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THE STATE OF THE ART AND THE STATE OF THE PRACTICE

TITLE: Metrics for uncertainty in organizational decision-making

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Abstract.
An agent's behavior is guided by static information from observation that has converged into a stable worldview, whether in human-social or computational-agent reality. Examples of convergent worldviews for human agents abound as single-sided stories, strongly held religious beliefs, well-defended political perspectives, or situation awareness. These are simple, mostly linear rational descriptions of the phenomena. However, the common interaction experienced between two or more human agents reflects the need to construct bi-sided perspectives for multi-agent systems, which until now have remained mathematically intractable. To advance the mathematics of social interaction, we propose that only bi-sided or quantum computational agents will be capable of replicating social phenomena such as the dynamics of human agents, including the more difficult problem of organizational decision-making.

Introduction.

The state of organizational theory is poor (Wieck & Quinn, 1999). There are several possible reasons. At the most basic or individual level, supposedly, individuals are less complex than organizations, making it more likely that individuals know themselves better than anyone else, yet their and others' beliefs about themselves are often erroneous (Baumeister, 1995). Moreover, surprisingly, human self-beliefs of behavior does not determine their behavior; e.g., self-esteem, arguably the most well-researched self-concept, does not correlate with either academic or job performance, although, and of critical importance, it does predict well with other aspects of an individual's worldview, such as life satisfaction (Baumeister et al., 2005). The implication is that while the static information that guides an agent's behavior converges into a stable worldview, it is insufficient to predict or recover the dynamics of an agent. As Campbell (1996) warned about his theory of convergence, still considered the essential methodology in social science research , in contrast to bi-sided perspectives, the convergence necessary to form single-sided story lines, to construct global meaning statements, or to simply understand social interactions limits scientific usefulness.

Further illuminating this point, in experimental game theory, the most stable preferences of an individual do not determine the choices an individual will make in the presence of other participants (Kelley, 1992). Nor do the *post hoc* justifications of decisions that have already been made correlate with these decisions (Shafir et al., 1993; see also Johanson, Hall, & Sikstrom, 2005). And for research on groups and organizations, aggregating the preferences of individual members does not determine the

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choices that a group or organization will make (Levine & Moreland, 1998). Jensen (2004) summarized this effect: "Interaction is able to produce properties at the collective level that are simply not present when the components are considered individually." (p. xi) Allport (1962), against the concept of groups until near the end of his career, foreshadowed this problem by calling the shift from individual to group member the major unsolved problem in social psychology. Many of these problems with decision-making in the laboratory led Klein to formulate "naturalistic decision-making" (Klein, 1997). We have concluded instead that the problem is the absence of first principles that address the phenomenon of social interaction, characterized by interdependent uncertainties, before applying theory to decision-making and organizations; i.e., those first principles must recognize that interactions between two agents are composed of four factors—two independent sets of perspectives and two independent sets of behaviors.

In an attempt to model these phenomena, two broad theories of organizations are methodological individualism (i.e., game theory; in Nowak & Sigmund, 2004) and the quantum physics of uncertainty in the interaction (Lawless & Grayson, 2004). After Bohr criticized the former theory, Von Neumann and Morgenstern (1953) concluded that if Bohr was correct, a rational theory of the interaction was "inconceivable" (p. 148). Bohr's (1955) model is predicated on uncertainty in the social interaction occurring in at least two complementary states for the conjugate variables of action and observation that produce the four factors noted above for a dyad; mixed energy states (normal and excited states) and time; or multiple stable states composed of the practices and observations of different cultures. Complementarity between these conjugate variables means that a full knowledge of one variable precludes simultaneously knowing its interdependent counterpart; e.g., in conflict situations, bi-sided aspects are recorded asynchronously in courtrooms, never simultaneously, to minimize interference, yet we have argued that any recording no matter how perfectly made is necessarily incomplete due to the conjugate nature of the variables, preventing a full reconstruction of events (Lawless et al., 2000). As a well-known illustration of this phenomenon, the more intensely an in-group's view is adopted, the more uncertainty that is generated in the knowledge of the corresponding out-group (Tajfel, 1970).

Background and previous work:

Extending our comment above about the courtroom, related conclusions have been drawn about business and political markets, which we have defined as the measurement problem (Lawless et al., 2005). It arises because reducing uncertainty with "truth-seeking" is an important goal of the attacks common to business and military operations. The ultimate goal of any military or business market venture is to defeat an opponent, but the more immediate goal is knowledge of the opponent, especially how the opponent plans and executes countermeasures in response to attacks; e.g., in Operation Iraqi Freedom, "fighting for intelligence" produced information and the power to control a military field of operation (LtGen. Boykin, 2004). Klein and Miller (1999) have observed that military planning occurs under time pressure and uncertainty, while Smith (2004) has observed that effects-based operations imply uncertainty in the execution and application of military force. Yet, attacks are common. For example, the attack by Southwest Airlines in Baltimore and Philadelphia against US Airways preceded its increase in market share and the bankruptcy of US Airways; the attacks by Dell Computer led to

IBM’s retreat from the PC market; and the attacks by political opponents in 2005 against G. Schroeder, Germany’s Chancellor, led to his fall from power.

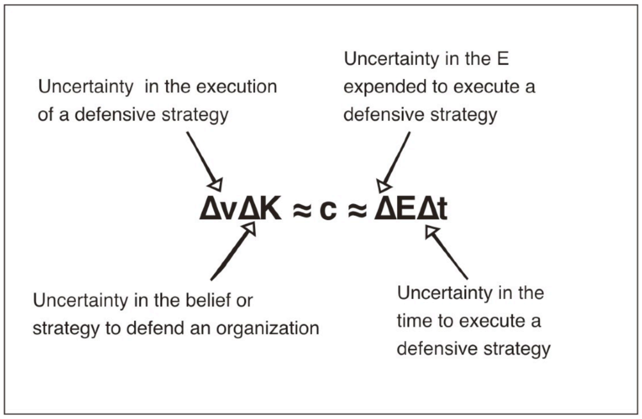

Figure 1 (Lawless et al., 2005). The measurement problem from the perspective of a merger target (bi-sided uncertainty relations exist for the acquiring organization). For example, **Strategy**: after AT&T Wireless put itself on the auction block in early 2004 and Cingular made the first offer, AT&T Wireless did not know whether bids would be received from other players such as Vodaphone, or how much more would be offered; **Execution**: Cingular expected that AT&T Wireless would execute its strategy by choosing the best bid by the deadline it had set, an expectation that turned out to be incorrect; **Energy**: AT&T Wireless did not know whether Cingular or Vodaphone would increase their bids to an amount it considered sufficient; **Time**: while the bidders believed incorrectly that the deadline was firmly established, AT&T Wireless was uncertain of the time when the bids would be offered. Finally, although power goes to the winner, it was not easy to determine who won and who lost in this auction. AT&T Wireless was unable to enact number portability and became the prey, but its CEO exacted a superior premium for his company and stockholders; while the merger on paper made Cingular the number one wireless company in the U.S., it may have overpaid for the merger; and during the uncertainty of regulatory review (both the length of the regulatory review period and the regulatory decision), with AT&T Wireless losing customers as competitors exploited the regulatory uncertainty, it was unknown how costly the eventual merger would be based on the assets remaining once the merger had been consummated.

In Figure 1, Lawless, Bergman, and Feltovitch (2005) attempted to formalize Bohr’s ideas about the measurement problem as a series of interrelated tradeoffs between two sets of interdependent factors. The central idea is that as convergence is constructed in order to reduce uncertainty in one factor, say planning, the uncertainty increase in the other factor is tracked mathematically. The uncertainty relations for social interaction are represented by the complementarity between strategy, plans, or knowledge uncertainty, ΔK (where K = function of social and geographical location, x) and uncertainty in the rate of change in knowledge, or its execution, as $\Delta v = \Delta\ (\Delta K/\Delta t)$. Similarly, complementarity also exists in the uncertainty in the energy expenditure committed to enact knowledge, ΔE, and by uncertainty in the time it takes to enact knowledge, Δt. That these two sets of bi-sided factors are conjugate means that a simultaneous full knowledge of either set is precluded.

As an example of Figure 1 in field research with U.S. Marine Meteorological Operation Centers (METOC), consensus (ΔK) has been found to slow and weaken execution (Lawless et al., 2005); the execution (Δv) of military operations to fully exploit the weather impacts across a battlespace hinges on the focus, commitment and coordination established by Command Elements (Gepp, 2003). For the right side of Figure 1, excessive satellite costs and narrow bandwidth communications slow forecaster reach-back (ΔE; see Gepp, 2003); but putting E into developing new software for forecasters can significantly reduce the amount of time (Δt) to produce a strike forecast (e.g., EVIS saves 40%; in Ballas, 2004).

Metrics.

This suggests a metric for military or business operations. The greater the unity of combatants, the better a Commander's intent is executed; however, to achieve this unity, a Commander's intent should arise from a wide search among competing interests across a military or business organization, characterized by conflict until an optimum solution is signaled by broad agreement, a process that is similar to random exploration and stochastic resonance. On the right side of Figure 1, and at the same time, the more energy leveraged on the battlefront, the more rapid a breakthrough that can be achieved (Franks, 2004); the key is the success that a technology or concept (battle plan, business model) enjoys, measured roughly by its number of users or endorsers (ΔN), its ease of use or facility, and its costs.

Current research

We believe that it would be a significant advantage to design a multi-agent system (MAS) based on first principles. We are following a multi-pronged approach to discovery and confirmation that encompasses the laboratory, field research, theory building and mathematical models (Galois lattices).

Laboratory.

Testing Figure 1 in the laboratory with human subjects. At present, we have successfully completed a pilot study and initiated a full experiment.

Background: The Department of Energy uses Citizen Advisory Boards to provide it with advice on cleaning up the widespread contamination and legacy wastes stored at its sites (Lawless, 1993). DOE's policy is to use consensus-seeking to provide advice based on the fairest and widest basis possible. However, in the application of its policy, DOE allows Boards to self-organize. The result is that five of the nine active Boards across the U.S. use majority rule (a "truth-seeking", conflict-based approach to decision-making) and four use consensus rule (a cooperative based approach), setting the stage for a field experiment that was successful (Lawless et al., 2005). Reviewed below is a pilot study that attempted to replicate the field study.

Hypothesis: Majority-rule (MR) decisions not dominated by a single person should lead to better information processing than consensus-rules (CR) decisions and high endorsement. The result should be no significant difference between MR and CR on participant endorsements. CR decisions take considerable time to complete (Miller, 1989), reducing the rate of decisions by the CR compared to the MR group. MR decisions should be characterized by practicality; an outside group judging these decisions should favor them over CR. Time for both groups will be fixed at 30 minutes.

Results from the pilot test of group decision making: The differences in a t-test between the two groups based on participant endorsement of the decisions made by MR over CR was larger but not significant ($t(98) = 0.35$, p. n.s.). A chi-square two-tailed test of the number of decisions made were significantly greater in frequency for the MR than the CR group ($\chi^2(1) = 4.83$, $p < .05$). A chi-square two-tailed test of the number of decisions judged by an outsider to be practical were significantly more for the MR than the CR group ($\chi^2(1) = 4.12$, $p < .05$). The time for both groups was set at 30 minutes and not allowed to vary.

Conclusions: The hypotheses for the pilot study were supported. A full-scale test was begun in late October (four of 57 groups have been processed).

Field research.

Work with DOE's CABs to further explore the relationship between cooperation and competition will continue in order to gain a better theoretical control in making predictions for consensus-seeking versus truth-seeking groups (Lawless et al., 2006).

Theory.

In Figure 1, at the atomic level, the constant *c* is Planck's constant, *h*, but it is presently unknown at the individual or social level. Penrose (in Hagan et al., 2002) suggested that Planck's constant should operate for humans as well. Penrose speculated that if we let *c* in Figure 1 be Planck's constant, *h*, then the right side of the equations in Figure 1 would become $\Delta\omega\Delta t \geq 1$. EEG evidence presented by Hagoort (Hagoort et al., 2004) indirectly indicates that Planck's constant serves as a lower bound for cognitive apperception processes.

But what to make of the equation in the left side has remained unknown until now. Given $\Delta\omega\Delta t > 1$, then $\Delta\omega/(v) * v\Delta t \geq 1$ leads to $\Delta\beta\Delta x \geq 1$, where β represents the wave number of an interaction. Recall that knowledge is a function of social location, *i.e.*, $\Delta K = f(\Delta x)$. Next we define $\Delta\beta$ as $\sim \Delta E/\Gamma \sim \Delta N/\Gamma \sim \Delta$ *(free energy, or roughly the number of agents associated with an interaction)* divided by Γ and equal to *f(exp [- free energy/average free energy*]) to reflect the barriers to interaction.

We plan to study this new equation to determine whether it can address efficiency (ΔE), random explorations and stochastic resonance (an element of Γ), the effect of perturbations on the geographical size of a group (where $1/\lambda = \beta$), and the minimum number of agents to fill a niche (*N*). Currently, we expect that *N* is a function of a group or organization's ability to share energy (Ehrlich, 2001), producing a tradeoff between efficiently exploiting a niche and increasing the number of groups at a niche. During environmentally stable times, this reduces internal group stability but increases overall social stability (e.g., as the stock market volatility index decreases, overall competition between groups and market confidence increases). The end result is an increase in evolutionary forces over dynamic forces. In contrast, unstable environments such as fuel supply disruptions promote the desire for dynamic stability, decreasing the number of groups (an increase in mergers) at the expense of social welfare.

Model building. From conflict to Galois lattices.

We speculate that a cube lattice model may provide a logic structure to capture uncertainty. With humans, conflict and competition generate information and uncertainty, test and rebut propositions, and hold the attention of neutral observers who serve as judges (Lawless & Grayson, 2004). But with logic, building differential operators in symbolic models requires negation or ortho-complements that are difficult to locate in non-modular logics (Chaudron, 2005). If problem solving is a cooperative process between rational human agents, and if transformations are necessary to determine the information to visualize, extract and act upon (Trafton et al., 2000), then transformations occur by negation, locating uncertainty at the point of least cooperation between the agents.

Let a cube lattice represent two approximately strong participants (A,B) in an argument along the horizontal axis at two of its vertices (forming a horizontal couple). Between these two horizontal vertices, locate the infimum and supremum along the vertical axis, with the infimum at the lowest vertex and supremum at the highest, the infimum being the greatest area of agreement and lowest level of energy between participants, and the supremum the least totality of the arguments in play and highest level of energy. In this model, conflict is proportional to the energy necessary to achieve agreement on the information in play, the information missing and the size of the space containing all of the arguments; convergence occurs as the argument moves closer to one side at the expense of the other; but as convergence to one argument or side occurs, uncertainty increases correspondingly in the other side of the argument, a Tajfel (1970) shift. Then a solution is located in the space created by arguments between the two participants. However, the solution is unstable as neither participant accepts it if the other departs the space. By extension, (A,B) could represent observation and action, producing Allport's (1962) shift between individuals and group members, until now entirely missing from formal methods.

To be sure, problems remain for the lattice model. For example, the uncertainty relations are not commutative logically, a requirement for lattice logic. Nonetheless, we believe that lattice models offer a rare opportunity. For example, we do not expect equal opponents to concede arguments unless the solutions are determined by neutral observers between the participants (A,B), replicating Schlesinger's (1949) vital center with logic.

Expected results, significance and application:

One of the problems with game theory is the focus on the impacts that decisions have on the players of the games but not on society. We propose to replace this 2-D view of games with a 3-D model that includes society. A further problem with game theory is its arbitrary assumption that cooperation has a higher social value than competition (Nowak & Sigmund, 2004). Our revised theory of games assumes instead that the social welfare of agents is determined by the number of agents (*N*) attracted to a choice, independently of whether this choice reflects cooperation or competition. Finally, game and other rational theories of the interaction have had a difficult time adding uncertainty into their formulations. In contrast, uncertainty in our theory is organic to the theory.

Future research

Guided by our attempts to construct a working model of an organization, the unusual techniques at this stage are rudimentary metrics of energy and execution in the interaction. In the future, we would like to incorporate EEG's (γ waves), fMRI's (energy), and voice (multi-levels of energy) into laboratory measures of decision-making.

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Metrics for uncertainty in organizational decision-making

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NVO Problem: Autonomy and Control of Human-Robot Organizations

- 5-6 humans per Predator w/staff of 20 (Russ Richards, JFC, 2003); 4 airborne over OIF
  - DARPA: Organizations ≈ 1 human w/many robots = "live weapons"
- Organizations based on traditional models:
  - Tambe (2003): ABM autonomy currently not possible
  - Bankes (2002): validating social ABMs not possible
- ANL's EMCAS (North, 2005): "The purpose of an ABMS model is **not necessarily to predict** the outcome of a system, rather … to reveal and **understand** the complex … system behaviors that emerge…"
- The danger is that ABM's -> "toys" (Macy, 2004).

Traditional Cognitive, AI Organization Theory

- "Methodological individualism" (MI) э game theory (Nowak & Sigmund, 2004)
  - Assumes: Stable Reality, mostly accessible *I*
    - multiple preferences can be resolved into a **consensus**
    - cooperation = highest social value
    - ∑(multiple preferences) = organization's preferences э **interviews**
  - Problems
    - Arrow impossibility & Nash possibility theorems limit multiple prefs
    - CR -> groupthink (Janis, 1982)
    - ∑ **individual surveys ≠ groups** (Levine & Moreland, 1998)
    - **Baumeister** (2005, Scientific Am): SE ≠ performance
    - **Shafir & LeBeouf** (2002, ARP): Rational model has failed
    - Organizational theory has failed (Pfeffer & Wong, 2005; Weick & Quinn, 1999)

Alternative Organization Theory

- Math physics of uncertainty (Quantum model of interdependence):
  - Assumption: Reality is bistable with *I* that is mostly inaccessible
    - Bohr's non-linear relations for the **dynamic interdependence of uncertainty between action and observation**
    - competition => "truth seeking"
    - **M problem**: M(bistability э group, org) -> individual (classical) *I*
- **Paradox**: data => rational d.m. from individual perspective is a fiction, yet m.p.u. => only classical *I* available from group
  - Predicts tradeoffs:
    - **Consensus (CR) -> + Risk Perceptions, + rational worldview**
    - **Majority (MR) -> + Risk Determinations, + practical actions**

Case Study I: Field Problem: DOE History -> Citizen Advisory Boards

- DOE claimed that its actions “Protect … [the] environment [and] health and safety of employees and public” (ERDA 1537, 1977)
- 1980’s exposed DOE cover-up of extraordinary environmental contamination (Lawless, 1985)
- Collapse of public trust -> Boards (≈ 1993)
- DOE current cleanup estimate Hanford + SRS ≈ $100B
- DOE-EM has 9 Boards (4 consensus, 5 majority rule)
- **CR versus MR = “microscope” into dynamic interdependence**

Field Problems w/DOE’s Policy of Consensus Rules (CR)

- DOE-EM’s **evaluation** (w/interviews): citizens “need to understand the science of the problem”
- But to let “participants reach an agreement that recognizes the validity of what the speakers say” (Bradbury et al., 2003) permits any opinion no matter how far fetched
- Thus, CR reduces responsibility of citizens to weigh evidence

CR -> Wider Conflict & - Diversity

- HAB consensus-seeking generates conflict w/its sponsor, DOE
  - DOE Manager of Hanford (1998): talks w/HAB on tanks ”have become increasingly contentious and do not provide a supportive environment where individuals and organizations can work together to effectively address these issues”
- HAB consensus-seeking -> less diversity
  - DOE Managers at Hanford: “HAB should strengthen its representation of the views of the broader Pacific Northwestern public … organized special interest groups appears to be dominating … the board’s actions.” (Schepens & Klein, 2003)

Literature on CR

- In Support of CR:
  - Miller (1989): **CR promotes discussion**, compromise decisions, public and private change in group member positions, and **satisfaction** with a group decision
  - Hardin (‘68), Axelrod (‘84): **cooperation requires coercion**
  - Dennett (2003): competition is “toxic”
- Against CR:
  - Janis (1982): **consensus-seeking is groupthink**
  - EU White Paper (2001):
    - “The requirement for consensus in the European Council often **holds policy-making hostage** to national interests in areas which Council should decide by a qualified majority” (p. 29)
  - The more competitive a nation => + scientific wealth, better human health, and less corruption (Lawless & Grayson, 2004)
  - Levine & Moreland (2004): **forcible CR -> poorer decision quality**
  - Kruglanski et al. (2005): **reaching CR takes considerable effort**

WM’04: Board Statements: Tru & HLW

HAB	HAB Recommendation 142; February 7, 2002 [41]	“The recent shipments of transuranic (TRU) wastes from Battelle Columbus (BCK) and Energy Technology Engineering Center (ETEC) to Hanford caused grave concern to the Hanford Advisory Board (Board).”
SAB	SAB Recommendation 130; September 26, 2000 [42]	“Due to the considerable taxpayer savings, the relatively low risk, and the use of funding external to SRS for the activity, the SRS CAB recommends that DOE-SR accept the [offsite] TRU waste shipments from Mound as long as the following conditions are met: 1. DOE receives approval to ship more TRU waste volume from SRS than received from Mound. The SRS CAB preference is … twice the volume”

HAB	DOE/RL 2002-47 Rev. D [8]	Hanford plans to close its first HLW tank no sooner than 2004, nor later than 5 years; Hanford plans to initiate vitrification by 2010.
SAB	WSRC-RP-2002-00245 Rev 6 [38]	SRS has closed 2 HLW tanks (Numbers 20 and 17, in 1997) under supervision of South Carolina’s DHEC, the first two regulated closures in the world, and two more are ready for closure (Tanks 18 and 19).

DOE Savannah River Site, Aiken, SC: LLW

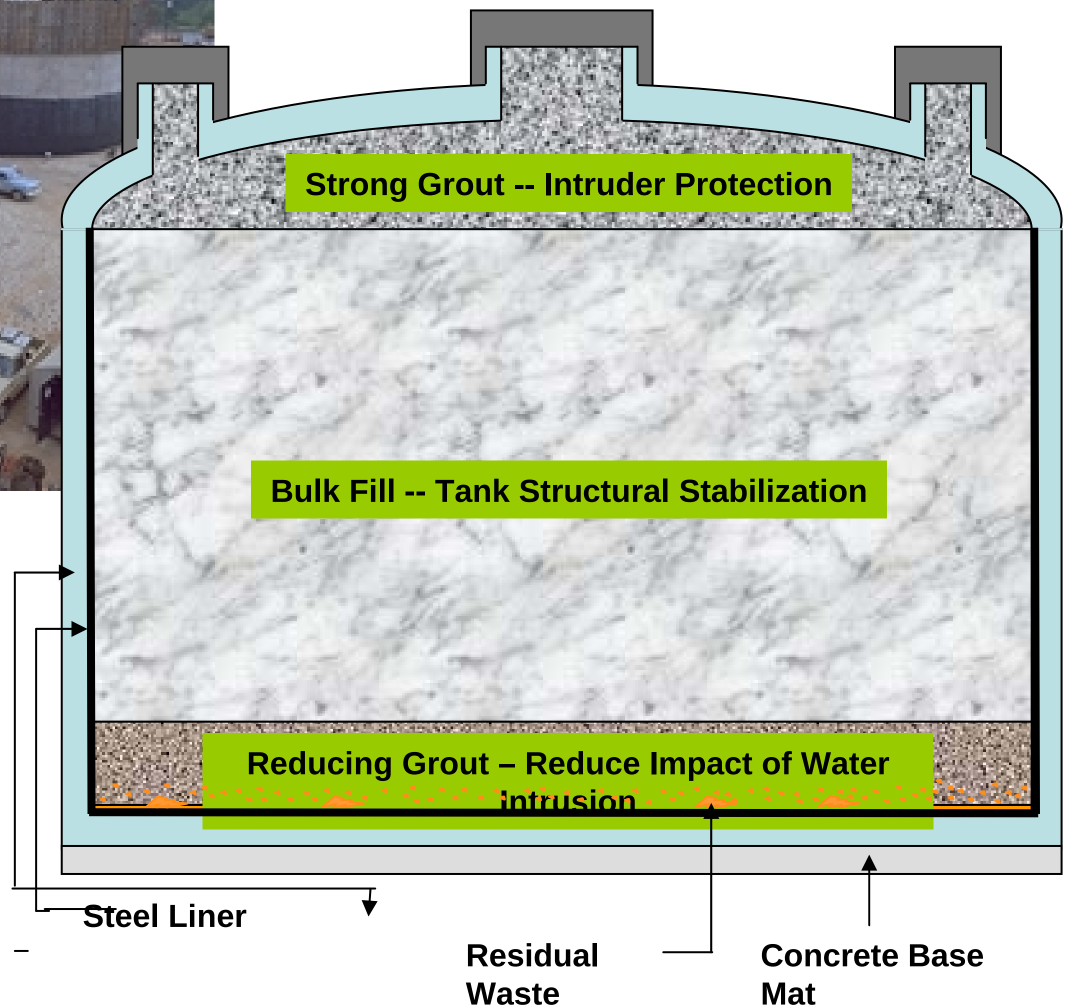
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

ER: Seepage Basins and Trenches (SRL trenches v Z-9 at Hanford)

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

HLW: Tanks 17F and 20F Closed

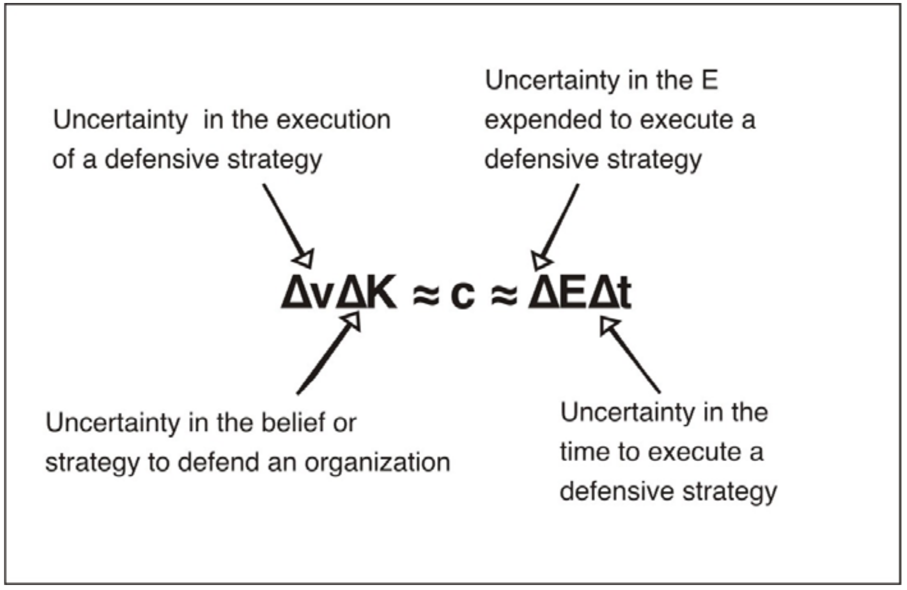


Interviews versus Field data

Based on interviews, you must conclude that HAB is more successful than SAB; however, based on field results, this conclusion is wrong.

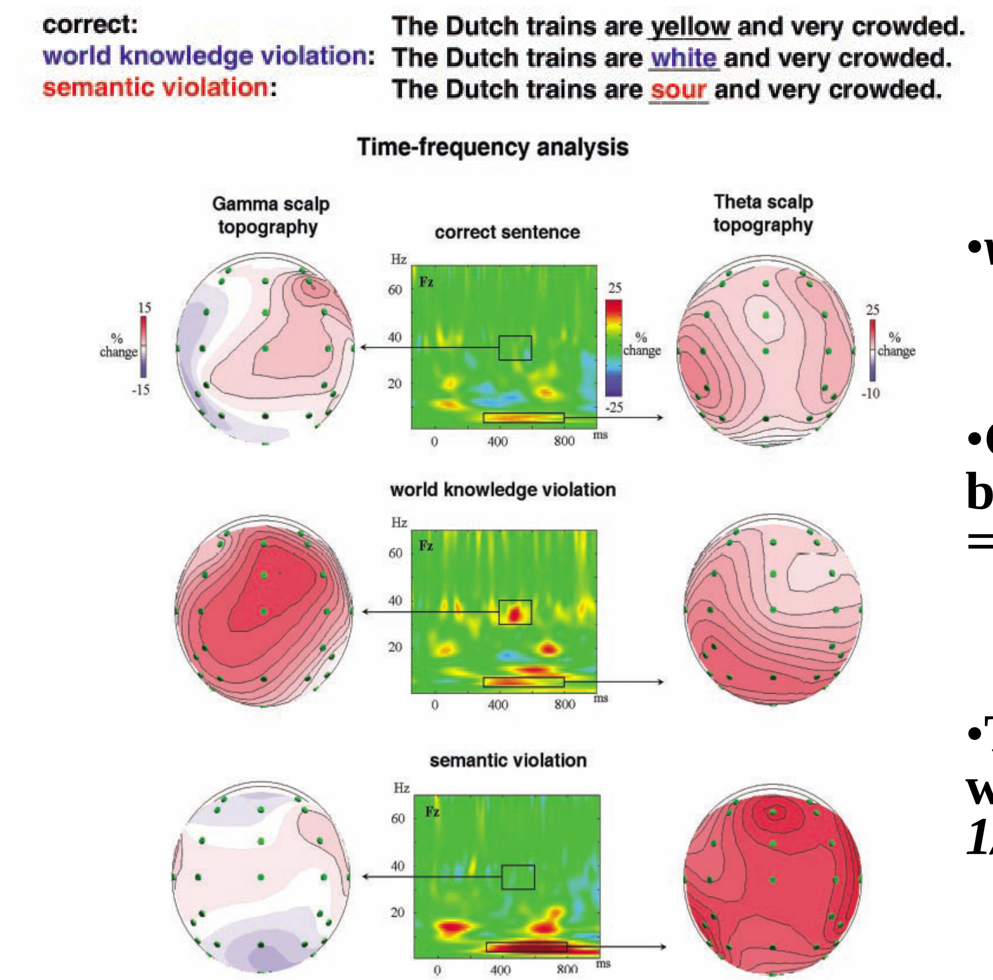
	MI	**MPU**
	Hanford/HAB **(CR: cooperation)**	Savannah River Site/SAB **(MR: competition)**
ER	ER about 7.1% in 2002	ER cleanup today ~ 62%
HLW	0/177 HLW tank closures postponed indefinitely HLW vitrification maybe in 8 y	2/51 HLW tanks closed 1997, closing tanks 19 and 18 in FY2007 2023 of 5060 canisters of v-HLW (- 32 ci/gal) Low-curie salt processing from tanks ~ 6/2006
Tru	TRU - 10% of SRS but w/much larger legacy (Gold Metrics, 2004) **Battelle Columbus tru blocked**	18,000 drums/33,000 legacy tru in WIPP w/Trupact II; Trupact III in 2008 => all legacy tru in FY09; **BC waste rec'd 12/05**
Results	**"Gridlock"**	**Successes**

Perturbations -> Measurement paradox (e.g., **hostile merger** of PeopleSoft by Oracle) = Heisenberg U.P. in Social interaction



Lawless & Grayson, 2004

What is the constant "*c*" ? Penrose: $\Delta t \Delta E \geq h \Rightarrow \Delta t \Delta \omega \geq 1$



Hagoort et al., 2004, Science, 304, 438-441, Fig. 2 [Note: 29 EEG recordings per subject, 30 subjects].

- ***wdp* => Perturbation Theory**
  <-- Note lack of *I*

- **Gamma Waves (feature binding): $\Delta t = 1/\Delta\omega = 1/(40$ Hz$) = .025$ s $\geq$ 25 ms**
  <-- EEG data ≈ 50-75 ms

- **Theta Waves (episodic and working memory): $\Delta t = 1/\Delta\omega = 1/(5$ Hz$) = .200$ s $\geq$ 200 ms**
  <-- EEG data ≈ 3-400 ms

- **Voice data agrees (NRL: Kang & Fransen, 1994)**

Case Study 2

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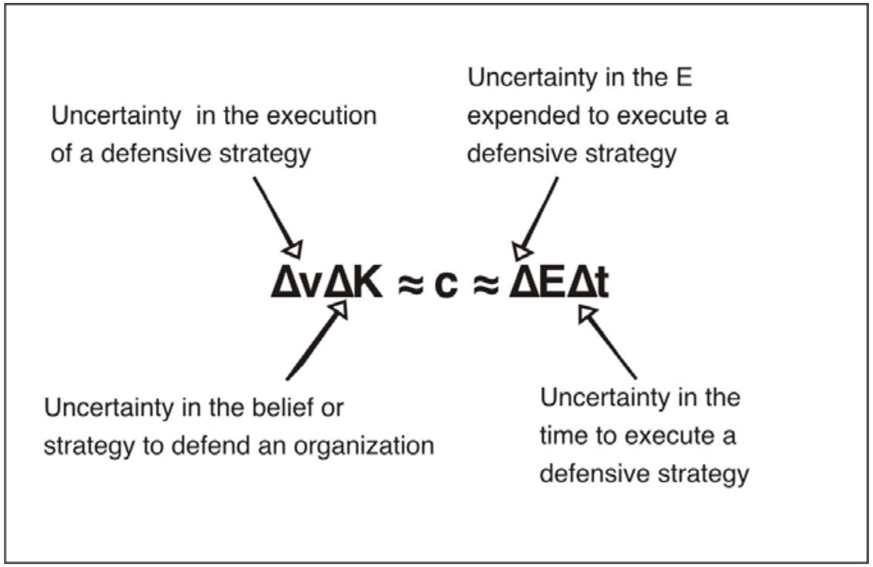
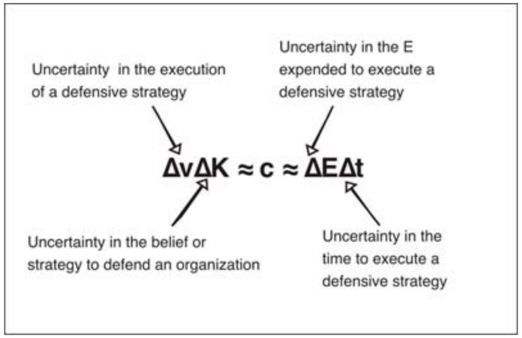


M (field test): In 2003, 13 Recommendations by DOE Scientists to CABs (N=105) for citizen endorsement to accelerate disposition of Tru at WIPP

Results: The SSAB Tru Workshop in Carlsbad agreed to accelerate Tru Wastes to WIPP (2003, January; *N*=105). Afterwards, however, the result: 5 of 9 Boards approved these recommendations (*MR Boards*: SAB (SRS), Oak Ridge, Nevada Test Site, Northern New Mexico; *CR Boards*; Idaho); 4 of 9 Boards disapproved (*MR Boards*: Paducah; *CR Boards*: Hanford, Fernald, Rocky Flats Plant), giving $\chi^2(1)=2.74$, $p\approx.10$. (Lawless et al., 2005)

Pilot lab experiment worked

- *Hypothesis*:
  - MR decisions not dominated by a single person or conflict -> + I processing v CR
  - No significant difference between MR and CR on participant endorsements
  - CR decisions take considerable time to complete
  - MR decisions should be more practical
- *Results from pilot test*:
  - Participant endorsement of decisions by MR preferred over CR ($t(98) = 0.35$, p. n.s.)
  - Number decisions MR >> CR ($\chi^2(1) = 4.83$, $p < .05$)
  - Judges preferred MR v CR ($\chi^2(1) = 4.12$, $p < .05$)
  - Time for both groups held constant



Organizational Performance Metric (MAGTF Metoc): dynamic *i* -> U Tradeoffs

- **<u>Planning</u> (Δ*K*):** (Observation => static *I*): The amount of complexity agreement; Common Data Exchange Format.
- **<u>Execution</u> (Δ*v*):** (Implementation; enaction => dynamic *I* flow): N, the number of participants seeking this tool as a solution process; *N*'s for acceptance => ~ consensus.
- **<u>Energy</u> (Δ*E*)**: The number of steps in a computation; computational complexity
  - Innovations (intellectual, technology) -> comparative advantage
- **<u>Time</u> (Δ*t*)**: the amount of time to compute or reach a solution (Murray Gell-Mann); time complexity

Galois lattices

- 2 agents: A is opposed to “aim” and “reasons” of a topic; B is opposed to its “reason” and “means”
  - A context can be defined and shown as:
    - A verifies: “aim” and “reas”
    - B verifies “reas” and “means”
- We can compute the Galois lattice of the conflict
- At the top, both disagree on “reas”, but at the bottom neither disagree about “aim”, “reas” and “means” simultaneously -> an area for exploration

GL of negations among 2 agents

A “aim” “reas”

B “reas” “means”

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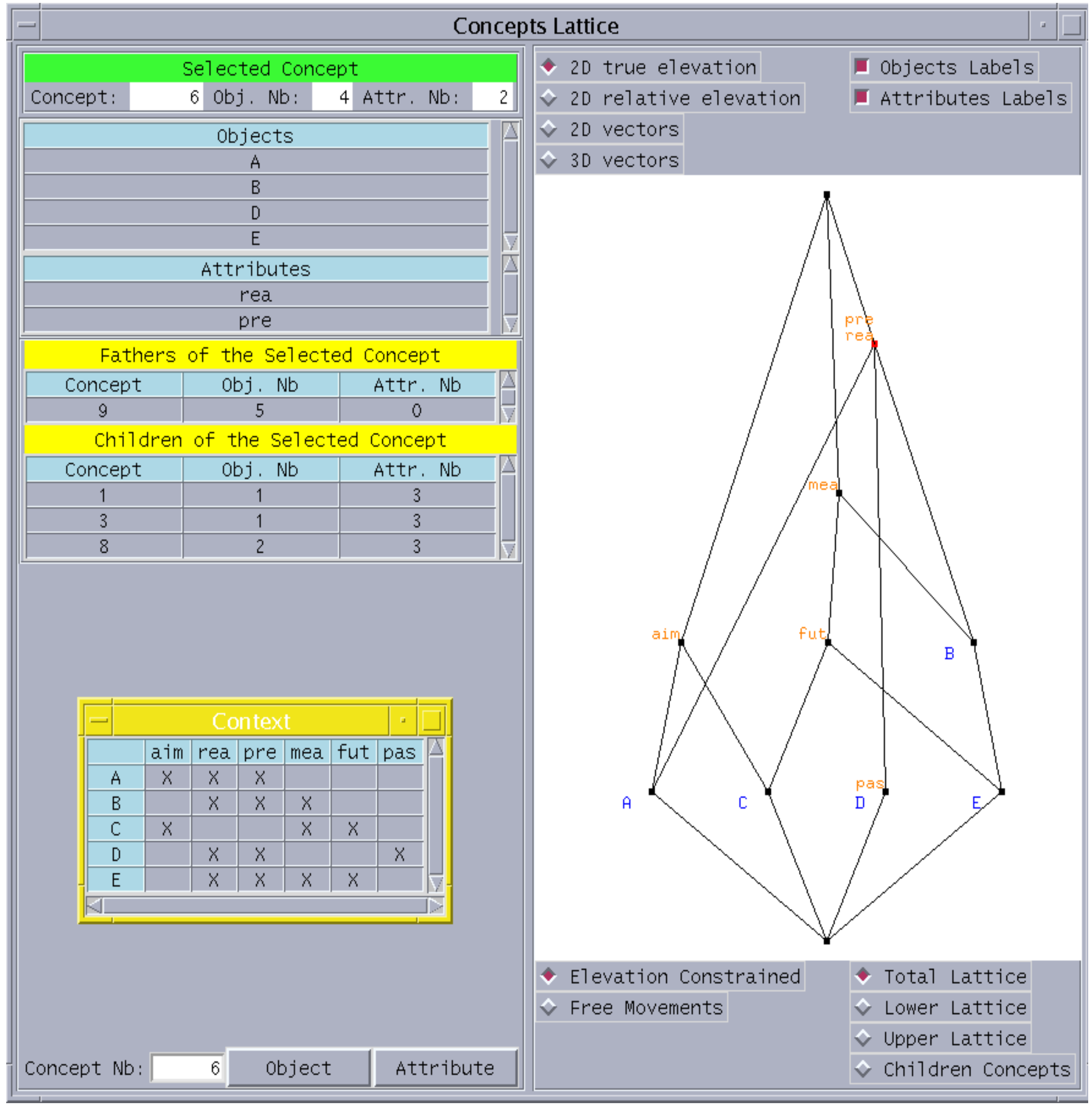
GL of negations among multiple agents

- •A aim rea pre
- •B rea pre mea
- •C aim mea fut
- •D rea pre pas
- •E rea pre mea fut

Result: C is neutral to arguments on “rea” and “pre”



Conclusions

	MI	MPU
Valued	**Understanding**	**Prediction**
Not Valued	**Prediction**	**Understanding**

- Consensus-seeking is inefficient, reduces agent diversity, responsibility
- MR's "truth-seeking" is efficient
  - –Increases Learning (Dietz et al., 2003)
  - –ISPR pierces "stories" by scientists (Trustnet, 2004)
- DOE-EM policy promotes anti-science, risk perception, and an uneducated citizenry regarding its nuclear missions and cleanup; however, its execution -> "grand field experiment
- **CR versus MR = "microscope" into dynamic interdependence**

Additional Reading

Lawless, W.F., Bergman, M., Louca, J. & Kriegel, N.N. (2006, forthcoming). A quantum metric of organizational performance: Terrorism and counterterrorism. Computational & Mathematical Organizational Theory.

Lawless, W. F., Bergman, M., & Feltovich, N. (2006). A physics of organizational uncertainty. Perturbations, measurement and computational agents. Computational Economics: A Perspective from Computational

Lawless, W.F., Bergman, M., & Feltovich, N. (2005), Consensus-seeking versus truth-seeking, ASCE Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management, **9(1)**, 59-70.

Lawless, W. F., & Grayson, J.M. (2004). A quantum perturbation model (QPM) of knowledge and organizational mergers. Agent Mediated Knowledge Management. L. van Elst, & Dignum, V. Berlin: Springer-Verlag (pp. 143-161).

Lawless, W. F., & Schwartz, M. (2002). "The social quantum model of dissonance: From social organization to cultural evolution." Social Science Computer Review (Sage), 20(4), 441-450.

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Lawless, W.F. (2001). The quantum of social action and the function of emotion in decision-making, Proceedings Emotional Agent II. The Tangled Knot of Cognition, pp. 73-78, AAAI Fall Symposium, Cape Cod, MA, November 2, 2001.

Lawless, W.F., Castelao, T., & Abubucker, C.P. (2000b), Conflict as a Heuristic in Development of Interaction Mechanics, In C. Tessier, H.J. Muller, & L. Chaudron, Conflicting agents: Conflict mgt in multi-agent systems, pp. 279-302, Boston: Kluwer).

Lawless, W.F., Castelao, T., & Ballas, J.A., (2000a), Virtual knowledge: Bistable reality and solution of ill-defined problems, IEEE Systems, Man, & Cybernetics, 30(1), 119-124).

DRAFT: AAAI-Spring 2007 Symposium at Stanford on Quantum Interaction: CFP deadline October 27

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are needed to see this picture.

- The organizers of this symposium are interested in bridging a theory of Quantum Mechanics (QM) and field practice and combining AI and QM. In considering whether to submit a paper for this symposium, we encourage speculative works, works in progress, and completed works that articulate a clear relationship with AI.
- QM is emerging out of physics into non-quantum domains such as human language (Widdows & Peters, 2003), cognition (Aerts & Czachor, 2004; Bruza & Cole, 2005), information retrieval (Van Rijsbergen, 2004), biology, political science and AI (e.g., Rieffel & Pollack, 2000).
- The QM model has already been applied to Game Theory (Eisert et al., 1999), political science (Arfi, 2005; Wendt, 2005), social science (Lawless et al., 2006), and brain models (Ezhov, 2001; Hagan et al., 2002; Stapp, 2004).
- This symposium will bring together researchers interested in how QM can be applied to solve problems with AI in non-quantum domains more efficiently or to address previously unsolved problems with AI in these other fields.
- Contact: keith@dcs.gla.ac.uk, p.bruza@qut.edu.au, lawlessw@mail.paine.edu