta t)^2 * \Delta t = \Delta E \Delta t \approx c. \qquad (3)$$

As $\Delta t \to 0$, then $\Delta E \to \infty$. This occurs as time sequencing becomes important. For example, the more celebrated a court case, the more important become issues of timing and the more uncertain become expenditures of E to prosecute or defend the case. In the two examples above (Lawless, Castelao, and Ballas 2000), the E expended by HAB to construct a consensus worldview was significantly greater than by SAB to reach its decisions with majority rule; and in the USAF study, the more E wasted by a pilot in air combat, the less successful he was.

As $\Delta t \to \infty$, $\Delta E \to 0$, reproducing Equation (1); e.g., resonance in the voice box provides unlimited vocalization ($\Delta t \to \infty$) with minimum E (Ladefoged 1996). Interaction resonance characterizes an organism, group, or system minimizing its marginal expenditures of E.

A recent example of E minimization comes from the *Wall Street Journal*: Despite a head start and extraordinary public financing given to the Human Genome Project by the National Institutes of Health (NIH), the private corporation Celera decoded the human genome first, winning patents and rich fees. Compared to NIH's "free" product, Celera's was more complete, had fewer mistakes, and has saved scientists effort in their discovery of new products; since then, NIH has become a client.

For the second re-derivation of Equation (1), x_i as agent i and $I(x_1,x_2)$ as joint entropy gives:

$$I(x_1,x_2) = I(x_1) + I_{x1}(x_2). \quad (4)$$

From Equation (4), $I(x_1,x_2)$ is minimum when x_1 and x_2 cooperate, and maximum when both are independent. The I transmitted between them, I_T, is

$$I_T(x_1{:}x_2) = I(x_1) + I(x_2) - I(x_1,x_2) = I(x_2) - I_{x1}(x_2), \quad (5)$$

indicating communication is minimum for independent agents and maximum under cooperation. Less I is available to witnesses when interaction partners cooperate, promoting deception, while competition produces more I for external witnesses, constraining corruption.

As a test, given free energy, ΔA,

$$-\Delta A = \Delta E - T\Delta I. \quad (6)$$

When $\Delta E/\Delta I > 1$, energy is available for competition to create new structures or technology; but when $\Delta E/\Delta I$ *is* < 1, cooperative systems are more successful. In support, we found significant and positive correlations between competition, E consumption, scientific knowledge ($\Delta I \rightarrow 0$), human health, and less corruption (Lawless and Castelao in press). And the more economically competitive a nation, the more cooperative it can be in addressing environmental disasters. Similarly, deteriorating economic conditions or increasing competition increase teamwork and business mergers.

Finally, qualitatively reproducing Equation (1), as opposing core beliefs of an agent enter its awareness, cognitive dissonance and anxiety occur until the agent selects one belief over the other (thereby shifting from cognitive independence of beliefs to cognitive consonance; in Lawless, Castelao and Abubucker 2001). Remarkably, this effect is self-similar (fractal) for the path from social conflict to compromise by social decision-makers.

But as part of the path forward, Equations (4) and (5) fail to tell us critical information. All things being equal, cooperation requires less E than competition. Yet the evidence cited for DOE and the USAF indicates that under competition, marginal expenditures of energy, dE/dt, are less under competition. Other evidence provides indirect support. While wealth is associated with increasing population size (Wright 2000) and while regional governments expend less E than central governments (Weiss and Bradley 2001), wealthier nations and families have lower birth rates and are more E efficient (Leone and Potter 1988), and, from the example of Celera, new technology directly reduces marginal E expenditures. Also, Latane (1981) discovered that cooperation among team members invariably produced less than the sum of the peak performances from each of the individuals comprising a team ("social loafing").

Marginal expenditures of E reflect self-interests. As resources become limited, individual survival responses are expressed in social interests (Dawkins 2000, p. 442); e.g., the more advanced a technology, the more hierarchical the processes for assembly (Ambrose 2001). But cooperation between groups reduces I and promotes deception (Lawless, Castelao and Abubucker 2001); conversely, competition increases I and promotes creativity.

It may be that cooperation is inefficient the more a structure shifts from resonance between interactants (e.g., bureaucracy); that within cooperative structures, competition is self-defeating, as is private collusion or public compromise between competitors. Thus, tension between cooperation and competition optimizes social behavior (Lawless and Abubucker 2001).

Social temperature and emotional arousal

One way to study tension is to link temperature, T, with emotional or social activation; e.g., as physical T increases, social violence increases (Anderson 2001). But no clear link exists between T in physical and social systems. However, T could represent the average activation experienced in a social I field, e.g., the greater the dissonance, the higher is T. Thus, activation breaks down social structure. Given $T = \partial E/\partial I$, the greater the activation, T, the more E is consumed to produce or process each unit of I. At the individual level, findings agree that as conflict (dissonance) increases, brain T increases (Zajonc 1998, p. 606, 616); the lower is expertise, the greater the emotional activation observed to process each unit of I (Landers and Pirozzolo 1990); and compared to hearing subjects, deaf subjects responded to speech with an order of magnitude more of non-verbal reactions (Zajonc 1998, p. 619). Finally, the greater the social status of an individual, the lower is pitch (Zajonc 1998, p. 606, 620); regular and angry voices can be distinguished (Kang and Everett 1984); and Kang (personal communication) recently found that the E expressed in anger is greater than for normal voice.

To model social T (see Figure 1) given k_B as Boltzman's constant (Hertz et al. 1991, p. 276), the strength, $f(E)$, of an interaction structure to channel I from interactions becomes

$$f(E) = 1/(1 + \exp(-2E/k_B T)). \quad (7)$$

Equation 7 indicates that as T drops, the I channeled from interactions becomes more stable and measurable, and the less competitive and more resistant to change becomes a culture. Conversely, as T increases, I channeled by interaction structures becomes random, causing channels to fail and social cohesion to dissipate, agreeing with Schumpeters' (1989) idea of the creative destruction that occurs from competition.

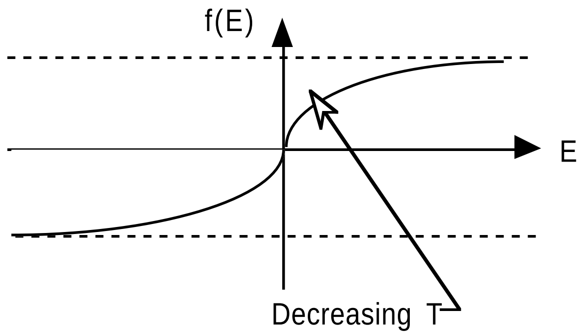

Figure 1. The relation for strength of a structure, *f(E)*, *T*, and *E*.

Emotion and cognition (Work in progress)

From his review of emotion, Zajonc (1998, p. 597-8) concluded that emotion had primacy over cognition. It takes around 150 ms to identify stimuli (Zajonc 1998, p. 604); but the mere exposure of stimuli becomes associated with emotional responses around 4 ms (Zajonc 1998, p. 618). Yet Zajonc concluded that the interaction between emotion and cognition remains unknown.

The tension from dissonance implies that emotions may be linked to cognitive states by a mechanism like set point theory (SPT). Physiologically, SPT suggests that equilibrium points exist for the intake of food (see Bennett and Gurin 1982). Diener and Oishi (2000) extended SPT to life satisfaction levels. By studying events like winning the lottery or suffering personal loss, which common wisdom associates with happiness or suffering, they found instead that life satisfaction quickly returns to pre-event levels. Thus, SPT may account for the stable reactance to social change we defined as information inertia, *j*.

Social loafing suggests that the members of a group are seeking the minimum *E* state to satisfy self-interest. This explains why game theory, which does not consider *E* formally (except as costs or time), cannot determine whether groups are more or less efficacious than the sum of the individual members who constitute the group (e.g., contrast Von Neumann and Morgenstern 1953, p. 275, with Luce and Raiffa 1967, p. 193).

To apply SPT to decision-making, assume that a stable cognition endorsed by an agent exists in a low *E* and *T* state (e.g., resolved cognitive dissonance). Next assume that adopting a new cognitive belief or skill requires the increased expenditure of *E* (e.g., Landers and Pirozzolo 1990). As *E* is increased above baseline, *T* increases and emotion set points activate to keep cognitive representations from changing, holding them in a square energy well, triggering a return to cognitive stability. Control would be employed in a similar manner. Thus, given the opportunity to freely consume food, eating a stable quantity each day is governed by set points that increase intake above a certain level and decrease it below another level (see Figure 2).

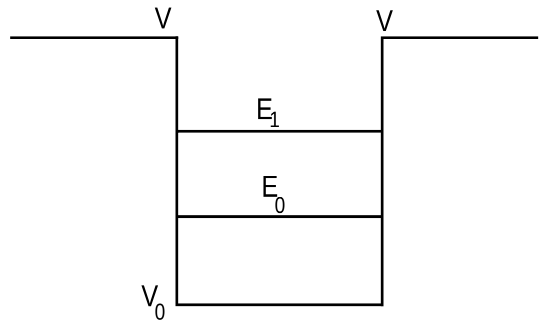

Figure 2. A square-well representation of energy (E_0 is baseline) associated with a rational belief and its emotional potential energy (V_0 is 0). As a cognitive representation gains *E* to redefine its meaning, emotional potential energy, *V*, repels the change, keeping the belief stable.

The advantages of the square-well model:

1. It is mathematically tractable. The Schrodinger wave equation can be employed, producing a stationary state (emotional stability; individual observations) and a time-dependent state for *I* flow (e.g., emotion during conflict). Shallow square wells produce more easily observed effects than deeper wells, agreeing with the evidence that the brains of experts appear “cooler” than novices performing similar tasks (Landers and Pirozzolo 1990).
2. Superposition of different emotional states occurs from adding different solutions of the social quantum equations in item 1, producing new solutions. Zajonc reports emotional states are additive (Zajonc 1998, p. 618; e.g., Zillman’s excitation transfer effect).
3. It offers a new rational approach to the interaction between emotion and cognition.
4. It indicates that different levels of emotion can be studied in natural settings with voice (e.g., resonance) instead of self-reports, which have proved unreliable.
5. It paves the way for a value-free theory of decision-making; instead, cooperation and competition both become important, rejecting the traditional model which designates cooperation as a superior social good (e.g., Axelrod 1984).
6. It indicates that combining the incommensurable processes of cooperation and competition in decision making is similar to the orthogonal *I* processing in quantum computation (Tessier et al. 2001).
7. To illustrate the square-well model with social decisions, cooperation reduces social activation *T* and reflect social stability (a deeper well), while competition increases social activation *T* to overcome stability. During the solution of an ill-defined problem (*idp*), competition increases *T* to

overcome the emotional barriers from stable states of cooperation. Once a problem is solved and becomes well-defined (w*dp)*, *T* reduces, allowing a new social structure to be built with potential energy, V_{new}. In this model, emotional agitation (e.g., from conflict) illuminates the link between individual and social behavior.

Conclusions

The thesis of logical positivism is that perfect knowledge builds consensuses, ending the need for conflict (e.g, Shearer and Gould 1999), encouraging researchers to make value judgments about *I* (e.g., Wright 2000). But social effects fail to emerge from traditional rational models of the interaction. And after nearly 60 years of research, game theory has not been validated in the laboratory (Kelley 1992) or the field (Jones 1998), nor has decision theory (Klein 1997; Shafir, Simonson and Tversky 1993). This situation arises from ignoring the physics of interaction. First, the logical positivist model overlooks the *E* invested in the structures that produce social stability (Luce 1997). Recent news items illustrate that when established structures are threatened, tension or conflict is a common response: the issue of barring ordination based on sexual orientation has bitterly divided Protestant denominations in the U.S.; and in Russia, fights broke out in the State Duma voting to permit the sale and purchase of private property. In science, tension is "essential" to discovery (Kuhn 1977).

Second, conflict generates information. Both of these shortcomings are addressed with interaction uncertainty relations (Equations 2 and 3). Instead of a focus on *I* intrinsic to the interaction, it considers the physics of *I* exogenous to the interaction (see Von Neuman and Morgenstern 1953, pp. 147-8, for a similar concern). The social quantum uncertainty relations are tractable mathematically, and they make strong connections between interaction concepts and reality, which Kuhn (1970) considers to be rare. If emotion is the critical ingredient that stabilizes the interaction, from which emerges social behavior, emotions are derived directly from the mathematics of the social quantum uncertainty relations. They suggest new measures of the interaction, including voice, may act as a surrogate measure of problem complexity when measures of communication density are included. In sum, the social uncertainty relations provide a step forward with theory and field research by laying a foundation for a physics of social interaction that offers a new and rational means to control autonomous agents.

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