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RATIONALITY, FOOLISHNESS, AND ADAPTIVE INTELLIGENCE

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Technologies of model-based rationality are the core technologies of strategic management, having largely replaced earlier technologies that placed greater reliance on traditional practice or on communication either with the stars or with the gods. The technologies used by organizations in their pursuit of intelligence can be imagined to change over time as a result of responding to the successes and failures associated with the technologies. Although technologies of rationality seem clearly to be effective instruments of exploitation in relatively simple situations and to derive their adaptive advantage from those capabilities, their ventures in more complex explorations seem often to lead to huge mistakes and thus unlikely to be sustained by adaptive processes. Whether their survival as instruments of exploratory novelty in complex situations is desirable is a difficult question to answer, but it seems likely that any such survival may require hitchhiking on their successes in simpler worlds. Survival may also be served by the heroism of fools and the blindness of true believers. Their imperviousness to feedback is both the despair of adaptive intelligence and, conceivably, its salvation.

INTRODUCTION

Organizations pursue intelligence. That is, they can be described as seeking to adopt courses of action that lead them over the long run to outcomes that they find satisfactory, taking into account any modifications of hopes, beliefs, preferences, and interpretations that occur over time, as well as conflict over them. The pursuit of intelligence is an ordinary task. It is neither mysterious nor unusually difficult. It is carried out by ordinary organizations in ordinary ways every day in ways that permit most of them to survive from day to day. Since the earliest recorded times, however, the pursuit of intelligence has been pictured, particularly by the intelligentsia, as requiring exquisite talents and considerable training. In the view of academic theorists of organizational intelligence, the task involves trying to understand a complex and changing system of causal factors on the basis of incomplete, ambiguous, and contested information. It involves anticipating and shaping an environment that consists of other actors who are similarly and simultaneously anticipating and shaping their environments. It involves confronting inconsistencies in preferences across groups and across time and making interpersonal and intertemporal comparisons of desires (March, 1994: Ch. 6).

Over the years, the pursuit of intelligence in organizations, like other organizational activities (Gavetti and Rivkin, 2004), has increasingly become the responsibility of people with special competencies. It has been organized around concepts and functions such as strategic management, planning, and economic and decision analysis that

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professionalize the making of policies and decisions. This professionalization has been buttressed by the development of elaborate tools for guiding organizations toward favorable outcomes. These tools comprise the technologies of rationality that have come to be recognized as a major post-enlightenment contribution to Western civilization, supplementing and to a large extent replacing earlier technologies that placed greater reliance on traditional practice or on communication either with the stars or with the gods. The basic rational rubric has become an almost universal format for justification and interpretation of action and for the development of a set of procedures (e.g., budgeting, planning, economizing, operations analysis, strategic analysis and management) that are accepted as appropriate for organizations pursuing intelligence (Odiorne, 1984; Buffa and Sarin, 1987).

The preeminence of rationality as an interpretation of human action is obvious, but so also are complaints about it. Not everyone agrees that rational models comprehend human behavior adequately. They are seen as ignoring the limits to rationality, the emotionality of human existence, and alternative logics of actions (Langlois, 1986; Halpern and Stern, 1998; Elster, 1999; March and Olsen, 2005). The position of rationality as a norm of intelligent behavior is less subject to criticism, but it has not escaped entirely (March, 1978; Elster, 1983, 1984; Arrow, 1992: 46, 50). Indeed, criticism of purveyors of rational technologies fills history and literature. Tolstoy (1869) satirized the rational pretensions of German and French military strategists, and Camus (1951) argued that more evil has been based on rationality than on convention or religion.

This paper explores some aspects of experience with rational technologies in the pursuit of intelligence and the place of those technologies within a framework of feedback-based adaptive intelligence. In particular, it examines the role of rationality in the balance between exploitation and exploration by which adaptive systems sustain themselves.

RATIONALITY AND ITS CRITICS

The notion that human action is, or should be, rational in the sense of being derived from a model-based anticipation of consequences evaluated by prior preferences permeates contemporary Western thinking. The notion builds on a set of Western European ideas that trace in a general way to Plato and Aristotle, were resurrected by scholars and writers in the 16th and 17th centuries and made into the scripture of modernity by Voltaire, Descartes, Bentham, and Mill, and were converted in the 20th century into a technology of operational procedures by Savage, Morgenstern, and von Neumann and by contributors to the elaboration of operations, policy, and systems analysis and the micro-economics of choice in the second half of the 20th century (Gal, Stewart and Hanne, 1999).

Throughout modern history, the primacy of this technology of rational analysis and choice has been challenged, most conspicuously with respect to large system decision making in the debate over planning and rational system design in the 1930s (Hayek, 1935; Popper, 1966) and in the shadow of the collapse of the Soviet Empire (Campbell, 1992; Solnick, 1998), but also with respect to individual or organizational choice more generally (Sen, 2002) and the functioning of complex technical and organizational systems (Perrow, 1984). Nevertheless, these procedures, in various degrees of elaboration, are commonly seen as being both common and desirable bases for making choices as varied as those of public policy, consumer goods, mates, careers or jobs, investments, military strategies, and education. The technology and ideology of rationality jointly sustain standard procedures of action in modern Western organizations. They are the bases for justifications of action, teaching of decision making, and management of organizations. They are the conventional commandments of policy making, planning, strategy formation, risk taking, asset and attention allocation, decision making, and the management of life (Davis and Devinney, 1997; Lichbach, 2003).

For example, most discussions of strategic action in business firms emphasize the use of a model-based rational logic to assess alternative strategies for changes in product, process, market, resource, or capability mix in response to information about expectations, threats, opportunities, and goals in a competitive environment in which others are making decisions similarly (Porter, 1998; Walker, 2004). Modern academic treatments of strategic action sometimes subordinate a conception of strategic planning based on the comparison of expected values across pre-specified alternatives to a conception of designing methods for assuring capabilities to deal flexibly with an unfolding future, but the underlying notion is that strategic choices should be made by some kind of model-based assessment of the likelihoods of different possible future outcomes and of preferences among them (Vertinsky, 1986; Rumelt, Schendel, and Teece, 1991; Barnett and Burgelman, 1996; Williamson, 1999).

The technologies of rationality involve three components: first, *abstractions*, models of situations that identify sets of variables, their causal structures, and sets of action alternatives; second, collections of *data* capturing histories of the organization and the world in which it acts; third, *decision rules* that consider alternatives in terms of their expected consequences and select the alternative that has the best expected consequences from the point of view of the organization's values, desires, and time perspectives. The technologies are embedded in an ideology that holds that action should be a product of mind and choice, not tradition, rule, routine, or revelation; that choice should be derived from carefully considered expectations of future consequences, not from the dictates of habit, custom, identity, intuition, or emotion; that insight into the dynamics of histories can be obtained from abstract models of them; and that levels of intelligence superior to those produced by other procedures can be achieved through model-based rationality.

This combination of theory, ideology, technology, and theology has shaped thinking in the social and behavioral sciences in the last 100 years, as well as applications to fields such as medicine, law, and management. In particular, it has become the bedrock of modern economic theory (Arrow, 1974: 16) and of both the derivatives of economic theory in other disciplines, including strategic management, and of important critiques of the use of that theory (Lippman and Rumelt, 2003a, 2003b).

Rational models are common; but for many parts of the social science intellectual scene, rationality is less a sacred belief than a convenient bête noire, organizing those who reject it as much as those who accept it. This includes the three incomparable figures of the history of the social and behavioral sciences—Sigmund Freud, Karl Marx, and Charles Darwin—all of whom provided bases for challenges to the centrality of rationality. Modern critics of rationality generally eschew the grander critiques made by those giants in order to make two, not self-evidently consistent, complaints. On the one hand, rationality has been characterized as overly conventional, lacking in creative imagination except within the narrow confines of received knowledge, too tied to established institutions and creeds, thus incapable of generating revolutionary approaches or novel ideas (Steuerman, 1999). The analytical rigidity of rationality is seen as limiting it to refinements on what is already known, believed, or existent and is contrasted with the imaginative wildness of various forms of creativity. The argument is that a technology of rationality has to be balanced by other technologies that free action from the constraints of conventional knowledge and procedures and introduce elements of foolishness into action (March, 1988: Ch. 12).

On the other hand, technologies of rationality have been described as sources of huge mistakes, habitually misspecifying or encouraging the misspecification of situations and thereby producing disasters of major scope (Sagan, 1993; Vaughan, 1996; Albin and Foley, 1998). Although it is possible to demonstrate that actions taken within such technologies are effective in achieving desired outcomes in a wide range of simple decision situations, ranging from textbook problems to short-run investment decisions, it is harder to show empirically that applications of such procedures are reliably beneficial in the more complicated problems with which it sometimes deals.

The list of difficulties noted by critics of the theory is long and includes:

- *Uncertainty*. The future consequences are often quite obscure, and estimating them is confounded by inadequacies of information and biases introduced by desires, prejudices, and the limitations of experience (Knight, 1921; Shackle, 1961; Weick, 1969).
- *Causal complexity*. The systems being modeled and analyzed are substantially more complex than can be comprehended either by the analytical tools or the understandings of analysts. As a result, important variables and interactions among them are invariably overlooked or incorrectly specified (Albin and Foley, 1998).
- *Confound of measurability and importance*. Some things are more easily measured or estimated than others. Variables that can be measured tend to be treated as more 'real' than those

that cannot, even though the ones that cannot be measured may be the more important (Halberstam, 1972; Wildavsky, 1979).
- *Preference ambiguity*. Preferences, in the sense of the values, wants, or utilities that are served by action, are unclear and inconsistent. Their summary and combination appear to demand metrics and procedures that are elusive (March, 1978; Winter, 2000; Greve, 2003). They change, partly endogenously (Lowenstein, Read, and Baumeister, 2003). Since consequences unfold over time, intelligence requires intertemporal trade-offs that are neither trivially specified nor easily accomplished.
- *Interpersonal trade-offs*. Different participants have different preferences and combining them requires some way of making interpersonal trade-offs. Such trade-offs are major problems for theories of multi-actor choice (Arrow, 1951; Pfeffer and Salancik, 1978).
- *Strategic interaction*. Outcomes, and therefore choices, of one organization depend on the choices of other organizations whose outcomes and choices are, in turn, simultaneously dependent on the first organization (Luce and Raiffa, 1957; Tirole, 1988; Gibbons, 1992; Ghemawat, 1997).

This partial disenchantment with rational models as a basis of intelligence in complex situations has come in parallel with a change in the adversaries of rationality within the social and behavioral sciences. Freud and Marx have been moved, temporarily perhaps, to those parts of the academic theater more closely allied with the humanities and critics of contemporary social and political regimes. Within social science, the principal current alternatives to rational models are more closely connected to Darwin. The metaphors, and to some extent the theories, of evolutionary change are as familiar to social and behavioral scientists today as those of Oedipus and the class struggle once were; and one of the primary discourses involves exploring how to think about processes of adaptation and theories that emphasize reacting to feedback from experience, rather than anticipating the future (Selten, 1991; Levinthal and Myatt, 1994; Börgers, 1996; Gregorius, 1997; Gavetti and Levinthal, 2000).

THEORIES OF FEEDBACK-BASED ADAPTATION

Contemporary theories that emphasize reacting to feedback include theories of:

- *Experiential learning*. A process by which the propensities to use certain procedures (or to have certain attributes) depend on the history of outcomes associated with previous uses in such a way that successes associated with a procedure in the past increase the propensity to use that procedure in the present (Cohen and Sproull, 1996; Lomi, Larsen, and Ginsberg, 1997; Greve, 2003).
- *Learning from others (diffusion, imitation)*. A process by which procedures or attributes of one unit are reproduced in another, and the likelihood of reproducing a particular procedure depends (positively) on the successes of the units using it (Abrahamson, 1991; Mezias and Lant, 1994; Miner and Haunschild, 1995; Strang and Soule, 1998; Miner and Raghavan, 1999).
- *Variation/selection*. A process by which the procedures used by particular units are unchanging but more successful units are more likely to survive, grow, and reproduce than are less successful ones (Nelson and Winter, 1982; Hannan and Freeman, 1989; Aldrich, 1999).

Each of these is a theory of feedback-based change over time. They posit that procedures or attributes associated with successes are more likely to survive and to replicate at a more rapid rate than procedures or attributes associated with failures. The reproductive history is sensitive to variety and change in the environments, including parts of the environment that are simultaneously coevolving. The adaptation may be imagined to occur at the individual unit (individual, rule, procedure, or organization) level or at the level of a population of units. The extent to which adaptation is seen as involving consciousness of its processes and opportunities for mindful intervention in them varies from one variant on the adaptive theme to another (Feldman, 2003).

Such feedback-based adaptive processes have long been noted as relevant to the pursuit of human intelligence and to organizations (Cyert and March, 1963). However, it is also well known that they do not necessarily result in the timely achievement of global optima (Brehmer, 1980;

Carroll and Harrison, 1994; Barron and Erev, 2003). There are numerous potential complications in using feedback-based adaptation to pursue intelligence. Some of those complications stem from properties of the settings in which adaptation occurs. Environments are often complicated, endogenous, subjective and contested. Some of the complications stem from properties of human actors. They are limited in their cognitive, attention, and memory capabilities and are dependent on a variety of well-known simplifications in historical interpretation and heuristics of judgment and action (Kahneman and Tversky, 2000; Camerer, Lowenstein, and Rabin, 2004). Some of the complications stem from properties of adaptive processes. Adaptive histories are inefficient in the sense that they proceed slowly and with error and can easily lead to stable equilibria that are far from global maxima. Except tautologically, the fittest do not always survive (Gould, 2002).

In discussions of these complications in recent years, one conspicuous difficulty has been noted repeatedly: the problem of maintaining adequate experimentation. Empirical observations of adaptive systems seem to suggest that they commonly fail to generate or adopt new ideas, technologies, strategies, or actions that would provide long run survival advantages. That issue arises in the context of discussions of innovation and the problems of stimulating it (Garud, Nayyar, and Shapira, 1997; Van de Ven, Angles, and Poole, 2000); in the context of discussions of entrepreneurship and new enterprises (Lant and Mezias, 1990); and in the context of discussions of diversity in species (Potvin, Kraenzel, and Seutin, 2001), work groups (Janis, 1982), and cultures (Martin, 1992).

The common observations are empirical, but it is not hard to derive the problem also from adaptive theory (Campbell, 1985; Baum and McKelvey, 1999). The first central requirement of adaptation is a reproductive process that replicates successes. The attributes associated with survival need to be reproduced more reliably than the attributes that are not. The second central requirement of an adaptive process is that it generate variety. Opportunities to experiment with new possibilities need to be provided. In order to meet these two requirements, adaptive processes engage in activities associated with exploitation—the refinement and implementation of what is known—and exploration—the pursuit of what might come to be known. Exploitation involves the application of established competence to problems. It yields reliable, good, standard answers, particularly in a stable world. Exploratory activities are sources of novel, unconventional, improbable, wild ideas and actions. Such ideas and actions become the bases for major innovations and responses to change when they prove to be right; they can lead to major disasters when they prove to be wrong.

In the face of an incompletely known and changing environment, adaptation requires both exploitation and exploration to achieve persistent success (Holland, 1975; March, 1991). Exploitation without exploration leads to stagnation and failure to discover new, useful directions. Exploration without exploitation leads to a cascade of experiments without the development of competence in any of them or discrimination among them. Specifying the optimal mix of exploitation and exploration is difficult or impossible (March, 1994: Ch. 6). In addition to the complications of dealing with a highly uncertain set of possibilities, determining an optimum involves trade-offs across time and space that are notoriously difficult to make. Although it can be shown that, everything else being equal, lower discount rates and longer time horizons make investment in exploration in standard bandit problems more advantageous than do higher discount rates or shorter time horizons (DeGroot, 1970: 398–399; Gittens, 1989: 82), such knowledge provides little precision in the identification of an optimum.

Furthermore, achieving a desirable mix of exploitation and exploration is made difficult by the local character of adaptation. Adaptive mechanisms are myopic (Levinthal and March, 1993; Denrell and March, 2001). Learning from others, experiential learning, and differential reproduction and survival all privilege outcomes, threats, opportunities, and preferences in the temporal and spatial neighborhoods of an adaptive agent. There are cognitive, motivational, and physical necessities that dictate this myopia. It is not something that can be routinely abandoned. Moreover, it makes considerable adaptive sense. For the most part, a local focus contributes to organizational survival. An organization cannot survive in the long run if it fails to survive in the short run, and the circumstances under which the self-sacrificing failure of a local component contributes positively to global success are fairly special.

It is well known that the myopia of adaptive processes poses a problem for exploration and therefore for long-run viability. Since the outcomes from novel initiatives generally have greater variability, longer lead times, and lower average expectations than do outcomes from known best alternatives, feedback-based adaptation favors exploitation over exploration, and thus favors technologies that yield observable, short-run returns (March 1991). In the name of adaptation, exploitation eliminates exploration; efficiency eliminates foolishness; unity eliminates diversity. As a result, adaptive processes are biased against alternatives that require practice or coordination with other alternatives before realizing their full potential, a bias that leads to the well-known competency trap (David, 1985; Levitt and March, 1988; Arthur, 1989). The myopia of adaptation also results in a bias against risky alternatives—those alternatives that have a relatively large variance in the probability distribution over possible outcomes (Denrell and March, 2001; Hertwig *et al.*, 2004). Adaptive agents learn to be risk averse (March, 1996); and although not all risky alternatives involve exploration, exploration almost always involves variability in possible outcomes. A bias against risk is effectively a bias against exploration.

Adaptive myopia underlies two classic sets of problems recognized in studies of collective choice. Within a myopic process, alternatives that provide benefits that are local in time or space and costs that are more distant are likely to be chosen more often than they should be. This leads to concerns about stimulating 'self-control,' the foregoing of local benefits because of more distant costs—something that adaptive systems have difficulty in accomplishing (Postrel and Rumelt, 1992; Elster, 2000). Conversely, alternatives that provide costs that are local and benefits that are more distant are likely to be chosen less often than they should be. This leads to concerns about stimulating 'altruism,' the acceptance of local costs in anticipation of subsequent or more global benefits—something that adaptive systems also have difficulty in accomplishing (Badcock, 1986; Cronin, 1991). The stimulation of altruism and self-control, when it is possible, counteracts problems stemming from the myopia of adaptive systems, but it introduces knotty conundrums of intertemporal and intergroup exchange and equity. Similar problems exist with other forms of diversity or variation, and efforts to shape adaptive processes to counteract their limitations often both conflict with other desires and are hard to implement.

THE SEARCH FOR MECHANISMS OF VARIATION

The ways in which adaptation itself extinguishes the exploration on which it depends are well understood; but theories of adaptation typically do not provide powerful understandings about the generation of new ideas, attributes, or actions, or about the ways in which persistence in novelty is supported. Adaptive theory generally leaves the endurance of exploratory initiatives and the mechanisms that produce them unexamined and unexplained. To a large extent, explorations in actions, attributes, and ideas, with their notorious low success rates, are accomplished by errors in the process. The underlying proposition is that nothing is perfect, that there will always be errors in the reproduction of success in any complex adaptive process, and that errors yield variation.

In most evolutionary theories, for example, variety is produced by sampling variation (e.g., the genetic combinatorics of mating) or arbitrary random error (e.g., mutation) (Harrison, 1988; Ayala, Fitch, and Clegg, 2000). In a similar way, students of organizational adaptation identify as sources of variation various forms of relatively random errors in adaptation (e.g., ignorance, failures of memory, emotion-based irrationalities). In addition, however, students of exploration in organizational settings have described several less random mechanisms. These include incentives that link exploration to immediate and near-neighborhood returns (e.g., competition for position), buffers of action from immediate feedback (e.g., organizational slack, inattention), and modes of action that are unresponsive to feedback on consequences (e.g., intuition, commitments to identities, and the tying of success to an adaptive aspiration level) (March and Shapira, 1992; Winter, 2000; Greve, 2003).

A more general basis for the endurance of exploratory mechanisms in a myopic adaptive process is found in the crudeness of adaptive discrimination. Adaptive processes operate on bundles of attributes rather than individual attributes. Organizational adaptation deals both with elementary components of action and with technologies that are amalgams of such components. It is possible that attributes associated with exploitation are so intermixed with attributes associated with exploration that the latter can be sustained by the replications fostered by the former. Surviving exploratory mechanisms are linked to instruments of selective efficiency.

For example, sexual reproduction is a fundamental instrument of mammalian replication of what is known to be related to success. Successful individuals mate, so the mating has elements of selective breeding; but successful individuals do not clone themselves exactly. There is substantial variation introduced by the arousal-based selection of mates and the sampling of genes. Since sexual arousal and receptivity are relatively unselective, they are simultaneously two of the main engines of the exploitative reproduction of success and sources of exploratory variation. The mechanisms of arousal and receptivity in mating among corporations, as well as those of reproduction, are different in detail from those associated with mammalian evolution; but it is easy to predict that selection among business firms is likely to have an imprecision comparable to that found among mammals.

Although it is recognized that mechanisms of variation can arise in these ways without conscious planning or intent, the designers of adaptive systems often proclaim a need for deliberately introducing more of them to supplement exploration. In their organizational manifestations, they advocate such things as foolishness, brainstorming, identity-based avoidance of the strictures of consequences, devil's advocacy, conflict, and weak memories (George, 1980; George and Stern, 2002; Sutton, 2002). They see potential advantages in organizational partitioning or cultural isolation, the creation of ideological, informational, intellectual, and emotional islands that inhibit convergence to a single world view (March, 2004). Whereas the mechanisms of exploitation involve connecting organizational behavior to revealed reality and shared understandings, the recommended mechanisms of exploration involve deliberately weakening those connections.

EXPLORATION AND TECHNOLOGIES OF RATIONALITY

Technologies of rationality are implicated in such stories. Organizations use a variety of technologies to generate actions. Some of those technologies are tied to rules and routines and depend on matching action appropriate to a particular identity or role to a particular situation. Some of those technologies accumulate knowledge through experience and attention to others and encode that knowledge in the form of action propensities. Some of those technologies use confrontation among contending interests and dialectical processes of conflict. Some of those technologies are based on logics of consequences, modeling, and rationality. The mix of technologies used by any particular organization or by families of organizations can be imagined to change over time as a result of some mix of adaptive processes, responding to indications of success or failure with the technologies (Chandler, 1962; Dutton, Thomas, and Butler, 1984).

The widespread replication of model-based rational choice as a technology of action and the sanctification of rational choice as a technique of problem solving testifies, in part, to a record of successes of rationality as an instrument of intelligence. There seems little question that technologies of rationality are often effective instruments of exploitation. Model-based rational analysis has led to numerous improvements, for example the introduction of slippery water in the New York Fire Department, the development of single queues in multiple server facilities, the design of auctions, and the implementation of flexible timing of traffic signals and other regulators of queues. Rational technologies are now used routinely to solve numerous problems of focused relevance, limited temporal and spatial perspectives, and moderate complexity (*RAND Review*, 1998). Rationality and its handmaiden, well-established knowledge, both increase average return and reduce variance (unreliability). A feedback-based adaptive process supports and replicates technologies exhibiting such exploitative capabilities; and model-based rationality has been widely replicated as a technology of action.

These successes have, however, not been repeated reliably in more complex situations. As complexity is increased and temporal and spatial perspectives are extended, returns (both of alternatives that are adopted and of those that are rejected) are likely to be misestimated by huge amounts. This means that those alternatives that are adopted are likely to have been overestimated by huge amounts. There are many instances in which the use of a technology of rationality in a relatively complex situation has been described as leading to extraordinary, even catastrophic, failures. These include the extensive efforts of the Soviet Union to manage an economy through planning and rational analysis (Campbell, 1992; Solnick, 1998); the attempts of various American firms to use learning curves as a basis for investment, pricing, and output strategies (Ghemawat, 1985, 2002); the attempt by the American political and military establishment to use rational analysis to develop strategies for war in Vietnam (Halberstam, 1972); the attempt by Long-Term Capital Management to use rational theories to make money in the options market (Warde, 1998); and the wave of corporate mergers in the United States from 1998 to 2001 (Moeller, Schlingemann, and Stulz, 2003, 2005).

To some extent, the poor record of rational technologies in complex situations has been obscured by conventional gambits of argumentation and interpretation. The failures have been pictured as stemming not from the technologies but from some features of misguided use of them. It is sometimes claimed that the schemes generated by such technologies are good ones but have been frustrated by implementation problems, by the perversities or incompetence of individuals involved in bringing them to fruition. It is sometimes claimed that although the rhetoric justifying a particular action is explicitly rational, a rational technology has actually been used only as a justificatory vocabulary not as a basis, thus did not produce the disaster. It is sometimes claimed that although the record is poor, it is at least as good as alternative technologies for dealing with complex situations.

Argumentation and interpretation cannot, however, conceal the essential problem: the unintended exploration produced through technologies of rationality in complex situations seems clearly to produce many more disasters than it produces glories of successful discovery. There is no magic by which this fundamental dilemma of adaptation can be eliminated. The use of rational technologies in complex situations may very well be maintained by generalization from successes in simpler worlds, by the enthusiasm of the industry that has grown up around it, and by the hubris and limited memories of decision makers (McMillan, 2004), but it seems unlikely to be sustained by experience in complex situations and feedback-based adaptation stemming from that experience.

This result, however, can be seen as a possibly unfortunate reflection of one of the more persistent problems associated with learning from history. Adaptation responds to the recorded events of history, not to the underlying distribution of possible events. In effect, adaptive processes treat realized outcomes of history as necessary ones. As a result, they essentially exaggerate the likelihood of what has happened and underestimate the likelihood of things that might have happened. If history is seen not as a fixed outcome of determinate forces but as a draw from a probability distribution over possibilities, then the lessons to be drawn from history are not contained simply in its realizations but extend to the hypothetical histories that might be imagined from simulating the inferred underlying historical process (Brenner, 1983; March, Sproull, and Tamuz, 1991; Ferguson, 1999; Tetlock, 1999). Any probabilistic historical process is subject to sampling error in its realizations, and historical processes involving small samples, highly skewed underlying distributions (such as those hypothesized to exist with respect to novel ideas), and sampling rates that are affected by sampling experience are particularly prone to being poorly represented by their realizations (Denrell and March, 2001; Hertwig *et al*., 2004; Denrell, 2005). The misrepresentation leads to faulty adaptation.

In the present case, historical interpretations are likely to ignore the extent to which the legendary mistakes of rational technologies may be symptoms of exploratory power. History is filled with cases where the technologies of rationality have initiated or supported experimentation with new actions or strategies that offer novel approaches of great predicted value. Characteristically, the predicted values have failed to materialize. The same methods that identify new possibilities, also contribute to substantial errors of estimation. The technology depends on abstract models of reality that reduce the complexity of any particular context to what are believed to be its essential components and relations. The models depend on strong assumptions about the extent to which present knowledge encompasses the causal structure of the world and the preference structures of human actors. Within such abstractions, the forecasts of rational calculation compound so that small errors or oversights multiply into large ones and multiply at an increasing rate as complexity increases. These errors are often costly, even deadly, in their consequences.

In a world in which great ideas are unlikely draws from a pool of apparently crazy ideas, the capability of rational abstractions to generate huge mistakes in their exploratory gambles is a potential gauge of their capability to discover dramatically useful surprises. Although it would be perverse to interpret all disasters as stemming from imagination, frequent cases of ventures that have turned out to be hugely misguided are one of the possible signs of a potential for generating a rich cache of wild ideas. The evidence from failures of rationality in complex situations, such as those identified above, suggests that imagination thrives on the power of rational technology and on the ambitions of utopian rational modelers. By a sophisticated (and optimistic) invocation of counterfactual histories, one can picture the capabilities of rational technologies for producing huge disasters as symptomatic of their capabilities for producing great discoveries. Thus, it is possible to imagine that the exploratory power of rational technologies might be sustained in an adaptive process. The sophistication, however, comes at a price that plagues counterfactual thinking. Learning from counterfactual histories blurs the distinction between data and theory. It thereby compromises the integrity of evidence and inferences from it. It solves one problem but creates another.

By this reading of history, however, technologies of rationality are not so much enemies of foolishness and exploration, as they are agents of them. Those who seek instruments of variation, exploration, and radical change in organizations are often inclined to scorn rational technologies, seeing them as allies of conventionality and of the institutions, disciplines, and professions of the status quo. It is argued that the link between rationality and conventional knowledge keeps rational technologies reliable but inhibits creative imagination. This characterization seems plausible, but it probably underestimates the potential contribution of rational technologies to foolishness and radical visions. Technologies of rational choice, and the technologists of model-based rationality are not simple instruments of exploitation but (partly) instruments of exploration hiding behind a façade of exploitation: revolutionaries in pin-stripe suits. As such, they should perhaps be seen less as stodgy agents of conventional knowledge than as dangerous fools, joining thereby the pool of dreamers out of which come great ideas as well as monstrous and idiotic ones.

Seeing the use of technologies of rationality in complex situations as a source of exploration, however, still leaves unresolved a classical normative question of exploration—whether the brilliant discoveries that might occasionally be achieved are adequate recompense for the many egregious stupidities committed. The mysteries of hypothetical histories and the conundrums of trade-offs across time and space make the answer to that question conspicuously indeterminate; but the outcome provided by adaptive processes is much less problematic. Whatever the potential value of rational technologies as a source of exploration, their adverse record in solving complex problems cannot be expected to sustain them in a myopic adaptive process that reproduces practices associated with local success and extinguishes practices that lead to local failure. Insofar as they have survived, they have done so because alternative technologies are not conspicuously better in complex situations and because of the effectiveness of rational technologies in simpler situations. The exploratory activities of rationality have hitchhiked on its exploitative successes.

As with all hitchhiking phenomena, and for the same reasons that exploration is disadvantaged by a myopic adaptive process, this kind of hitchhiking solution to the exploration problem is potentially ephemeral. The same adaptive process that selects among technologies also shapes the applications of the technologies, matching applications to situations of success. The differentiation among situations may be slow, but it seems reasonable to expect that in the long run, and in the absence of some other mechanism, organizations will learn to use technologies of rationality for simple problems, but not for complex ones. Learning to differentiate simple problems from complex problems and using the technologies only for the former would eliminate most of the exploratory output of rational technologies. There are folkloric indications of such a differentiation. Decision makers now frequently comment that technologies of rationality are not particularly useful in major complex decisions but should be focused on 'more narrowly defined problems' (*RAND Review*, 1998: 5). One of the architects of the attempt to model the competition between the United States and the U.S.S.R. during the Cold War era described the complications in these terms:

> If we really are to understand the nature of the competition, the nature of their interaction process, we will need to understand much better than we

> do now the decision making processes within both the U.S. and Soviet political–military–industrial bureaucracies. We need an understanding of the processes that lead to the selection of specific R&D programs, to R&D budgets and their allocations, to procurement decisions, to the operation of the whole of the weapon system acquisition process. We would need to understand how the perceptions of what the other side is doing come about in various places within these complicated bureaucracies, and how these perceptions influence the behavior of the various organizations and the decision makers involved in the complex decision processes that drive the evolution of the several defense programs involved. (Marshall, 1971: 7)

Such an understanding is likely to be elusive within models of rational technology. As a result, attention to feedback from experience in complex situations discourages the use of the technology (Popper, 1961: Myrdal, 1971; Hirschman, 1981). For example, the imaginative and provocative set of ideas pioneered by John von Neumann and Oskar Morgenstern (1944) under the rubric of game theory has proven to be enormously useful in analyzing simple forms of conflict but arguably less powerful in more complex situations. From the late 1940s to the mid 1960s, academic scholars working at the RAND Corporation, including such luminaries as Kenneth Arrow, Merrill Flood, John Nash, Thomas Schelling, Martin Shubik, and Lloyd Shapley, produced research memoranda on game theory, its possible applications, and its pitfalls. By the end of that period, game theory was well-established as a domain, and its applications to some (but not all) relatively simple situations were viewed as successful (Ghemawat, 1997); but the relevance of game theory for dealing with complex situations such as that involved in the confrontation of the United States and the U.S.S.R. was widely questioned. This negative adaptive experience with game theory as a basis for dealing with international conflict is not unique. It appears not to be a product of any particular application of any specific rational technology but an inherent characteristic of the technology itself.

It is possible to imagine that the feedback disadvantages of the wild ideas of rationality might be reduced by reshaping organizational experience. The most obvious possibility is to discover ways, at an early stage, to distinguish novel ideas that will be spectacularly successful from those that will be disasters, thus to change the success rate of experience. This possibility has supported considerable research on creativity. The evidence is strong, however, that such early discriminations are almost impossible to make, particularly when the novel ideas deviate substantially from received truths—precisely the case of interest. Historically, new ideas that have subsequently been shown to change things dramatically have generally looked distinctly unpromising initially (Aronson, 1977; David, 1990). Most attempts to distinguish creative instances of craziness from useless or dangerous ones at an early stage impose criteria of conventionality on craziness and thereby impose self-defeating filters that reduce novelty.

Alternatively, if it were possible to make small experiments with wild ideas, while retaining the possibility of diffusing those that prove to be good ones, the adaptive position of exploration would be strengthened (Romano, 2002; Holahan, Weil, and Wiener, 2003). Since structures that protect the system from the catastrophic consequences of wild ideas generally also inhibit the transfer of major discoveries (Cohen and Levinthal, 1989, 1990), there is no perfect solution to the problem. However, two kinds of strategies seem to have appeal: the first involves controlling the 'bet size' of developing ideas. If small-size experiments can be devised to examine an idea, and if they can be scaled up without loss of validity subsequently, bad ideas can be sorted from good ones at a cost that is less than the return generated by the few good ones when they are scaled up. There are difficulties associated with the problems of scaling up from small experiments to large implementations, particularly when one of the common complications is the failure to capture the full complexity of the system, but small experiments are a classic device.

A second strategy involves partitioning the audience into subgroups. Technologies of action spread so that practitioners and theorists share a common sense of what is true, just, and beautiful. The community is often fractured, however, into segregated subgroups pursuing different practices and ideas. Experience with the good or bad consequences of those practices is localized to the subgroups, and the resulting smaller sample sizes of experience increase the possibilities for a locally favorable result from a practice having a poor expected value (Dubins and Savage, 1965), and thus for local persistence in pursuing technologies that generate wild ideas. Although most of that persistence will turn out to be unproductive, the segregation of subgroups sustains experimentation in a few cases that are ultimately deemed successful. Provided the segregation of groups is not complete, these successes can spread more widely (March, 2004). There is, however, an obvious complication: subgroup segregation contributes to local differentiated persistence with ideas, but it also inhibits the diffusion of good ideas to groups other than the ones that originally discovered them. As a result, the optimum level of segregation is difficult to specify.

THE HEROISM OF FOOLS

Enthusiasts for rational technologies in complex situations, like other enthusiasts for variation in adaptive systems, generally proclaim an unverifiable confidence in two propositions. The first proposition is that the current level of exploration is less than would be optimal. The second proposition is that, in a long-term and global perspective, the threats to survival posed by the disasters of rational technologies applied to complex situations are less than those posed by failure to discover and exploit the beneficial ideas generated by the technologies. Neither proposition is obvious, nor is it obvious how one might easily confirm or disconfirm either of them.

We do know something, however. Exploratory foolishness may sometimes be desirable, and technologies of rationality may be important sources of exploration; but the use of rational technologies in complex situations is unlikely to be sustained by the main events and processes of history. Technologies and practices that produce wild ideas have large variances in their returns and relatively low means. Their positive returns are disproportionately realized at temporal and spatial distances from the point of action. These properties make them vulnerable to a myopic adaptive process. Some ameliorations of the dilemma are possible, but it cannot be eliminated. In the end, foolishness and exploration are the natural (and largely unlamented) victims of adaptive processes. Their sustenance requires errors of adaptation, in particular the errors produced by the heroism of fools and the blindness of faith.

A commitment to rationality as an instrument of exploration might be imagined to be proper for academic scholars of strategic management. Persistence in such a commitment is not, however, a likely product of experience outside the world of the mind. Foolishness in the service of exploration will usually turn out to be dangerously unwise: it is unlikely to be rewarded by the histories recorded in the temporal or spatial neighborhoods of the craziness, nor can it be guaranteed to be justified in a longer or broader perspective. Belief in the exploratory value of rational technologies requires a leap of faith about the virtue, joy, and beauty of imagination, the contribution of abstract thinking to fostering it, and the pleasures of deriving surprising implications from unrealistic assumptions. Such enthusiasm for exploratory rationality fulfills academic obligations to defend a utopia of the mind against the realism of experience, and academic purities of belief can endure within a relatively closed community of similar academics. Such faith-based imperviousness to feedback is both the despair of adaptive intelligence and, occasionally but only occasionally, its salvation.

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