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Melioration: A Theory of Distributed Choice

Richard J. Herrnstein and Dražen Prelec

In modern expositions of the theory of rational choice, the notion of what constitutes an object of choice is kept deliberately vague, so as not to restrict unduly the range of possible problems to which the theory will be applied later on. A recent advanced textbook on consumer behavior (Deaton and Muellbauer, 1980), for example, initially defines the objects of choice as “individual purchases of commodities” (p. 269), but this concrete definition yields quickly to the more abstract notion of a commodity “bundle,” which is rarely obtained through an individual purchase. Implicit in this exchangeability of terms is the supposition that in applying the theory it does not matter whether: A) the “choice” corresponds to an actual decision, made at a specific point in time; or B) the “choice” is an aggregate of many smaller decisions, distributed over a period of time.

In this paper, we develop a theory of individual choice called *melioration*, for which the distinction between choices of type A and type B is critical, and which implies that choices of type B may be reliably and predictably suboptimal, in terms of the person’s own preferences. If true, this would imply that preferences as revealed in the marketplace may be a distortion of the true underlying preferences whenever the measured economic variables are aggregates of a stream of smaller decisions; the extent and direction of the distortion is then something that the theory will need to explain.

Our theory draws support from two sources. First, experimental psychologists have accumulated much data about repeated choice over the last 25 years,

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indicating that for both human and animal subjects, the long-run distribution of choices between alternatives conforms in many cases to a rule that optimizes return only under special circumstances. At the same time, this rule has a deceptive appearance of rationality, so that it is easy to mistake it for a form of gradual optimization.

The second source of support is somewhat more speculative. Consider some typical examples of type B choices, or *distributed* choices, as we will hereafter call them:¹ expenditure rate on various non-durables; frequency of athletic exercise; rate of work in free-lance type occupations; allocation of leisure time; rate of savings (or dissavings); expenditures on lottery tickets, and other forms of gambling. When people express dissatisfaction about their choices, their discontent seems clustered around these sorts of distributed choices. For example, complaints that one is working too hard (or not hard enough), exercising too little (or too much), wasting time, overeating, overspending, and so on, are commonplace. Many of these anomalously suboptimal patterns of behavior have already been noticed by economic theorists, and have stimulated a burgeoning literature on models of “self-control” (Ainslie, 1975, 1982, 1986; Elster, 1984; Schelling, 1980; Thaler and Shefrin, 1981; Winston, 1980).

The next two sections of the paper spell out the basic theory we are proposing. The following section then applies the theory to “pathological” consumption patterns, and shows that one should find a general underinvestment in those activities that exhibit increasing average returns to rate of consumption, and an overinvestment in activities that have an addiction-like interaction between value and rate. The final section compares the theory with other approaches to suboptimal choice.

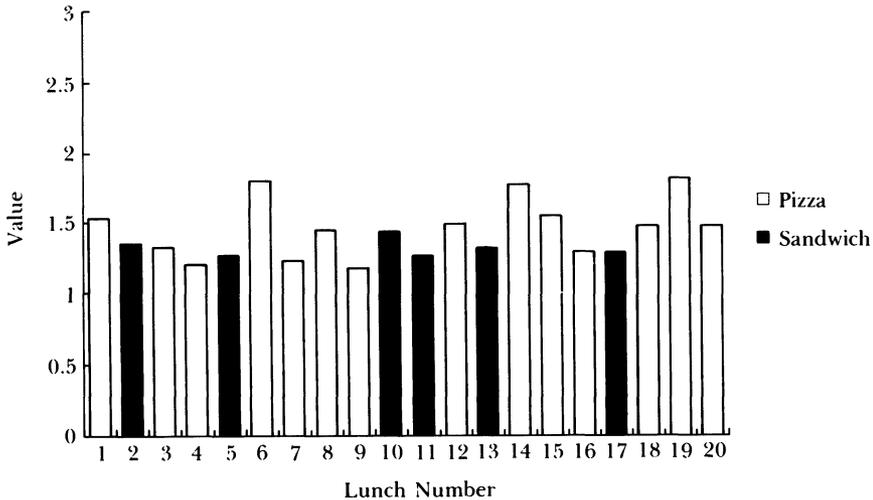
Melioration: Basic Concepts

We begin with a standard problem in consumer theory. Consider a person lunching at the company cafeteria, five times a week. Unfortunately, there are only two items on the menu: pizza and a generic sandwich, which happen to have the same price. In a typical month with 20 workdays, for example, the person might choose pizza 13 times and sandwiches 7 times. If this distribution is stable from month to month, with the person dividing choices in roughly a 2 : 1 ratio, standard consumer theory implies that the *optimal* utility maximizing allocation is two to one in favor of pizza.

Now, this is not the type of choice that a normal person would fuss over at great length. But suppose that our consumer is determined to optimize, and to

¹The boundary between type A and type B choices will vary across individuals. For example, for some people the savings rate is determined by a deliberate, perhaps automatically enforced policy, while for others it is the unintentional by-product of their expenditure rate.

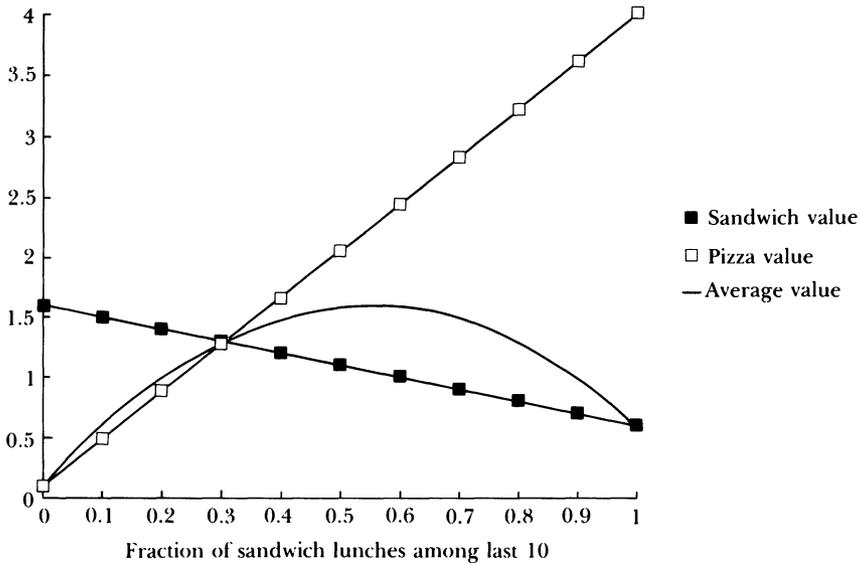
Figure 1
A Utility Log of Satisfaction Derived from Lunch in a Typical Month



that end decides to keep a daily utility log in which the satisfaction derived from each lunch episode is written down. Figure 1 displays the entries for one month, with the height of each bar representing the introspected quality of a lunch, recorded on an interval scale (differences are comparable, but the zero point is arbitrary). Based on the information in the utility log, is there anything that the person can conclude about the efficiency of the 2:1 allocation? No. The log reveals that pizza is still a slightly better meal, in spite of its greater consumption frequency, and that consuming the same thing on two consecutive days usually (but not invariably) leads to a reduction in satisfaction. To test for optimality, the person would have to know the details of the hedonic mechanism that links present satisfaction with past consumption, and that mechanism is a black box.

But now take a look inside the black box responsible for this utility log. For this example, we postulated a hedonic mechanism that remembers the last ten choices, from which it computes the sandwich fraction, plotted on the x-axis of Figure 2. This is a “sufficient statistic” for consumption history. Since the fraction of pizza choices is one minus the fraction of sandwich choices, the pizza fraction can be read from the x-axis, too. The value of a sandwich on any given occasion diminishes with the number of times a sandwich was chosen in the last ten days, as indicated by the declining series of black squares in Figure 2. Likewise, the value of pizza, given by the white squares, diminishes with recent pizza consumption (reading the x-axis from right to left). Finally, to simulate the variability in a natural system, the values along the x-axis were subject to a

Figure 2
Value of Pizza and Sandwich Lunches, as a Function of Last Ten Days' Consumption



random perturbation of up to 5 percent, so that, for example, three sandwiches out of the last ten would yield a fraction anywhere from 25 percent to 35 percent, with all values equally likely. This contributes to the fluctuations in Figure 1.

To determine a utility-maximizing pattern of choices in this situation, one would have to compare the average utility levels maintained by consuming pizza and sandwiches in different relative proportions. This average value, indicated by the solid curve in Figure 2, lies between the satisfaction levels obtained from pizza and from sandwiches—specifically, it is a weighted average of the two quantities, with the weights corresponding to the relative fractions of pizza and sandwich choices. The average value is maximized if sandwiches are selected about 50–60 percent of the time.

Although the example is exceedingly commonplace, it has several aspects that make it difficult for the individual to maximize utility. The optimal distribution could be derived in at least three ways: (1) guessing the incremental utilities of the next pizza and sandwich choice; (2) comparing the overall utility levels associated with various long-run allocations of choices; or (3) estimating the shapes of the value functions and computing the maximum (as in Figure 2). All three approaches are problematic. Let us consider them in turn.

Always choosing the item that has higher incremental value is an optimizing strategy, provided one knows the correct incremental values. Suppose, for

example, that a person has been choosing sandwiches 40 percent of the time, and now wants to decide whether the next selection should be pizza. The difference in the incremental values of pizza and sandwich is composed of two parts, the first being the difference in satisfaction experienced at the time of consumption (about +.4 in favor of pizza, reading from Figure 2), and the second being a slight change in the values of the next ten meals. This second factor counts in favor of the sandwich selection (because the value of sandwiches is less sensitive to its own consumption rate), but who can tell offhand where the net balance of these two incremental value components lies?

Turning to the second approach, it is fine in principle to attempt to compare the average returns associated with differing choice distributions. But to conduct this introspective exercise, one would have to mentally consume, say, a 40–60 mix of the two meals, and compare it to a 60–40 mix, and a 80–20 mix, and so on. Can a person discriminate among satisfaction levels produced by meal series that differ in the relative frequencies of items?

Finally, the third approach presupposes not only that a person knows the shape of the value functions—how value diminishes with consumption frequency—but also that the consumer recognizes the need to compute a weighted average of the value levels at different relative consumption frequencies.

The central conjecture we now make is that in problems of this general type people will not use any of these three methods to calculate the overall utility level associated with particular distributions of choices. Instead, they will choose as if guided by the following pair of rules:

1. *Value Accounting*: Keep track of the average satisfaction (or value) received per unit invested on each alternative (where the unit of account might be a single choice occasion, a time interval, or a money unit).
2. *Melioration*: Based on these value accounting calculations, shift behavior (choice, time, money) to alternatives that provide a higher per unit return.

If this process continues, we will observe a stable distribution of choices such that the accounted values in the long run of both alternatives are equal, or, as the other possibility, that only one alternative is chosen (see Thaler, 1980, for an early consideration of value accounting). In our example, the natural value-accounting scheme credits satisfaction to either a “pizza” or “sandwich” category. Figure 2 indicates that pizza will appear more tasty if it is consumed less than 70 percent of the time, less tasty if consumed more than 70 percent of the time. The intersection of the two value lines, at 30 percent sandwiches and 70 percent pizza, identifies the allocation at which a person who is practicing value-accounting and melioration will stabilize. However, this is not optimal, and the person would suffer a modest loss in overall value or utility relative to the maximum that the situation makes potentially available (at 60 percent consumption of sandwiches).

Implicit in the melioration model, then, are some assumptions about how a person summarizes information about satisfaction (utility) derived from alternative sources. Expressed in ordinary language, the model assumes that people are primarily able to assess how much they like specific activities or objects: whether they like a good book more than TV, sports more than classical music, Chinese or Italian food, and so on. What they have difficulty with, however, is in assessing the relative standing of entire distributions of activities or objects—whether a 20–80 mix of reading and TV is preferred to a 50–50 mix, for example. The source of the difficulty is that pairs of distributions are not concurrently available for comparison, unlike the objects or activities over which the distributions are defined.

A Melioration Experiment

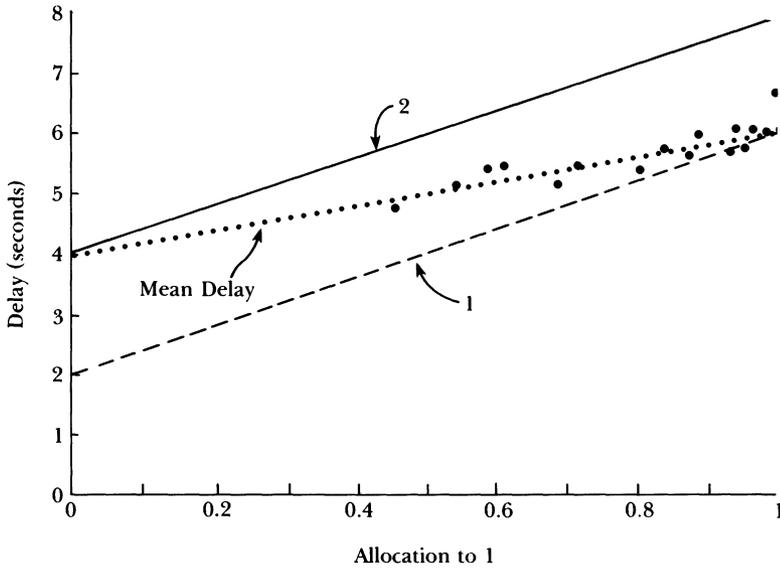
A recent experiment by Herrnstein, Prelec, and Vaughan (1986) provides an illustration of meliorating behavior leading to a suboptimal allocation. In the experiment, human subjects were instructed to complete a series of binary choices as quickly as possible. Each choice was followed by a pause, which lasted anywhere from 2 to 8 seconds, prior to the next opportunity to make a choice. The duration of the pause depended on the current choice, as well as on previous choices, in a manner that will be explained below. The subjects were not told of the relationship between choice and pause-duration; they were, however, given 100 practice trials, during which they could try to figure out “how the program works.” Overall speed, as measured by the total number of choices executed during the subsequent 10 minutes, determined the pay for the experiment (which ranged from \$3.50 to \$6.50).

As in our lunch problem, the “quality” (represented here by delay) of a 1- or 2-choice was a function of choices made over the previous ten trials (including the current trial). The algorithm went as follows: Alternative 1 exhibited *increasing* marginal cost, in that pause duration following a 1-choice increased from a minimum of 2 seconds to a maximum of 6 seconds, in linear proportion to the number of 1-choices among the previous ten. Alternative 2, on the other hand, exhibited *decreasing* marginal cost, in that the pause duration decreased, from a maximum of 8 seconds to a minimum of 4 seconds, in linear proportion to the number of 2-choices among the previous ten.

Despite its deterministic structure, the game proved hard to figure out. Presumably, a player recognizes that the problem is to keep the time intervals low and make as many choices as possible. The optimal strategy, given perfect information about the structure of the problem, is to choose the second alternative exclusively, thereby enduring a pause of four seconds each time.²

²We ignore here the “endgame” problem, which would make a few 1-choices at the end of the experiment advantageous. In fact, the subjects showed no evidence of having been influenced by the endgame contingency.

Figure 3

Individual Choices in a Melioration Experiment

Source: Adapted from Herrnstein, Prelec, and Vaughan (1986).

The majority of our subjects, however, preferred alternative 1, with some individuals stabilizing virtually at exclusive preference for it, which is the worst of all possible strategies, yielding a 6-second delay.

Figure 3 presents a typical outcome for the experiment, providing data for 17 subjects who worked on this procedure during a single session. The x-axis shows the proportion of the previous 10 choices that were 1-choices, while the y-axis shows the delay from various options. The solid line shows the delay, given a certain percentage of 1-choices in the previous 10, after choosing 2. The dashed line shows the delay, given a certain percentage of 1-choices in the previous 10, after choosing 1. The dotted line shows the mean delay after choosing either 1 or 2, given the percentage of 1-choices in the previous 10. The subjects cluster at the high end of the mean delay line, with many of them getting almost as high a delay as is possible.

To gain an intuitive appreciation of how this result comes about, consider the following explanation. For any strategy that is entertained as a provisional “solution” to the problem, the 1-choice components of that strategy will produce pauses that are 2 seconds shorter, on average, than pauses that follow 2-choices. This differential in delay creates an impression that an even better strategy would be to increase 1-choices at the expense of 2-choices. The melioration process thus guides the subject toward 1-choices. Any such substitution, however, will increase both pauses, while keeping the 2-second differential

intact. The only point that is immune to such incremental “improvements” is at exclusive preference for alternative 1, which is the least successful strategy.

As with all laboratory experiments, we may wonder about how well the experiment elicits the strategies and decision processes used in natural settings. But while little money was at stake, two other motivating factors amplified the financial incentives. First, delays are genuinely annoying and the difference between two and four seconds is not trivial, as any computer user will appreciate. Second, the “puzzle” nature of the experiment presents a challenge that is presumably satisfying to solve.

As for the general relevance of the finding, the procedure can readily be seen as a laboratory simplification of real-life economic situations. The decision-maker’s past choices interact with the reward structure. Choices of restaurant, entertainment, product brands, minor investments or expenses (like clothing, decorative jewelry, repairs to an automobile or television set) are typically made without proper regard to the way they may, in turn, affect the reward structure by having been chosen. Effects like this can be created by economies of scale, by depletions of the reward resource, by time-dependent changes in the external environment and in motivational states, and the like, all of which, in turn, may be affected by past behavior.

General Definitions of Value Accounting and Melioration

The results of this experiment and many others (cited below) prompted the following formal definition of the conditions that a choice distribution should satisfy for it to be a possible end result of a meliorating process. As stated earlier, our intended area of economic application is to the class of problems in which total expenditure on a commodity is an aggregate of many temporally distinct choices. This section uses the standard notation of utility maximization to explain how this model of choice differs from the standard model.

The basic variables, denoted by x_i , are the rates at which individual items, indexed by $i = 1, \dots, n$, are chosen (that is, purchased) over an observation interval. The total choice rate is subject to a budget constraint, $\sum p_i x_i = k$, where k denotes income. A complete choice distribution is the vector of rates at which items are purchased, $x = (x_1, \dots, x_n)$. A utility function $U(x)$ represents the individual’s true welfare (in terms of utility) if his or her purchase rates are stabilized at x . While it can be said that the individual is aware of $U(x)$ in the sense that he or she experiences the current value of $U(x)$, it is not assumed that the individual knows which x is optimal, nor indeed which of two distributions has higher utility.

Instead, choice in this framework is driven by a complement of value accounting functions (or value functions, for short), $v_i(x)$, one for each alterna-

tive, that indicate how much value or satisfaction is perceived to be obtained (on average) from a single purchase of type i , when the choice rates are given by x . The only constraint on the value functions is that they must account for all utility obtained: $\sum x_i v_i(x) = U(x)$.

Given freedom to redistribute choice, a meliorating decision-maker will favor higher-valued activities at the expense of the lower-valued ones. The process of redistribution will then stop either at a corner distribution, where one alternative absorbs all choice, or at a distribution where all surviving alternatives have equal value per dollar (or per other behavioral investment). In the experimental literature, this distribution is referred to as “matching,” inasmuch as all active alternatives yield equal returns per unit of behavior (or money) invested.

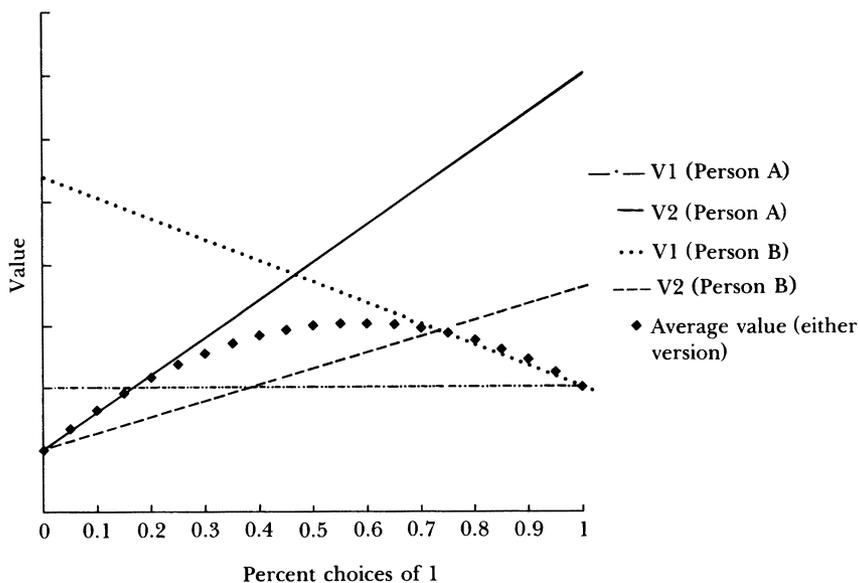
Like the original utility function, $U(x)$, the value functions define the relationship between tastes and consumption; in addition, however, they also reflect the manner in which a person interprets the information that the body and imagination provide. The analogy with an accounting system is quite apt here, since an accounting system also decomposes a single dimension of value (overall profit) into the per-unit profitability of individual products, which then must exhaust total profit.³ However, two firms with different accounting systems might believe that their profits spring from different sources, which would lead the firms to behave differently. By analogy, it follows that two individuals might share the same “tastes,” in the sense of having the same total utility function $U(x)$, but might interpret the source of their utility differently, by employing a different value accounting scheme. In that case, their choices and “revealed preferences” will, of course, not coincide. The extra measure of theoretical flexibility created by the value functions allows analysts to relate apparent suboptimality in consumer choice to particulars of the accounting scheme, as well to other specific biases or illusions in value-attribution.⁴

Figure 4 illustrates this indeterminacy by displaying two different pairs of value functions consistent with the same overall utility function. From the earlier sandwich/pizza example, remember that the overall utility function can be thought of as the weighted average of the value functions for each of the two

³Faulhaber and Baumol (1988, p. 592) have observed that the influence of marginal analysis on business and government decision making has been minimal. Elsewhere, Baumol (1977) has listed several reasons why firms conduct their calculations in terms of average rather than marginal quantities, reasons that are relevant to our model of individual choice, as well. Perhaps the most important of these is that average quantities can be obtained on the basis of information about the firm’s current operating levels, while marginal quantities, as Baumol (1977, pp. 34–35) notes, must intrinsically “represent answers to hypothetical questions.”

⁴This paper does not deal explicitly with the way the melioration principle can make contact with some of the paradoxes of choice arising in particular accounting schemes, or what is also called the “framing” problem (Tversky and Kahneman, 1981; Thaler, 1980), but see Herrnstein and Mazur (1987) and Rachlin, Logue, Gibbon, and Frankel (1986) for examples.

Figure 4
Two Sets of Value Functions Consistent with the Same Total Utility Function



items separately. But two very different pairs of value functions can have the same average, as shown in Figure 4. The value function for commodity 1 is flat for person A, and declining for person B; the value function for commodity 2 increases more rapidly for A than for B. If they behave as meliorators, person A will choose commodity 1 only 18 percent of the time, while person B will choose it about 75 percent (at equal prices), even though the true preferences of the two individuals coincide perfectly, as shown by the fact that the same curve of diamonds represents a weighted average for both A's and B's preferences. Again, the analogy with corporate accounting systems is quite tight. Two firms with the same production function may have different policies for allocating overhead or advertising costs, and as a result would reach different production decisions.

If value functions are allowed to vary freely, it becomes possible to explain any behavior whatsoever. Thus, if value functions are to provide genuine insight into behavior, they should codify an accounting scheme that is psychologically plausible. The early experimental demonstrations of meliorating behavior provided a good example of what we mean by psychologically plausible accounting schemes. These experiments trained animal subjects to make long series of choices between two gambling devices, each of which would occasionally deliver some reward—usually a small amount of animal feed. The probability of reward on each alternative was not constant, from one choice to the next,

but increased with the time since the last response on that alternative, thus implementing a nonlinear reward-response technology.⁵

Several hundred experiments have confirmed the prevalence of meliorating or matching behavior in human and animal behavior with respect to a “natural” value accounting rule, according to which the current value of an alternative equals the ratio of benefits to costs, i.e., the rewards per responses for that alternative. A review by Williams (1988, p. 178) in the *Stevens’ Handbook of Experimental Psychology* states that: “The generality of the matching relation has been confirmed by a large number of different experiments. Such studies have shown matching, at least to a first approximation, with different species (pigeons, humans, monkeys, rats), different responses (keypecking, lever pressing, eye movements, verbal responses), and different reinforcers (food, brain stimulation, money, cocaine, verbal approval). Apparently, the matching relation is a general law of choice.”

An efficient allocation of effort, one that extracts the most reward for a given rate of work, would require that the marginal benefit per marginal increase in choice rate be the same across all sampled alternatives.⁶ At the matching point, however, the average benefit per dollar is equalized. The resulting inefficiency can be likened to an *externality*, in that the meliorating individual ignores the effect of a change in choice rate on the values of the sampled alternatives (including, importantly, the value of the alternative in question).

Among possible meliorating outcomes some will be unstable, in the sense that a small—perhaps unintentional—increase in the choice rate for a particular alternative will cause that alternative to increase in value relative to the others, thus initiating a further increase in its choice rate. In contrast, there are other cases where any brief period of experimentation with the new distribu-

⁵In the notation that has become standard for experimental psychology, the central result of these experiments was stated as a matching principle (Herrnstein, 1970):

$$\frac{B_1}{B_1 + B_2} = \frac{R_1}{R_1 + R_2},$$

where B_i and R_i respectively refer to the rates of responding and of reward collected on a pair of alternatives, $i = 1, 2$. The rates are simply the number of events (responses or rewards) over the duration of the experimental session. The equation implies that $R_1/B_1 = R_2/B_2$, or that the same fraction of responses is rewarded on both schedules.

⁶What does a “first-order” optimality condition look like for a meliorating decision maker? Noting that the true utility function is a sum, $\sum x_j v_j(x)$, we can write out the marginal utilities as:

$$\frac{\partial U}{\partial x_i} = v_i + \sum_j x_j v_{ji},$$

where $v_{ji}(x)$ is the partial derivative of $v_j(x)$ with respect to x_i .

tion will cause the alternatives to appear worse, so the original meliorating outcome is stable in that sense. In the delay experiment described in the earlier section, for example, excursions away from choice 1 will appear to make the delays longer, rather than shorter.⁷

Although stable meliorating choices are not necessarily optimal, they do exhibit a semblance of rationality. If the values of all alternatives are constants, independent of choice rate, then the unique stable matching point is at exclusive preference for the alternative that offers highest value per dollar (more precisely: all corner distributions satisfy the matching law, but only the best one is stable). Even if values are dependent on consumption, the person will “correctly” adjust consumption in response to a uniform improvement or deterioration in the quality of a single alternative in the way that standard utility theory would predict. A more entertaining television program will fetch a larger audience; likewise, the information that cigarettes are harmful will cause people to reduce their smoking rate, on average, and so on. As a result, much of the behavior of a meliorating person will appear rational on the surface. However, such examples do not discriminate between optimization and weaker forms of reward-seeking behavior, such as melioration (an analogous point was made by Becker, 1962, in a different context).

Pathologies of Distributed Choice

Although the meliorating process has a flavor of rationality to it, the meliorating consumer will generally not home in on the optimal distribution, and may, in some situations, settle at the worst possible distribution. Do similar examples of poor, yet stable, choice distributions exist outside the laboratory?

It is a commonplace that certain patterns of consumption may diminish personal welfare. Most people agree about extreme examples, like severe drug addiction, perhaps because of the clear testimony of former victims. But such obviously disastrous consumption patterns are surrounded by a penumbra of less clear cases. For example, television has been labelled addictive by some, as has gambling, shopping, athletic exercise, personal relationships, and even plain work (Becker and Murphy, 1988). If the concept of consumption is

⁷A necessary condition for stability is that the value per dollar on each alternative is no greater than the value per dollar obtained from all alternatives:

$$\frac{v_i}{p_i} \leq \frac{\sum_j x_j v_j}{\sum_j p_j x_j}, \text{ for all } i,$$

or otherwise alternative i would be chosen more often. The issue of stability can become fairly complex when there are three or more alternatives, and is discussed in detail elsewhere (Herrnstein and Prelec, forthcoming, *b*).

broadened to cover choice of lifestyle, or character, we would find a host of tenacious yet unsatisfying patterns of behavior, ranging from the traditional seven deadly sins (lust, wrath, avarice, pride, envy, sloth, gluttony), to those that modern psychiatry recognizes as personality defects (Ainslie, 1982).

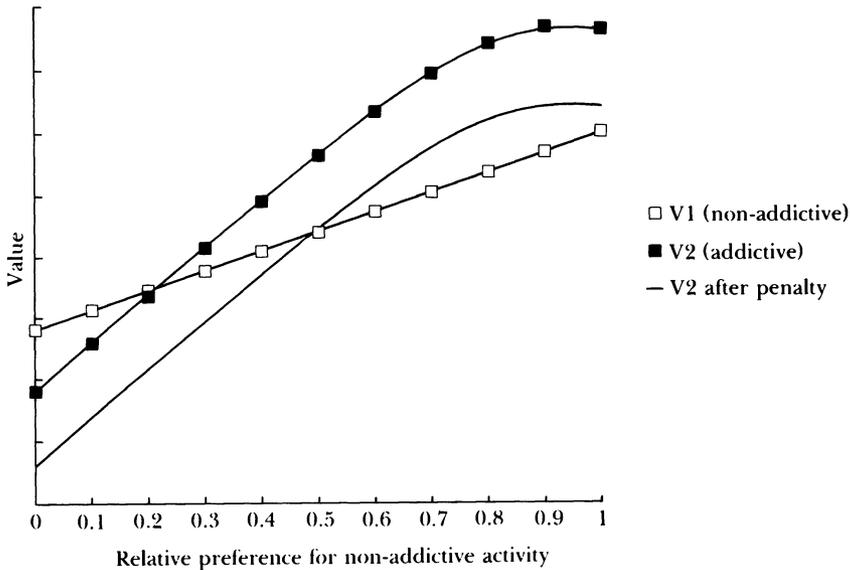
These phenomena share a common element: they are all instances of distributed choice, as the term is defined here. A person does not normally make a once-and-for-all decision to become an exercise junkie, a miser, a glutton, a profligate, or a gambler; rather, he slips into the pattern through a myriad of innocent, or almost innocent choices, each of which carries little weight. Indeed, he may be the last one to recognize “how far he has slipped,” and may take corrective action only when prompted by others.

In its most egregious form, the slippery slope of distributed choice leads to addiction, which is to say, a devastating level of overindulgence in some commodity or activity. To the extent that economic theory has addressed the problem of addictions, it has done so in essentially two ways. One approach, initiated by Stigler and Becker (1977) and further developed by Becker and Murphy (1988), builds a taste-changing mechanism into a global, multi-period consumption function, so that the marginal substitutibilities among various commodities change as a function of consumption history. The demand functions that result from a once-and-for-all maximization of the intertemporal utility function will exhibit changes over time (in demand elasticities, for example) that mimic “harmful” and “beneficial” forms of addiction. Because tastes are fathered by a global utility function, each consumer, no matter what his or her consumption pattern, is still at a personal optimum, according to this theory, and would presumably benefit from a reduction in price, or increased general availability, of any commodity or substance, no matter how lethal by ordinary standards.

The second (but earlier) approach, associated with the work of Pollack (1970) and von Weizsäcker (1971), among others, assumes that the taste-change process (also called “habit-formation”) is essentially opaque to the consumer. In von Weizsäcker’s two-period model, for example, a consumer myopically maximizes current-period preferences, which are themselves conditioned by consumption in the previous period. However, this work draws a sharp separation between a type of taste-change to which the person adjusts optimally, namely the taste-change that is encompassed within the one-period preference structure, and a second type of taste-change, across periods, which the consumer ignores completely. It is not made clear in this theory why the process of taste change encountered in addiction should be treated differently from the ordinary taste change that occurs when, for example, one eats fish too many days in a row.

The meliorating theory of distributed choice developed here models choice as potentially suboptimal whenever tastes (“values,” in our terminology) are affected by rate of consumption. What distinguishes more or less non-problematic choices, such as allocating the food budget, from clearly problematic

Figure 5
An Addictive Configuration of Value Functions



ones, like addictions, is not that the typical individual has a technique for maximizing the former, which he fails to apply to the latter, but, rather, that the value-functions for the first category produce a stable matching point that is relatively efficient (in terms of maximizing utility), while those for the second category do not.

Figure 5 displays a configuration of value functions for the choice between a non-addictive and an addictive behavior. In this case, the resulting equilibrium can be markedly inefficient. Notice that the value function for choosing higher proportions of the non-addictive activity (open squares) is steadily increasing, while the value function for choosing the addictive activity (filled squares) starts at a high level and then decreases (reading right to left). The result of meliorating behavior will be an equilibrium where a great deal of time is devoted to the addictive activity, even though a higher utility level could be reached by sticking exclusively to the non-addictive behavior. Consider two possible interpretations of the pattern in Figure 5.

One possibility is that alternative 1 represents an activity whose value intrinsically depends on its own rate of choice, and the value is increasing with rate. This type of value function would be characteristic of skilled activities (like music or sports) which provide greater satisfaction if maintained at higher rates. It is a necessary property of meliorating equilibria that any activity whose value increases with consumption will be underconsumed. To understand this point, consider a move away from the equilibrium in the direction of more 1-choices (this would be a rightward movement in Figure 5). If the equilibrium

was stable, then this change in v_1 will have to be accompanied by an even greater positive change in v_2 , so that behavior is pushed back to equilibrium. But both alternatives have increased in value! As a result, total utility must increase with increased allocation to 1; hence the original equilibrium was inefficient.

A second possibility is that alternative 1 does indeed have the usual property of diminishing marginal value with consumption, but this effect is swamped by a negative impact of alternative 2 on the value of 1. Consuming the second alternative, in other words, destroys the satisfaction produced by engaging in alternatives complementary to it. This seems to correspond to the common understanding of harmful addiction, as a process in which consumption of the addictive substance casts a shadow over other pleasures. (A more complete account of addiction in the melioration framework is presented in Herrnstein and Prelec, forthcoming, *a.*) Students of opiate addiction often observe, for example, that addicts lose their appetite for food, making simple malnutrition one of the primary health risks for addicts. In other words, as the consumption level for v_2 (heroin) rises, the value of v_1 (food) declines. Or as another example, the habitual heavy use of alcohol erodes the gratifications to be had from family, work, and even ordinary physical pleasures as one's health deteriorates.

The sharply diminishing value of v_2 as a result of its own consumption is likewise consistent with the phenomenology of addictive substances. For the usual addictive substance, high rates of consumption typically lead to the development of "tolerance," which is to say, a shrinking harvest of utility from a given quantity of the commodity. Richard Solomon's opponent-process theory of acquired motivation (Solomon and Corbit, 1974) describes how positive pleasures at a low rate of consumption are transformed into the avoidance of the agony of withdrawal at high rates. The remaining pleasures are then minimal.

At the eventual stable meliorating equilibrium, the value of the addictive alternative has itself almost evaporated, that is, it has been reduced to the value level of a low amount of the complementary activity. In the case of overeating, for example, this state describes a person who eats at a more or less continuous rate, not allowing true hunger to develop. As long as food is readily available, such a person would not experience eating as especially pleasurable, a finding which has some support in the research literature on obesity (Schachter, 1971).

In this analysis, a nonfinancial penalty, hindrance, or a substitution of an inferior commodity for the original alternative 2 (like methadone for heroin, for example) may improve individual welfare.⁸ Effectively, by offering an addictive alternative that is less attractive, it would amount to moving the v_2 -curve down, which would move the meliorating equilibrium to a higher value level. This is illustrated in Figure 5 by the intersection between the

⁸The effect of a *financial* penalty, such as a tax, is ambiguous, because of the income effect.

non-addictive alternative and the addictive alternative labelled “ v_2 after penalty.”

The element common to both interpretations of addiction is an underconsumption of the first alternative; the difference is that in the first case the suboptimality is accounted for by a peculiarity of that same alternative, namely, its increasing returns to consumption, while in the second case the culprit is addictive alternative 2, because it destroys the value of the complementary activity. Using the terminology of Stigler and Becker, we would say that meliorating persons generally underinvest in beneficial addictions, for which training and exposure build up “enjoyment capital,” and overinvest in harmful addictions, for which enjoyment capital depletes rapidly. Stigler and Becker’s choice of “beneficial” and “harmful” as labels is quite revealing, given that their theory does not allow for any suboptimality in consumption patterns. Melioration theory explains why the errors people make in executing an optimal plan cumulate in different directions for so-called beneficial and harmful addictions. Maximization theory, which allows no systematic errors, does not.

The value functions that lead to meliorating behavior may have the shape they have in Figure 5 for many reasons. Exogenous or endogenous chemical agents may alter reward centers in the brain in a particular way, one may learn how to enjoy (“acquire a taste for”) a certain class of rewards, different rewards may have different time horizons associated with them, and so on. But if, for whatever reason, the resulting structure conforms to that outlined here, the result is a pathology of choice.

Concluding Remarks

Most social scientists have certain favored explanations about the most prevalent causes of inefficient or dramatically suboptimal behavior, intuitions that sometimes give rise to full-blown theories. In this concluding section, we would like to clarify the relation of our approach to some other approaches to suboptimal choice behavior.

Satisficing. According to the satisficing concept (Simon, 1955, 1956), economic agents fail to maximize utility perfectly, but do maximize “well enough,” as defined by their own aspirations. In our theory, agents may sometimes maximize, but in other circumstances, their choices may be suboptimal, far worse than any conceivable level they may originally aspire to. One could say that the critical difference between melioration and satisficing is that melioration describes an endogenously changing aspiration level, which is the mean value obtained from all sources at a choice point, while satisficing assumes an aspiration level that is externally set, typically by a larger institutional context.

Excessive Discounting or “Myopia.” The behavior of a person with a high discount rate would in some respects resemble that of a meliorator, in that such

a person would on each occasion choose the alternative that offered the highest value, but nevertheless be choosing suboptimally in a broader time frame. Time discounting is often invoked as an explanation of this same pattern of over- and under-investment: A person with a sufficiently high discount rate would simply not care about acquiring the skills necessary to enjoy the so-called beneficial addictions, nor would he worry about the future penalties of harmful addiction. Unusually sharp time preference may indeed be a contributing factor to addiction, but it is conceptually distinct from melioration.

First, consider the psychological cost of a single drug-consumption episode as composed of two separate factors. The cost—an increased tolerance level, a degradation of other activities—is delayed in time compared to the “benefit” of drug use, which may be instantaneous; this is the time-discounting perspective. In addition, the impact of that single episode on the tolerance level and on other activities is small, and probably difficult to imagine even if one were perfectly informed; that is the perspective peculiar to distributed choices. The total cost of the episode, one should remember, is the aggregate, appropriately discounted, future reduction in pleasure caused by the incremental shift in tolerance, as well as a degradation in the future value of competing activities. Even in the absence of time discounting, we claim, people would still be vulnerable to addiction if they were unable to assess correctly and compute such costs.

It seems to us that addiction is more often a process of invidious slippage than a cool decision adventitiously supported by a high discount rate. Educational materials designed to discourage addiction typically do not work on altering time-preference, but on persuading people to think of addiction as an all-or-nothing decision. They warn that you cannot maintain a reasonable or moderate rate of drug consumption, that it is a case of all or nothing at all. The task of the educator is, in short, to get the person to act as if the choice is a one-time event, rather than distributed.⁹

Another way of noting the difference between discounting and melioration is to remember that a myopic person should shift toward the optimal allocation as the time scale over which the choices are made is systematically reduced. Melioration, in contrast, makes explicit reference to time only insofar as it distinguishes between distributed choice and nondistributed choice. Given that choice is distributed, it makes the same prediction irrespective of whether the choices are made once a week, or once every few minutes. Certainly, the experimental results described earlier cannot plausibly be attributed to time discounting, since the consequences of single choices were typically deferred for

⁹A discussion of how to avoid or escape addiction within the melioration framework is offered in Prelec and Herrnstein (forthcoming, *b*), Herrnstein (1990), and Herrnstein and Prelec (forthcoming, *a*).

less than a minute, and the entire experiment for a subject did not last much more than 20 minutes.

Ignorance or Incomplete Learning. A person who believes mistakenly that values remain constant, independent of choice rate, would behave exactly like a meliorator. However, this does not imply that melioration is necessarily produced by the assumption of constancy. It is possible that a person is aware of the relationship between choice rates and values, but that he sees no reason to doubt that a melioration-like process is nevertheless an efficient behavioral choice rule. When people are asked to imagine choosing among alternatives whose values interact in a particular way with choice rate, and they have been told what this interaction is, their answers typically display the same kinds of suboptimalities as are observed in experimental simulations of these situations (examples in Herrnstein and Mazur, 1987; Herrnstein, 1990). People can be given the information they need to maximize and fail to use it correctly.

Taste Change. In the standard utility-maximization theory, changes in the marginal rates of substitution, embodied in indifference curves, constitute an implicit theory of taste formation in response to consumption levels. Indeed, any theory that includes a concept of subjective utility or value must infer the subjective entity, which is in principle not directly observable, from some observable aspect of behavior. The difference between the present theory and the standard one is, then, not in the fact that it postulates taste changes, but in the hypothesis it uses to connect subjective utility or value to behavior (Prelec, 1982, 1983). The present theory employs the hypothesis of melioration, rather than maximization. It is this difference, rather than the particular suppositions about taste changes, that sets the theories apart.

The notion of melioration echoes ideas at other levels of analysis (Vaughan and Herrnstein, 1987). At a more inclusive level, consider an n -person, noncooperative game (Schelling, 1978). Each player will adopt the strategy most favorable to him, which, because of various externalities, may not be the optimal distribution of strategies for the players as a group. At a much smaller level of analysis, evolutionary biologists have been alerted to the importance of "frequency-dependent selection," the recognition that the selective fitness of a gene may depend on its proportion in a population. Genes in competition are, in other words, subject to the effects of externalities. As a result, the equilibrium points for genetic competition may not coincide with the optimum for the species as a whole (Dawkins, 1976).

What is new here is the suggestion that the familiar notion of externalities producing nonoptimal equilibria applies to the analysis of individual human (or animal) behavior. One could say that the difference between maximization and melioration is that melioration contains a weaker concept of personal identity. Within the maximization framework, the alternatives are, in principle, so perfectly articulated with each other that they lose their individuality. Only the utility of the whole choice bundle matters, rather than the utility attached to its

constituents. Within the melioration framework, the alternative behaviors are in competition with each other, vying for the organism's investment of time, effort, and so on. Beyond the dynamics of this competition itself, no one is in charge.

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