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LEARNING THROUGH REPLICATING SUCCESS

Extracting lessons from natural experience presumes a learning cycle that begins with observing associations between actions and outcomes, the rudiments of finding order in history. Learning takes place when the observation of associations produces changes in actions or rules for actions. Learning serves intelligence when those changes improve the actions or the rules. Changes from learning occur often and relatively easily, but their contribution to intelligence is more problematic. Experiential learning makes many mistakes.

TWO MODES OF INTELLIGENT ADAPTATION

It is useful to distinguish two different modes of achieving intelligence through experience. The two modes reflect different kinds of processes and encounter different kinds of

complications, so the distinction may be useful as long as it is recognized that actual occasions of learning involve mixtures of the two (Zollo and Winter 2002; Winter, Cattani, and Dorsch 2007; Starbuck, Barnett, and Baumard 2008; Winter 2009). The first mode—which might be called “low-intellect” learning—is one in which actions associated with success are replicated with little or no effort at causal understanding. The second mode—which might be called “high-intellect” learning—is one in which explicit efforts are made to understand the causal structure of the events of experience and to derive action implications from that understanding. The distinction is closely related to that made by Starbuck, Barnett, and Baumard (2008) between noncognitive and cognitive learning and by Gul and Pesendorfer (2008) and Camerer (2008) between mindless and mindful economics, though the different terms contain somewhat different nuances. Low intellect and high intellect are not differentiated by merit. Each has its place; each has its limitations.

Low-intellect mechanisms of learning from experience are built on the replication of success and are common among both humans and other animal species. They often generate rules or heuristics of behavior that are surprisingly effective (Hutchinson and Gigerenzer 2005). High-intellect mechanisms, on the other hand, appear to be less prominent in the learning of other animals than they are among human beings. The entire academic apparatus for developing, recording, and dispensing knowledge derived from theories about the underlying causes of outcomes of experienced history is

a distinctively human construction. That apparatus depends on the power of written language and instruments of symbolic manipulation that not only are uniquely human but have existed among humans only for the past few thousand years.

THE REPLICATION OF SUCCESS

The basic idea of replication of success is inherent in a familiar set of ideas in studies of organizations. Organizations are often seen as comparing performance with an aspiration for performance and searching for changes primarily when performance falls below aspiration (Cyert and March 1963; Greve 2003; Baum and Dahlin 2007). Thus, actions associated with success are more likely to be reproduced than are actions associated with failure.

In its barest form, the replication of success is elegant in its simplicity:

- (1) Act by choosing an alternative from among those available.
- (2) Record a result and evaluate it in terms of its success.
- (3) Replicate the choice of alternatives associated with successes more often than the choice of alternatives associated with failure.

Practices, forms, and rules that are associated with good outcomes survive longer and reproduce more than practices, forms, and rules that are associated with poor outcomes.

It should be observed that describing the replication of success as low-intellect (or “noncognitive”) is potentially misleading. Such a description ignores cognitive complications involved in the adaptive process. For example, in a classic binary learning task, a learner chooses repeatedly between two mutually exclusive and exhaustive alternatives. When consistently rewarded on one of the alternatives, the learner normally learns to choose it. However, even as elementary a situation as a T-maze leaves the cognitive definition of the alternatives unspecified. For example, are the two alternatives “go left” or “go right”? Or are they “go to the same place as last time” or “go to the other place”? The classic Bush-Mosteller-Estes model of learning in two-choice situations (Bush and Mosteller, 1955) predicts quite different learning patterns depending on the definition of the alternatives if the reward schedule alternates rewards on the two alternatives (Lave and March, 1975).

The intellect (cognitive) component becomes even more obvious when discussions of replication turn to issues concerning the generalization of learning to situations that are not identical to those in which previous experience has occurred but might be imagined to be, in some sense, similar (Winter 2009). “Similarity” can be provided a somewhat objective meaning in experimental settings; but in the real world it becomes a mental construct of considerable indeterminacy. Issues such as these are, for the most part, ignored in the discussion below.

The paradigmatic situation for the replication of success is one in which a choice is made repeatedly among a number

of alternatives. The alternatives might be actions, strategies, products, technologies, locations, partners, or any number of other mutually exclusive and exhaustive items. In each time period, a particular alternative is chosen and an outcome is experienced. Subsequent choices favor alternatives associated with better past outcomes over alternatives associated with poorer outcomes. The capability generated by the replication of success is contextual. It may generalize to new situations that are, in some sense, similar to the original situation; but there is little reason to expect it necessarily to do so. And the capability reflects no significant element of causal understanding.

A process that simply replicates success is attractive for many reasons. It captures truth without the necessity of articulating it. It is a democratic instrument, being as accessible to the weak as to the powerful, as accessible to the uneducated as to the educated. It is a practical instrument, dealing more with the pragmatic necessities of ordinary life than with the abstract imaginations of ideas and theories. It is a tailored instrument, reflecting considerations in a specific concrete situation by virtue of having been developed in the same context. It is a compelling instrument, mobilizing a sense of personal relevance by its link to success and failure in direct experience.

Three Mechanisms

The replication of success may occur in a number of different ways. In particular, we consider three classic mecha-

nisms. The three mechanisms differ in important ways, but they also share common structural features that are significant.

The first mechanism is *trial-and-error learning*. Learning replicates success by modifying rules so as to repeat successful actions more readily than unsuccessful actions. The paradigmatic experiential trial-and-error learning situation involves a set of alternatives with associated outcome distributions and a learning rule that modifies actions as a result of realized outcomes. There are two enormous literatures dealing with trial-and-error learning. The first is the literature on so-called bandit problems in operations research (Gittins 1989). A bandit problem is one involving sequential choices among a collection of alternatives with unknown payoff distributions. Information about a specific alternative can be obtained only by choosing it. The usual objective of the research on bandit problems is to find an optimal strategy for engaging such situations, or at least a strategy that is better than other known ones. The key strategic question is whether to select the apparently best alternative (on the basis of experience to date) or to sample alternatives further in order to gather more information. In general, the research on bandit problems indicates that optimal strategies depend on the time horizon chosen. The longer the time horizon, the more advantageous is the expanded sampling of unknown or apparently inferior alternatives.

The second enormous literature on trial-and-error learning deals with reinforcement learning in a T-maze (Mowrer and Klein 2001; Lovie 2005). The objective of the research

is to understand animal and human learning in simple choice situations under various conditions of reward, and to model that learning. In general, the research indicates that learners characteristically improve performance as experience increases but that there are numerous situations in which choices that are made do not conform to what appears to be optimal behavior. For example, consider a situation in which there are two alternatives with probabilities of reward unknown to the learner but one with a probability p_1 of reward and the other with a probability $p_2 < p_1$ of reward. Many experiments of this sort have been run, leading to numerous attempts to confirm or disconfirm expected utility hypotheses about human behavior or specify the conditions under which they hold. For example, if the outcome for each alternative on each trial is revealed regardless of which alternative is chosen, an expected utility-maximizing learner would adopt a strategy of always choosing the more frequently rewarded alternative. Such a result is not always observed.

The second mechanism for replicating success is *imitation*. Imitation replicates success by having actions associated with success when executed by one actor imitated by another actor. Replication through imitation probably represents the majority of what is normally called “innovation” in the organizations literature (Mansfield 1961; Mahajan and Wind 1986). The ways in which known attributes and processes spread within a population of organizations have been studied extensively in research on innovation and change in organizations (Reinganum 1989; Haunschild and Miner 1997). The empirical study of imitation is complicated by the diffi-

culty of distinguishing the aggregate results of a diffusion process from the often similar aggregate results of the independent adoption of a practice, product, or form in a heterogeneous population (Gray 1973; Volden, Ting, and Carpenter 2008). There seems little doubt, however, that imitation is often involved in the replication of success (Holden 1986; Conell and Cohn 1995).

The idea that things spread among organizations is well known in discussions of fashion and fads (Abrahamson 1991; Newell, Swan, and Kautz 2001; Kieser 2002), contagion (Burt 1987; Galaskiewicz and Burt 1991; Strang and Soule 1998), and institutionalization (Zucker 1987; Bergevärn, Mellemvik, and Olson 1998; Scott 2003; Greenwood and Suddaby 2006). Studies of imitation emphasize the ways in which the successful actions of one actor are replicated in the actions of another (Miller and Dollard 1941; Nehaniv and Dautenhahn 2007) and the ways in which networks of associations affect the spread of ideas, beliefs, routines, or actions through a population (Podolny, Stuart, and Hannan 1996; Powell, Koput, and Smith-Doerr, 1996; Uzzi 1996).

Studies of replication through imitation build on standard epidemiological representations that assume the following (Bartholomew 1982):

- (1) a set of alternatives with associated outcome distributions;
- (2) a direct contact matrix that indicates the direct contacts for each actor; and

- (3) a contagion rule that defines the likelihood of actor i imitating actor j at time t .

The prototypic models examine the replication of the behavior of the successful who are connected (Granovetter and Soong 1983; Strang and Soule 1998). The results depend on properties of the “donor” and the “recipient,” properties of the “disease,” and properties of the structure of linkage. In general, diffusion processes often exhibit threshold effects (Schelling 1971; Gladwell 2000), and they more reliably yield convergence (but see Greenwood and Suddaby 2006; Purdy and Gray 2009) than they do optimality (Strang and Macy, 2001). The effectiveness of imitation in finding optimal solutions depends on the structure of connections among learners; but it is not, in general, true that effectiveness increases monotonically with the density of connections.

Simple epidemiological conceptions embrace two assumptions that are particularly problematic when applied to replication among organizations. The first problematic assumption is that an object of diffusion is invariant as it diffuses. Studies of the spread of things among organizations indicate that the object of diffusion often is transformed as it is transferred from one organization to another (Czarniawska and Sevón 1996; Scott 2003). In fact, the ability to copy exactly is sometimes described as an essential feature of effective replication in organizations (Winter 2009). The second problematic assumption is that the links among adopters are unchanged by the process. In populations of organizations, the connections themselves are likely to be affected by the history of the diffusion process.

In particular, an instance of imitation is likely to strengthen the linkage through which the imitation occurs (March 1999a).

The third mechanism for replication of success is *selection*. Selection replicates success by reproducing attributes (e.g., rules, routines, forms) associated with success and eliminating attributes associated with failure. Theories of replication through selection assume a set of fixed attributes, a selection rule that determines survival among the attributes, and replication rules that determine the reproduction of attributes. In the organizational versions of replication through selection, the elimination of attributes depends on relative performance within a group of competitors, and successful attributes are replicated more often than unsuccessful ones (Alchian 1950; Winter 1964; Baum and Singh 1994).

These ideas, of course, draw upon other enormous literatures in evolutionary biology and evolutionary economics (Mayr 1963, 1982; Selten 1991; Gould 2002; Nelson and Winter 2002; Witt 2003). They posit various forms of variation in attributes and various processes of selection among them. The results depend on the specific forms taken by variation and selection and the nature of competition. The processes are generally slow relative to the changes in the environment to which they respond; and they often have multiple equilibria, not all of them equally attractive.

Two Sets of Questions

The literature on processes of adaptation that replicate success addresses two related, but different, sets of questions.

The first set includes: What *do* individuals or organizations do in this situation? How do they act? How do their actions change over time as a result of experience? To what extent, in what way, and at what rate do they respond to knowledge of experienced results? To what extent do they learn to pursue the best alternative?

The second set of questions includes: What *should* an intelligent person or organization do in this situation? How long should several alternatives be sampled in order to obtain information about them? When should a choice be made and on what basis?

With respect to the second set of questions, mechanisms for the replication of success share a fundamental problem that is also conspicuous in calculative rationality—indeed, in all adaptive processes: How do they recognize and achieve an optimal balance between exploitation and exploration? (See Kuhn 1962, 1977; Holland 1975; March 1999c, chap. 7; Chen and Katila 2008; Fang and Levinthal 2009.) Exploitation refers to the utilization and refinement of what is known. It is reflected in efforts toward efficiency, standardization, accountability, and control. Exploration is the pursuit of what is not known. It is reflected in efforts to generate and experiment with deviant procedures and new possibilities. In processes involving the replication of success, the problem is typically a problem of allocating resources between efforts to learn more about the world (exploration) and efforts to take advantage of what is already known (exploitation). A frequent question about the replication of success is whether, as it responds to immediate feedback, it

allocates too few resources to exploration (Starbuck, Greve, and Hedberg 1978; Miller 1994).

There are some obvious criteria that can be applied to evaluate the effect of replicating success on any particular set of rules for action:

Improvement: Does average performance improve with experience?

Stability: Does the likelihood that a choice at time t repeats the choice at $t-1$ increase with experience?

Reputation error: Is the past realized performance (reputation) of the chosen alternative greater or less than its expected value? How does the error change with time?

Optimality: Is the best alternative discovered and adopted? How long does it take? Or alternatively, how close is the chosen alternative to the optimum in expected performance over time?

COMPLICATIONS IN SUCCESS REPLICATION

Trial-and-error learning, imitation, and selection have different properties as adaptive mechanisms, but they have a set of basic structural elements in common. These shared elements and the complications they create are the primary foci of the present discussion. For the most part, the phenomena considered here stem from properties of the learning environment and the adaptive mechanisms, not from any distinctive

features of the cognitive apparatus that may be brought to bear on them. Thus they are different from, and substantially independent of, well-known cognitive limitations of individuals. These “structural” complications can be understood, but an understanding of the complications by an adaptive agent does not eliminate the difficulties.

First, history is complex. Even though the world may be orderly in the sense of following immutable laws, it is filled with complex causal relations. Forming correct inferences about history in the face of such complexity requires a complicated experimental design, a multivariate model, and a large sample. Unfortunately, the conditions underlying the replication of success in real experience include simple implicit experimental designs, simple implicit correlational models, and small samples. As a result, the replication of success is subject to extensive elements of misspecification and superstition.

Second, history is subject to stochastic uncertainty. The orderliness of the world is obscured by probabilistic variations. Identifying the best alternative through experience involves untangling the joint consequences of signal, noise, and sample size. *Signal:* The greater the true differences among alternatives, the greater the chance of identifying the true optimum by observing a sample. *Noise:* The smaller the stochastic variation in the observed outcomes, the greater the chance of identifying the true optimum by observing a sample. *Sample size:* The larger the sample, the greater the

chance of identifying the true optimum by observing a sample.

Since experience in organizations often suffers from weak signals, substantial noise, and small samples, it is quite likely that realized history will deviate considerably from the underlying reality. Adaptation responds, not to the distribution of potential histories but to the specific history realized in a small sample. The results may lead to a more favorable experience with an alternative than is warranted, thus leading to a mistaken replication. Alternatively, the results may lead to a less favorable experience than is warranted, thus leading to a mistaken avoidance of replication.

As is well known to students of stochastic processes, stochastic variation produces some quite striking, counterintuitive surprises (Feller 1968). Many of these surprises are variations on so-called first-passage theorems or competitive maximum theorems. An example of the former is the case of coin flips: If a single fair coin is flipped a large number of times, what is the distribution of length of runs in which more than half of the results are heads? The usual intuition is that a fair coin should lead to relatively short runs of dominance by either heads or tails; the actual result is that the runs are, on average, rather long.

An example of competitive maximum theorems is provided by comparing two identical competitors, each of whom realizes each period a draw from a normal distribution with mean=0 and variance=1. Suppose we consider the average realized performance of the two competitors over time. As experience accumulates, the likelihood increases

that the competitor with the greater average realized return at time t will also have the greater average realized return at $t+1$. That likelihood becomes quite high as t increases. The rankings of two competitors, in terms of average performance to date, persist for an extended time even though the two are identical in capabilities and even though the difference in average performance declines.

Third, the outcome possibilities for the various alternatives are affected by the sequence of choices made and the outcomes realized. Replication of success naturally affects the alternative chosen and thus the distribution of possibilities from which an outcome is drawn. Less obviously, it also often affects the distribution of possibilities for a given alternative. In standard terminology, the individual outcome distributions are endogenous to the choice or the realized outcome.

Some of the endogeneities can be characterized as cases of depletion: that is, the replication of success results, on average, in a lower performance because the replication itself is detrimental to subsequent outcomes. The most obvious cases involve resources that are depleted by use or competition. Other cases involve the corrosion of advantage through exploiting it (Barnett and Hansen 1996). Suppose, for example, that a tennis player follows a strategy of hitting the ball to the weaker side of his or her opponents, thus increasing the short-run prospects of victory but at the same time providing more practice for opponents in using their weaker hands than in using the stronger. Over time, practice effects

will reduce the differences in competence between the two hands of competitors and thus reduce the competitive advantage of hitting to the weaker side. Other examples include cases of boredom or cynicism. Still others involve the adjustments of others, as for example when crying wolf changes the longer-run likelihood of a response to the cry.

Of possibly even greater importance, however, are cases involving outcome distributions that are augmented by use—where the replication itself improves the outcome distribution. An important case involves the effect of practice on performance. Each time a given alternative is chosen, its capability improves. It seems reasonable to assume that, typically, the effect of practice is to increase the mean and decrease the variance of the outcome distribution for the chosen alternative.

Practice effects complicate the use of success replication in finding an optimum choice. This complication is usually described in terms of “competency traps” (Levitt and March 1988; Arthur 1989). Suppose performance in a particular activity is a product of a fixed potential for the activity and a variable level of competence at it. Competence is characteristically low initially but increases through practice. Since performance reflects the product of competence and potential, practice effects make identification of the alternative with the highest potential more difficult than it would be in the absence of practice effects. It is quite possible that an alternative of lower potential will come to dominate one of greater potential by virtue of greater current competence on the former. This is particularly likely when comparing an ex-

isting inferior alternative at which an organization has a prolonged history of practice with a new superior alternative with which the organization is relatively inexperienced. Replication of success is more likely to aggravate this problem than to ameliorate it.

Similarly, if success makes subsequent success more likely, as in the “Matthew Effect” (Merton 1968), outcome distributions are endogenous to choices. Suppose, for example, that realized performance at time t , r_t , is a draw from a normal distribution with mean $=x_t$ and standard deviation $=s_t$. If x_t is a function of r_{t-1} (for example, $x_t=r_{t-1}$) the process takes on martingale characteristics, with the result that small initial differences among alternatives are converted, over time, into large differences. An obvious organizational example is the way in which evaluations of early performance influence evaluations of subsequent performance so that small initial variability in evaluations of personnel becomes large variability. A related example is found in the way that the likelihood of imitation of a particular practice depends on its “legitimacy,” which in turn depends on the number of others who have already adopted the practice (Carroll and Hannan 1989; Hannan 1998).

The replication of success is also affected by the definition of success in terms of a relation to aspirations and the ways in which aspirations are affected by achievements (Payne, Laughhann, and Crum 1980, 1981). Suppose the aspiration level at time t is a mix between aspiration at $t-1$ and performance at $t-1$. Thus, aspiration tends to track performance (is, in fact, an exponentially weighted moving average

of performance) and essentially discounts current performance by a positive function of past performance. This makes subjective success or subjective failure particularly sensitive to noise in outcome determination. By making success (and thus the replications of success) depend on the history of past performances, adaptive aspirations tend to slow learning, especially if the rate of aspiration adjustment is rapid (March and Shapira 1992). On the other hand, if aspirations do not adjust to experience, so that success or failure tends to be stable, learning can become superstitious (Lave and March 1975).

Thus there are three simultaneous elements of learning. The first is *learning what to do*: looking for a good (or best) alternative technology, strategy, partner, etc. The second is *learning how to do it*: refining and improving competence with an alternative. The third is *learning what to hope for*: modifying the aspiration level for performance. The simultaneous adaptation of these three elements complicates the effectiveness of locating the best alternative. Adaptiveness in making a technology work and adaptiveness in aspirations interfere with adaptiveness in choosing a superior technology.

Fourth, sampling rates of experience are affected by sample outcomes. Experience in a particular time period can be seen as a draw from the distribution of possible outcomes associated with an alternative. Any particular experience is likely to be misleading to the extent to which there is variation in possible outcomes; and small samples of experience

will have greater sampling error than will larger samples. The repetition of alternatives associated with success and the avoidance of alternatives associated with failure assure that the sample size of experience with successful alternatives will be larger than the sample size of experience with unsuccessful alternatives. As a result, the sampling error associated with unsuccessful alternatives will be larger than the sampling error associated with successful alternatives.

Two types of errors in experiential learning stem from sampling errors. The first is the error produced when a sample of experience has unrepresentative high returns. The second is the error produced when a sample of experience has unrepresentative low returns. Since the sample size of successful alternatives is increased by the repetition of success, the errors made by overestimating the value of an alternative tend to be self-correcting. Repetition reduces the sampling error associated with experience with a successful alternative, thus exposing errors of overestimation. On the other hand, errors made by underestimating the value of an alternative are not self-correcting. Alternatives that are better than their early results will tend to be persistently underrated and underchosen.

Some of the phenomena can be illustrated by a simple model, as long as it is recognized to be a very stylized representation. Suppose a choice is made each time period among a set of fifty alternatives. Each alternative (A_i) is characterized by a normal outcome distribution with a mean= x_i and a standard deviation= s . The x_i 's and s are fixed over time. The x_i 's are themselves draws from a normal distribution

with a mean=0 and a standard distribution=S. Each alternative has an initial reputation, $R_{i,0}=0$, the mean expectation within the population of alternatives. Subsequently, the value of $R_{i,t}$ for each chosen alternative equals the mean realization associated with a choice of that alternative. Thus, reputations at t may be based on as few as zero observations or as many as $t-1$. Each time period the alternative with the highest reputation, $\max R_{i,t}$, is chosen and an outcome realized (a draw from the distribution for that alternative).

The properties of this simple model illustrate the consequences of the endogenous sampling rate. *Improvement*: When the alternatives have different means ($S>0$), the replication of success improves performance over time. Better alternatives are discovered and replicated. *Stability*: There is a strong tendency for the replication of success to become very stable in its choice of alternatives. This result occurs, though with less force, even when there are no differences among the alternatives ($S=0$). *Reputation error*: The difference between the reputation of the chosen alternative and the true mean of the outcome distribution for that alternative ($R_{i,t}-x_i$) is positive—that is, reputations of chosen alternatives overestimate capabilities. The error is large initially but declines over time, ultimately (after a very large number of periods) approaching zero. *Optimality*: If we compute the ratio between the mean of the chosen alternative and the mean of the best possible alternative among the fifty alternatives where $S>0$, the mean fraction of the optimum that the process realizes increases over time, but it falls far short of 1.0. The process rarely discovers the optimum.

A mixed story. The result is a mixed story. In simple situations where the causal structure is not complicated, replication of success frequently leads to improvement in performance over time if there are differences among the alternatives, their outcomes are relatively reliable (low variance), and an adequate sample of experience is obtained. Replication of success usually leads to stability, a steady increase in the likelihood of repeating a choice. It usually leads to improved reputation (past performance) of chosen alternatives for an extended period. Part of the improvement in reputation is due to the likelihood of choosing a better alternative, but part of it is due to selection of positive sampling error.

On the other hand, learning through the replication of success has troubling unfavorable properties. Even in simple situations, the choices made through replication of success are very likely to be substantially suboptimal. The replication of success at one level of learning confounds the replication of success at another level, producing, for example, competency traps. Even though the deviation of average performance from the expected value of the alternative ultimately approaches zero, for an extended period the realized performance of the chosen alternative reflects a substantial overestimation of that alternative's potential. Even when there are no differences among the alternatives (and thus nothing to learn in terms of having a preference among them), replication of success usually leads to increased stability of choice. The subjective sense of learning is likely to be profound even when there is nothing to be learned.

A striking feature of these results is the extent to which they depend less on attributes of the learner than on attributes of experience. When experience unfolds in a way that makes learning effective, intelligence is augmented by the replication of success. But when experience is organized, as it often is, by complexity, ambiguity, stochastic variability, and limited sample sizes, the replication of success—whether through trial-and-error learning, imitation, or selection—is likely to lead to suboptimal outcomes.

LOW-INTELLECT LEARNING AND HIGH-INTELLECT EXPLANATIONS

Although it is flawed in important ways, replication of success is a ubiquitous instrument of learning. In one form or another, and despite its substantial disabilities, it characterizes much of the adaptiveness of human actors. At the same time, however, the low-intellect simplicities of trial-and-error learning, imitation, and selection conflict with high-intellect hopes. Human conceit (both among actors and among observers) often seems to eschew attributions of human behavior to success replication in favor of more complicated, cognitive comprehensions, explanations, and justifications.

The joint ubiquity of success replication and of preferences for high-intellect explications of history and learning suggests the possibility that behavior that is commonly described in high-intellect terms actually may reflect rules learned through low-intellect replications of actions associated with

success. It is an old idea, much beloved by Pavlovians and behavioral psychologists and (in a different form) by economic theorists.

Suppose the mechanisms of human behavior are actually much less complicated than the interpretations humans make of human behavior. In particular, suppose it were possible to show that important elements of observed behavior are “explainable” as products of simple success replication. Such a demonstration would hardly prove that success replication is the primary mechanism producing the observed behavior, but it might invite some skepticism toward more elaborate explanations. To illustrate, consider two familiar areas of human inquiry into human behavior: the taking of risks and the choosing of mates.

Risk Taking

The most common observation (assumption) about risk-taking behavior is that human beings have different risk traits, some of them being risk averse, some risk-seeking. Generally it is assumed that most humans are risk averse. For example, they tend to prefer a certain reward of k dollars to a lottery that offers a probability, p , of receiving k/p dollars and $(1-p)$ of receiving nothing, although the expected value of either alternative is k .

A standard explanation of risk aversion for money is the presumed decreasing marginal utility of money so that the expected utility of a certain alternative is greater than that of a lottery with an equivalent monetary expectation. More

generally, in classical theories of rational choice, “risk preference” is defined simply as any nonlinearity in the utility for money.

Studies of risk-taking behavior have suggested that risk taking is not so much an individual trait or a nonlinearity in utility as it is context dependent. The most common characterization is that with respect to alternatives whose expected returns exceed an aspiration level (“gains”), individuals tend to be risk averse, but with respect to alternatives whose expected returns lie below an aspiration level (“losses”), they tend to be risk-seeking (Kahneman and Tversky 1979). This has sometimes been given a “satisficing” interpretation (March and Shapira 1992).

Suppose that risk preference is neither a trait nor immediately context dependent but is the result of learning. It has been shown that simple success replication learning will lead to risk aversion for gains and risk seeking for losses (March 1999c, chap. 15; Denrell 2007). The possible advantages to be reaped from high-variance alternatives in the gains area are poorly assessed by small samples, and those alternatives tend to be abandoned on the basis of poor small sample results. In the loss area, on the other hand, negative results from the low-variance alternatives induce sampling of the high-variance ones.

An important special case of this phenomenon involves learning in cases having very low-probability, extreme outcomes. Very low-probability events result in a highly skewed distribution of the number of occurrences. For example, what happens with respect to a major scientific breakthrough

in a laboratory? Such an event is extremely positive, but the chance of its occurring is very small. Most researchers in a laboratory will never experience such an event. In effect (or possibly in fact), most learners will underestimate the likelihood of an extremely rare, positive event. Their resulting actions will be implicitly risk averse, and researchers will fail to replicate the behaviors (e.g., intense commitment and involvement) associated with a great scientific discovery as often as might be justified.

Alternatively, consider what happens in cases involving low-probability, extremely negative consequences. An example would be nuclear accidents in a nuclear power plant. The likelihood is extremely low, so most operators in a nuclear power plant do not experience the event. In effect (or possibly in fact) most learners will underestimate the likelihood of an extremely rare, negative event. Their resulting actions will be implicitly risk-seeking, and they will replicate behaviors (e.g., carelessness) that increase the likelihood of a nuclear accident's occurring. In such cases, risk aversion for gains and risk seeking for losses would be produced simply by learning.

Notice the difference between the two cases. In the case of the rare, positive event, the failure to experience the event induces individuals to avoid repeating actions (e.g., working diligently on the project) that would make the positive event more likely, thereby not only *reducing* the chance of correcting the implicit underestimation of its likelihood but also actually making its occurrence *less* likely. Learning reduces the chance of a major scientific breakthrough. In the case of the

rare, negative event, the failure to experience the event induces individuals to repeat actions (e.g., sloppiness, inattention) that make the negative event more likely, thereby not only *increasing* the chance of correcting the implicit underestimation of its likelihood but also actually making its occurrence *more* likely. Learning increases the chance of a major nuclear accident, “correcting” the underestimation of the risk both by greater experience with it and by making its occurrence more likely.

In this respect, Beverly Sauer, after reviewing experience with regulations in hazardous environments, observes, “Agencies write standards because experience is a poor teacher” (2003, 37). Sauer explains that constant exposure to danger without its realization leaves human beings less concerned about what once terrified them, and therefore experience can have the paradoxical effect of having people learn to feel more immune than they should to the unlikely dangers that surround them.

Mate Choosing

Consider a world in which a person experiences and records each performance of a candidate for selection as a mate. To simplify, assume the candidates, on their part, make no choices but are simply available to be chosen. Each candidate’s performance is a draw from a normal distribution of possible performances. A candidate is chosen each time period by evaluating past experience with all candidates, recording the average performance of each candidate previously

chosen, and anticipating that candidates who have not been chosen previously will, on average, have a performance equal to the mean of those who have.

What will be the key properties of such a world of mate seekers who learn from experience by replicating successes? Three properties of interest may be worth noting:

- (1) The likelihood that a mate chosen in this way will be the best possible mate is small.
- (2) The process will yield monogamy; that is, the choices made in one time period will tend increasingly to be repeated in the next. That tendency to monogamy will be moderated by postdecision disappointment but accentuated by competency gains from experience in the relationship.
- (3) Participants in the process will understand themselves as having learned from experience successfully and will have confidence in their choices.

Thus we are led, perhaps, to what might be called the behaviorist manifesto. Risk aversion is not necessarily to be seen as a thoughtful choice, a mysterious trait, or a consequence of context; it can be pictured as a propensity produced by simple learning from ordinary experience. Monogamy is not necessarily produced by cultural norms or morality or by calculated rationality; it can be seen as a consequence of simple learning from ordinary experience.

It is not necessary to embrace entirely such skepticism about the more elaborate stories and theories articulated by

scholars. The more elaborate stories may, in fact, be true even though particular aspects of the behavior can be approximated by a simple replication hypothesis. In both cases, however, the more complex interpretations by human actors and by economists, philosophers, psychologists, sociologists, and theologians can be seen as possibly reflecting elements of human conceit about the role of human intention and intellect in human behavior. They can be seen as stories told to honor and reinforce that conceit, a purpose possibly as noble as reflecting truth but different from it.

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