Hyperbolic Discounting as a Factor in Addiction: A Critical Analysis

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Rational choice theory (RCT) is the conventional decision-making model in not only economics and behavioral psychology but fields ranging from philosophy to law (see Korobkin and Ulen, 2000). RCT holds that utility is the selective factor for all choice - all behavior that is not reflexive - and thus that all choice must maximize expected utility. Psychology also looks at the process by which utility is realized, which it refers to as reinforcement or reward. We will talk of RCT as the theory that all choice maximizes expected reward.

There is now an enormous catalog of behavior patterns that violate RCT (Kahneman *et al.* 1982; Thaler 1991; Loewenstein and Elster 1992). The greatest contradiction to this theory in terms of sheer amount of motivation involved is inconsistent preference, usually manifested as temporary preference for options that are inordinately costly or harmful in the long run. Such options range from the extreme intertemporal ambivalence seen in alcoholism and drug abuse to more ordinary phenomena such as overeating, credit card debt, overconsumption of passive entertainment, and other bad habits too widespread to be diagnosed as pathlogical (e.g. Offer 1998).

Hyperbolic discounting supplies a mechanism for temporary preference

Parametric research has revealed a fundamental property of reward that has some obvious bearing on the phenomenon of temporary preference, and hence on the clinical problems of addiction in particular: It has long been known that the value of an expected reward diminishes with delay. The (relatively) new finding is that this temporal discounting does not occur at a fixed rate per unit of time, but rather in proportion to overall delay; the longer the delay that already precedes a reward, the less the reward is further devalued with additional delay. Mathematically, this is represented by temporal discount functions with delay in the denominator (Baum and Rachlin 1969; Mazur 1984; Myerson and Green 1995; Grace 1996). Mazur's formula is simplest:

$$V = \frac{A}{1 + kD} \qquad (1)$$

where V is value, A is the undiscounted reward value, D is delay, and *k* is a constant describing the individual subject's degree of impatience. Functions in this class are referred to as *hyperbolic* as contrasted with *exponential* functions which model temporal discounting as occurring at a fixed rate over time.

The implications of hyperbolic discounting clearly bear on phenomenon of temporary preference. A subject who discounts expected rewards hyperbolically is apt to choose imminent but inferior alternatives that she would pass up if she chose at a distance. Giving up $20 of a $100 prize to get it one month sooner would be absurd if choosing a year in advance, but if it is one month in advance, and the $80 could be received immediately, the alternative may be attractive. This pattern of preference (which Loewenstein and Prelec (1992) refer to as "the common difference effect") has been demonstrated in humans (Bohm 1994; Kirby and Herrnstein 1995), rats (Deluty 1978), and pigeons (Ainslie and Herrnstein 1981). Systematic preference reversals of this type would not occur for an exponential discounter; given a fixed rate of discounting per unit of time, the more compelling of a set of alternatives does not change based on temporal distance to the option set (Figure 1). Thus hyperbolic discounting supplies a promising mechanism for temporary preference.

FIGURE 1 ABOUT HERE

Temporal discount rate can be used as an individual difference measure
Hyperbolic discounting provides a framework for understanding the cycles of resolution, indulgence and regret that are the *sin qua non* of addiction. However, fruitful application of the temporal discounting perspective to the field of addiction requires moving beyond the generalities of hyperbolic discounting. In particular, practical application requires an individual difference variable that will gear into variability in clinically relevant measures like vulnerability (who becomes addicted), severity (who has the better prognosis), treatment matching (who will benefit from a particular type of treatment), or perhaps efficacy of treatments (which psychotherapy or pharmacotherapy is most effective). The natural place to turn for an individual difference measure is the steepness of individuals' discounting[1]. If problematic drug use is the choice of an immediate but transient reward at the expense of a delayed but more substantial reward, then individual differences in the steepness with which the future is discounted ought to relate to the problem of addiction.

Methodologies for assessing rate of discounting in humans
A variety of paradigms have been used to quantify steepness of temporal discounting in humans. In terms of the rewards used, points (Forzano and Logue, 1994), health outcomes (Chapman 1996; Chapman 2000; Chapman *et al.* 2001; van der Pol and Cairns 2001), hypothetical drug or alcohol (Madden *et al.* 1997, 1999; Bickel *et al.* 1999; Petry 2001), hypothetical money with context (e.g., "you just won some amount at a casino") (Thaler 1981; Chapman 1996; Chesson 2000; Bohm 1994], hypothetical money without context (Fuchs 1982; Ainslie and Haendel 1983; Madden *et al.* 1997), actual money (Ainslie and Haendel 1983; Crean *et al*. 2000; Kirby and Herrnstein 1995; Richards *et al*. 1999; Wallace, 1979)[2], consumer goods (Kirby and Herrnstein 1995), food (Mischel 1967, 1969; Forzano and Logue, 1994); and juice (Logue et.al., 1990) have all been used. Less frequently, choices among punishments have been used, including shocks (Cook and Barnes 1964; Hare 1966; Mischel *et al.* 1969) and aversive noise (Navarick 1982). In terms of the procedures used, some studies have used choices among a fixed set of alternatives (Ainslie and Haendel 1983; Kirby and Marakovic 1996; Kirby *et al.* 1999; Monterosso *et al.* 2001; van der Pol and Cairns 2001), some have used a titration procedure with choice stimuli generated so as to narrow in on the subject's level of discounting (Kirby and Herrnstein 1995; Madden *et al.* 1997; Richards *et al.* 1999; Crean *et al.* 2000), while others studies have required subjects to generate indifference amounts rather than to make choices (Chapman 1996; Cairns 2000).

Since delay discounting is offered as an operational definition for impulsive choice (Mowrer and Ullman 1945; Ainslie 1975, 1992), it is useful to consider it in relation to more traditional self-report measures of impulsivity. Overall, correlations between temporal discount rate and impulsivity measured by self-report have been modest (Madden *et al.* 1997; Vuchinich and Simpson 1998; Kirby *et al.* 1999; Mitchell 1999; Richards *et al.* 1999). However, it should be noted that dozens of impulsivity scales and sub-scales have been created to measure impulsivity, and the intercorrelations among them are modest as well, suggesting different underlying conceptions of the construct (Corulla 1987; Parker *et al.* 1993).

Application of temporal discount-rate assessment to addiction

The most expedient way to make empirical contact between temporal discount rates and the phenomenon of addiction is to compare the discount rates of addicted and non-addicted populations. In particular, it has been hypothesized that addicted populations may be more myopic (have higher *k* values) than non-addicted populations (Ainslie 1975; Vuchinich and Tucker 1988; Madden *et al.* 1997; Bickel *et al.* 1999). Across a range of addicted populations, the evidence has been consistent with this hypothesis. Using hypothetical money, a heterogeneous group of substance-dependent subjects discounted more steeply than controls (Ainslie and Haendel 1983); heavy social drinkers and problem drinkers both discounted delayed rewards more steeply than did light drinkers (Vuchinich and Simpson 1998); smokers discounted the future more steeply than non-smokers (Fuchs 1982; Bickel *et al.* 1999; Cairns and van der Pol 2000); and opioid dependent patients discounted money more steeply than controls (Madden *et al.* 1997; Bretteville-Jensen 1999; Madden *et al.* 1999). Similar results were obtained using actual monetary rewards. Compared to controls, heroin-dependent subjects chose more immediate nickels over tokens exchangable for dimes in 10 days (Wallace 1979), regular smokers discounted money more steeply than did a population who had never smoked (Mitchel 1999), and heroin-dependent subjects had steeper discount functions than demographically matched (age, gender and education) controls (Kirby *et al.* 1999). Also of interest, Odum (2000) found that heroin addicts who shared needles discounted money more steeply than heroin addicts who did not[3].

Some limitations on drug versus non-drug group comparisons of discount rate
Steeper discounting among addicted populations does not necessarily imply that steep temporal discounting is a causal factor in addiction. First, addicted and non-addicted populations are self-selected, and so are liable to differ in myriad ways other than their drug use. Several studies have taken efforts to match drug and control samples on characteristics such as IQ, age, race, and income (Madden *et al.* 1997; Kirby *et al.* 1999). However, even the most conscientious attempts to match samples cannot eliminate the problem of self-selection. Firstly, matching samples on a dimension in which the respective populations differ systematically produces undermatching. However, this is only a small problem, and can be compensated for. A more vexing problems is that of systematic *unmatching* (Meehl 1970). Causal inference requires controlling for nuisance variables - those which may affect both the hypothesized causal antecedent and the *explanandum*. If we hypothesize that temporal myopia is a causal factor in addiction, then we might want to control for, say, religion (though we know of no such study that did.). Rates of drug-dependence are lower among people who identify themselves as religious. Furthermore, as one would expect given differing proscriptions, differences in rates of dependence exist across religious affiliations (Anthony *et al.* 1994). It is entirely possible that religiosity might also be related to choices made on a delay discounting experiment. For instance, more religious people may overall demonstrate shallower (we suspect) temporal discounting. And so, if we wanted to gain support for our hypothesis that steep discounting is a causal factor in addiction, we might want to match our sample on identified religion. This way, if we did see a relationship between group membership (addict versus control) and discount rate, we could rule out the possibility that it is merely a byproduct of religiosity's relation to both drug use and delay discounting.

The problem however, is that while religiosity may be a causal contributor to addiction, *it is certainly not the only causal contributor to addiction*. And those

unconsidered variables (and there is no way to exhaust that list) will have been made systematically unmatched as a result of the care taken to match religiosity.

> "…for any but the most trivial and "unpsychological" examples of input variable X [addiction], the naturalistic self-selection of the organism for treatments or levels of X [addiction] must itself be determined. Hence the result of holding constant an identified nuisance variable Z [religiosity] will, in general, be to systematically unmatch pair members with respect to some unidentified nuisance variable." (Meehl 1970: 376-7, parentheses added)

As an illustration, suppose low parental love is one of the countless other causal factors in addiction. What can we say, in terms of parental love, about a religious person who, despite religion's protective effects, becomes addicted? Or about a non-religious person who, despite the absence of this protective factor, does *not* have problems with addiction? On average, the former will be less loved than is typical, and the latter more loved. And so, by artificially matching our groups on religious affiliation, we have unmatched on parental love, and thus have a new variable to worry about as far as a potential basis for a spurious relationship between delay discounting and group membership.

Furthermore, there are demand characteristics to worry about as well (Orne 1962). From the standpoint of the drug dependent subject, she is very likely participating in a study in which she sees her drug problems as, to the experimenter, her primary identity. Such a subject, aware she is in the lab *as an addict*, may even conceive the experimenter's hypothesis with respect to the presentation of delay of gratification choices. Indeed, subjects in our experiments have indicated as much. And she may, in general, be inclined to give the experimenter what he wants.

Finally, even if discount rate could be shown to be causally linked to drug use, it is unclear from the cohort-comparisons reported in which direction the causal arrow points. It is possible, for example, that the effects of chronic drug use on the brain (Volkow *et al.* 1988, 1991; London *et al.* 1990; Kosten 1998) might affect performance on delay discounting tasks, as has been shown in other decision-making procedures (Rogers *et al.* 1999; Grant *et al.* 2000). Or, perhaps the life-style of the addict might dispose her to emphasize immediate attainment of reward. Of course, the possibility that drug use, or being a drug addict, may lead to steeper discounting does not preclude that the causal arrow points in the other direction as well, but it weakens the ability to infer such a connection from group differences.

All said, the existence of consistent steeper discounting among addicted populations supports but does not prove the hypothesis that individual differences in temporal discount rate, as measured by existing procedures, have anything to do with addictive behavior.

Hyperbolic discounting alone is not enough

> "There is considerable doubt whether the psychological processes underlying [intertemporal choice] actually draw on a personal discount function... Decision makers appear to have as many discount rates as choice situations into which they can be placed. Moreover, different measures of discount rates are either

uncorrelated, or are correlated weakly or idiosyncratically" (Roelofsma and Read 2000: 171-2).

While hyperbolic discounting has consistently provided a better account of intertemporal choice than has exponential discounting, the story has been far from simple. Over the past fifteen years, researchers have demonstrated patterns of choice that seem anomalous even from the framework of hyperbolic discounting (for reviews, see Loewenstein and Prelec 1992; Loewenstein and Thaler 1989; Roelofsma 1996). Some of these patterns are of particular interest to behavioral economic researchers in the field of addiction. We will address the following problems with the hyperbolic discounting hypothesis,:
and suggest how they might be solved within the hyperbolic framework:
1. Discount slopes in humans are variable and unstable.
a. Steepness of discounting varies enormously across qualitatively different rewards.

b. Steepness of discounting is not even well correlated across modalities of reward within an individual.
c. Discounting measures have only modest reliability
2. Humans' discounting is shallower for larger rewards.
3. Addictive behaviors often do not depend on the proximity of temptation
4. People may come to feel imprisoned by their self-control, while a hyperbolic shape seems to predict that avoiding temporary preferences will always increase long range reward.
5. Some discount rates in humans appear to be negative - that is, delayed rewards may be valued more than immediate ones.
6. The most prudent rewards often lose their rewarding power, even after periods of nonoccurrence when appetite should be fresh.

1. Discount slopes in humans are variable and unstable.
a. Steepness of discounting varies enormously across qualitatively different rewards.
Some rewards are regularly discounted more steeply than other rewards. Indeed, Navarick suggested the possibility that different rewards might be ranked "according to their potential for producing effects of delay of reinforcement" (Navarick 1986: 354). In general, when points or money are used, discounting is relatively modest. In fact, with points or money, researchers have sometimes failed to show *any* discounting on the time-scale of minutes - the duration of a typical experiment (Logue *et al*. 1986, 1990). Plotting the discount function with money (at least large quantities of money) requires a more extended time scale, and thus favors a procedure where subjects do not respond to contingencies experienced during an experiment, but only to questions they are presented with (e.g., Would you rather $500 tomorrow, or $1,000 in 1 year?) In an experiment in which subjects expressed preferences for hypothetical amounts of money to be received in the future, adults discounted $10,000 by only about half over 10 years (Green *et al*. 1997).

In contrast, studies using other rewards have found steep discounting. Navarick (1982) found subjects on average preferred five seconds of silence followed by 75 seconds of aversive noise over 75 seconds of aversive noise followed by 20 seconds of silence (Navarick 2001). Similarly, with a positive reward - access to slides of famous people - subjects chose ten seconds of reward followed by 70 seconds of time-

out over 40 seconds of time-out followed by 40 seconds of reward slightly more than half the time (Navarick 1986). With Juice as reward, Logue et.al. found subjects to be, on average, indifferent between an immediate three seconds access to juice and six seconds access delayed by 39 seconds (Logue et.al., 1990). In each of these cases, the value of a reinforcer was diminished by half or more in an amount of time on the order of a minute. This represents a difference of six to seven orders of magnitude when compared to discounting of large hypothetical monetary quantities.

While the above discrepancies are based on comparisons across studies, variability in steepness of discounting across qualitatively different rewards has also been demonstrated within the same study. Of special interest to the field of addiction, recent studies have reported that heroin-dependent subjects discounted hypothetical heroin more steeply than hypothetical money (the median k parameter was 19 times as high in one study and 15 times as high in the second, better controlled study) (Madden *et al.* 1997, 1999). Comparison between smokers discounting for cigarettes versus money yielded a qualitatively similar result, though the magnitude of the difference was much smaller; discounting for cigarettes, again in terms of median k, was approximately 17% higher than for money (Bickel *et al.* 1999). Results of a fourth study suggest that active alcoholics, abstinent alcoholics, and controls all discounted alcohol more steeply than money (Petry 2001). However, this study did not control for magnitude of the qualitatively different rewards, and so is difficult to interpret (see section b below).

b. Steepness of discounting is not even well correlated across modalities of reward within an individual.

All the studies of which we are aware that sought to relate steepness of discounting to drug use have used monetary rewards, or else monetary rewards and a second reward (hypothetical drug). Implicit in this design is the expectation that discounting is not modality specific--that a steep discounter of monetary rewards will be a steep discounter also when different rewards (such as those most relevant to their addiction) are at stake. However, research assessing the generality of individual discount rates across modalities has been rather discouraging. In a careful comparison of outcomes related to health outcomes and outcomes related to monetary outcomes, Chapman (1996) found little relation between variability in subjects' discounting in one domain as compared to the other (r=.11). Furthermore, a principal component factor analysis of the monetary and health items she used suggested a clear two-factor solution which neatly separated monetary and health dimensions. A more recent study again found only a modest relationship between discount rates in the modalities of money and health (r=.24) (Chapman *et al.* 2001). Furthermore, discount rates in this study were virtually unrelated to subsequent real-life choices hypothesized to relate to delay discounting - getting a flu vaccination and contributing to a retirement fund. More encouragingly, the data reported in Madden (1999) allow the correlation to be computed between discounting of hypothetical heroin and hypothetical money. By our calculation, after logarithmic transformation, the correlation is .69. Nevertheless, there appears to be, at least in some instances, considerable modality specificity to temporal discount rates.

c. Discounting measures have only modest reliability

The value of any individual difference measure is subject first to the limits of its reliability. Are measures of individual temporal discounting reliable? Is a steep discounter on Monday a steep discounter on Friday? Given that methods for assessing individual discounting vary widely, there is no single answer to the

question. One study that presented cocaine-dependent subjects with a fixed set of questions about hypothetical money reported split-half reliability (that is, within session) of .79 (Monterosso *et al.* 2001). Also using hypothetical money, another study found the test-retest reliability (after one week) to be an encouraging .84 (Simpson and Vuchinich 2000). Less encouragingly, using vignettes in the domains of health and money, test-retest reliability after a one year interval was only .26 in the domain of health and .39 in the domain of money. (Chapman *et al.* 2001). The higher rate of test-retest reliability in the domain of money as opposed to health is consistent with other studies reported by Chapman and colleagues (Chapman and Elstein 1995; Chapman 1996). Unpublished data reported by Chapman and colleagues suggest that the low rates of reliability they found were likely to be due to the long intervening interval rather than the type of measurement procedure used; with similar health and financial vignettes but only a two-week interval, test-retest reliability was a more respectable .73.

Suggestion: Human subjects' responses have been modified by impulse control
Apparent discounting in human subjects is much more variable than in nonhuman animals. In human experiments in which the standard delay discounting procedure is used, subjects at the 10^{th} percentile in discount rate may differ from those at the 90^{th} percentile by a factor variously found to be 200 (Monterosso 2001), 250 (Richards 1999) and 600 (Madden 1999). In animal experiments this factor has been just seven for both pigeons (Mazur 2001) and rats (Ainslie and Monterosso 2003). Much of this difference is probably attributable to differences in the modalities of reward commonly used in humans and animals. Most human studies have used amounts of money over long time delays, arguably judged by some subjects as calling for prudence. The rewards in the animals studies were food. When Logue et.al. (1990) studied students' preferences for juice, the 90^{th} percentile was only 13 times the tenth. This suggests that when rewards call for a gut reaction, discounting is relatively similar among subjects; when rewards lend themselves to higher order process like planning and calculation, differences in subjects' backgrounds come much more into play.

Dependence on such higher order processes may also account for the variability of discounting within subjects. We know of no comparisons between modalities of reward in individual animals, but we have measured the test-retest reliability of discount rate in rats to be .81 over ten weeks, a very long time for these animals (Ainslie and Monterosso, 2003).

2. Humans' discounting is shallower for larger rewards.
Within the same class of rewards, human subjects discountless steeply rewards that are larger or more valued. Given the choice of $5 today or $10 in 1 year, many people would be inclined to take the immediate $5. If, however, a sufficient number of 0's are added to each of those amounts, the number of people willing to wait for the "later-larger" money rises dramatically. Far fewer people would choose $50,000 today over $100,000 in one year. Thus the devaluation that occurs appears to be inversely related to the magnitude of the reward. This intuition has been confirmed in lab experiments with monetary outcomes (Thaler 1981; Benzion *et al.* 1989; Green *et al.* 1997) as well as for outcomes in the domain of health (Chapman and Elstein 1995; Chapman 1996). By the same token, in experiments using primary rewards (food and

juice), both children (Mischel and Ebbesen 1970) and adults (Logue et.al., 1990) made more self-controlled choices when the reward was especially valued.

Thus human subjects discount less when more is at stake. Significantly, shallower discounting with larger amounts occurs only in humans. In animal experiments the reverse has been found. Wogar *et al.* (1993) found that the amount of additional time hungry rats were willing to wait in order to double their pay-off of food was greater when the choice was between one and two pellets than it was when the choice was between three and six pellets. This contrast suggests that the shallower discounting seen with large amounts in humans does not reflect a basic property of the discounting process. People's greater patience when larger rewards are at stake must have a more complex cause; as with the great variability in human discount ratesthe elicitation of self-control is a leading possibility.

Hyperbolic discounting motivates self-control

There have been many opinions about how people achieve self-control. The simplest would be that people learn to modify the steepness of their discount curves directly. Certainly reductions in apparent impatience are observed, but the hypothesis that the basic discount curve changes faces one probably fatal difficulty: If organisms can directly change the steepness of their discount functions, they will always be motivated to discount the future as little as possible, since the current effectiveness of a given delayed reward is greatest when there is least discounting. Given a choice, they should always choose to make delayed rewards be worth as much as possible. To learn to discount the future less, that is, to value the future more, would be to learn to coin reward.

The literature of cognitive psychology often implies that people can learn to ignore reward, or at least to distance themselves from its effect, and make decisions according to reason instead. However, this approach treats reason as a force separate from motivation, an imponderable factor that makes a systematic analysis of choice virtually impossible (see critique in Ainslie, 1996). Hyperbolic curves suggest a less mysterious possibility: foresight provides leverage that the attenuated motives at a distance from expected outcomes, "the still voice of reason," can manipulate to constrain future passions. These curves predict several self-control mechanisms.

Since a person’s preference among a fixed set of alternatives can vary predictably as a function of the passage of time, it follows that one of the obstacles she may face in trying to attain her current preferences is the expected preferences of her future selves. The dieter who has just finished bingeing has both a current clear preference for moderate consumption in the future, and an equally clear expectation that her own future self may pose a threat to this current preference. She may thus be expected to behave strategically towards the competitive interests of her future self - that is, to try to *commit* to her current interests. Ainslie (1975, 1992, 2001) has identified four distinct commitment tactics, three that must be chosen in advance and one that can be invoked concurrently with temptation. To the extent that a subject in an experiment has learned such mechanisms, they might influence her valuation of delayed outcomes. Thus variability of individual discount rates might relate less to differences in basic discounting than to differences in self-control style or sophistication. Furthermore, the different ways that a subject applies such tactics

across modalities of reward could well cause differences in her apparent discounting of these modalities.

Extrapsychic devices. The most direct method of commitment is to arrange for some external control or influence. A current preference for eating in moderation can be secured by undergoing gastric bypass surgery or, less permanently, by checking into a "fat farm." Buying only healthy food at the supermarket does not guarantee that you will not go on a late-night junk food binge, but it adds the disincentive of having to go to a store when the urge strikes. David Laibson (1997) has suggested that a need for this kind of commitment accounts for people's otherwise unaccountable preference for relatively illiquid investments. Extrapsychic commitment has been demonstrated even in pigeons (Ainslie 1974; Green and Rachlin 1996), though only in a situation where the commitment method was highly salient; presumably people are far more creative at finding external factors that may have a committing effect. For instance, proclaiming to your friends that you will never eat meat again does not eliminate it as an option, but it adds a new cost – that of losing face. Reputation may be a major vehicle of commitment (Becker 1960).

Control of attention. Another method to guard against future changes of preference is by the control of attention. Someone struggling to maintain fidelity to a spouse may not allow herself to notice the flirtations of an attractive third party. Attending to such information may foreseeably lead to the likelihood of creating preferences in opposition to current preferences. Attention control can occur as either deliberate avoidance of information or an avoidance that is not itself acknowledged. The latter case is the repression that Freud at one time held to be the cornerstone of all defensive processes (Freud 1914/1956, p. 16). The repressive individual avoids unwanted thoughts, feelings or behaviors by not attending to the psychically loaded information. Aside from the distortions that Freud noted, its disadvantage is a loss of information that may be needed for other decisions.

Control of emotions. Emotions such as fear, jealousy, and arousal can, up to a point, be vicious circles. After the emotion has gotten underway, there is a lower threshold for further emotional activity of the same kind, until some satiation point is reached. If a person expects an emotion to make currently unpreferred reward dominant, she may commit herself not to choose the reward through early inhibition of that emotion. There have been some experimental demonstrations of this tactic. For instance, Walter Mischel and colleagues found that while children below around six were poor at self-control, many older children were able to resist the temptation of an immediately available marshmallow in favor of a more preferred reward. Those that succeeded in avoiding the impulsive preference reversal often used emotion control in the form of thinking about the immediately available marshmallow in a "cool" way, or by imagining it to be undesirable (Mischel and Moore 1980; Mischel and Mischel 1983). However, emotion-forestalling devices tend to distort rather than normalize motivation, and may make people emotionally unresponsive, as in alexithymia (Nemiah 1977). At the moment, there seems to be no way to analyze them using animal models.

Prior commitment is not enough

Tactics that commit choice in advance are admittedly not conspicuous in subjects' evaluations of experimental rewards. They are sometimes evident in addicts' efforts

to avoid temptation, so we have summarized them briefly. However, although these commitment devices are recognizable,
, they are also marginal. We mostly do not need to bind ourselves by some physical device, or contract, or even reputation, to keep our intentions steady. It is certainly good advice for an addict to avoid the haunts where her substance is readily available; but most people who have given up a bad habit do not depend on keeping temptation at a distance or out of sight. People who have given up smoking, for instance, often say that they "just did it" one day. They are said to have used *willpower*. If they relapse, they are more apt to attribute it to an exceptional circumstance - the pressure of an exam, a resentment of meddlesome advice givers - than to the imminent availability of a cigarette. Rationalization, not proximity, is the most notorious threat to willpower.

Western culture has long been familiar with commitment that does not entail keeping a distance from temptation. Writers since antiquity have related self-control to choosing according to principle, that is, choosing in categories containing a number of expectable choices rather than just the choice at hand. Aristotle said that incontinence (*akrasia*) was the result of choosing according to "particulars" instead of "universals" (Aristotle 1984; *Nichomachean Ethics* 1147a24-28]; Kant said that the highest kind of decision-making involved making all choices as if they defined universal rules (the "categorical imperative,"; Kant 1973/1960: 15-49); the Victorian psychologist Sully said that will consists of uniting "particular actions... under a common rule" so that "they are viewed as members of a class of actions subserving one comprehensive end" (Sully 1884: 663). This strategy lets people resist temptation “with both alternatives steadily held in view” (James 1890: 534). In recent years behavioral psychologists have followed this approach to decrease pigeons' preference for smaller-earlier rewards - Heyman and Tanz (1995) by giving them extra reward for choosing according to "overall" rather than "local" maxima, Siegel and Rachlin (1996) by making choice depend on only every 31st peck, thus arguably creating a "molar" rather than "molecular" choice pattern.
The fundamental insight is that you increase your self-control by choosing according to category rather than on a case-by-case basis (e.g. a preference for being a non-smoker, even as you prefer this particular cigarette). But just such an effect is predicted by hyperbolic discount curves. Although hyperbolae spike up sharply in the period just before a reward is due and are thus exquisitely sensitive to short delays, their tails become not only more level, but also higher than the tails of exponential curves at long delays. The relatively high tails of hyperbolic curves imply a potential for great increases in value if series of expected future rewards are added together - and there is good evidence that the discounted values of series of rewards are additive (Mazur 1997). Exponential curves keep declining relentlessly at a constant proportion of their remaining height for every unit of time that passes. Hyperbolic curves level off more. The greater height of their tails means that curves from series of alternative rewards, if bundled together, will favor the larger-later rewards increasingly as the series lengthens (Figure 2a). Exponential curves do not predict increased tolerance for delay with summation of series of choices (Figure 2b).

FIGURES 2a AND 2b ABOUT HERE

Experiments with both human and rodent subjects confirm a greater tolerance for delay with bundled rewards. Kirby and Guastello (2001) gave college students

choices between smaller and earlier rewards and larger but more delayed alternatives, both with money and food. In one condition, the choice was made five times, each time separated by a week. In another condition, the choice was made between the two alternatives up front and for all five weeks at once. As predicted from the summation of hyperbolically discounted rewards, preference for the later larger alternative was increased in the condition in which a series of choices was bundled together (Kirby and Guastello 2001). We recently demonstrated the same phenomenon in rats. Eight rats were run through two conditions of a procedure designed to determine how much immediate sugar water was equal in value to a delayed standard reward of 150 ml after a three second interval. In one condition of the procedure, choices were made on a trial by trial basis, while in another condition, every choice determined the reward that would be delivered for three consecutive trials. As predicted by hyperbolic discounting, tolerance for delay was greater for all subjects in the bundled condition (Ainslie and Monterosso, 2003).

But a piece of the puzzle is still missing: if a person is a population of reward-seeking processes, what could make this throng choose according to principle? We suggest that it is the same thing that determines trust among nations, or among business people in areas not regulated by law: hard experience of the relevant bargaining contingencies. If a person has no awareness of a relationship among her decisions, then the life of any long-range plans will be short. Before it reaches its goal an incompatible plan will become more attractive at some point. A child who wants friends may have too many urges to be selfish. Someone who wants to lose weight may encounter too many tempting foods. An imminent payoff for an individual act of selfishness or particular snack is apt to be worth the little damage it does to friendships or the minor weight gain. It would probably not be worth losing all expectation of friendship or slimness, but such huge outcomes are rarely at stake in individual choices. As long as she attends only to the contingencies of each individual decision, a person stays riddled with impulses. There is no incentive to plan, because plans are usually rendered idle by the experience of reversing preferences.

However, an astute person - or someone who borrows the astuteness of her culture - is aware that her preferences are volatile. The best way she has to predict what she will do in the face of a future temptation is to see what she does with a similar temptation in the present. The act of selfishness predicts further selfishness and the eventual loss of friendship with all but the most long-suffering people. The snack predicts future snacks and inevitable weight gain. However, insofar as she is responsive to this rough insight about self-prediction, she will move toward choosing according to principle. Her current choices will become test cases, choices about selfishness and eating which this elementary insight will bundle together in her expectations to form series. When she chooses to be selfish, she chooses an expectation of future selfishness as well, and when she overeats the act bodes more overeating. She looks principled, but what literally happens is that her successive selves form a repeated prisoner's dilemma relationship, which they come to solve in the same way as tacit interpersonal bargainers do; each expects future selves to perceive the current choice as a precedent for cooperation or defection, and this expectation adds to those incentives that depend on that choice alone[4].

Our hypothesis is that the will is an intertemporal bargaining situation, dependent for its force on a person's recursive evaluations of the prospects for her own behavior. Such an internally fed back process is probably impossible to study with controlled experiments. However, given its formal similarity to the repeated prisoner's dilemma, we have tried to use an *inter*personal prisoner's dilemma as a model (Monterosso, Ainslie *et al.*, 2002). Subjects played long strings of sequential prisoners dilemmas. When stable cooperation or stable defection spontaneously occurred, false-feedback was given to subjects indicating to them that their counterpart had broken the trend. A large asymmetry was observed, with false defection doing far more damage to mutual cooperation than a false cooperation did to undo mutual defection. While original levels of mutual defection were restored after a single "recovery" move, cooperation rates were incompletely restored after even eight rounds of recovery moves following a single defection. While this may not confirm the usefulness of the interpersonal analog to intrapsychic bargaining, it is certainly consistent with the lore on self-control (e.g. "every gain on the wrong side undoes the effect of many conquests on the right; Bain 1886: 440).

It is also instructive that an intertemporal bargaining model fits descriptions of will over the centuries better than other published theories of will, and solves thought experiments that have otherwise seemed paradoxical in the philosophy of mind (see Ainslie 2001: 117-140 for discussion of Kavka's problem and Newcomb's problem, as well as the venerable argument over freedom of will.) Thought experiments may prove to be a particularly useful way of isolating the active ingredient of subtle incentives like the value of precedents. Consider a smoker who is trying to quit, but who craves a cigarette. Suppose that the choice at hand – to smoke the cigarette or not - is explicitly disconnected from future similar choices by specifying what those choices were destined to be. For example, suppose it were a forgone conclusion that she is destined to smoke a pack a day from tomorrow on. Given this certainty, she would have no incentive to turn down the desired cigarette - it would seem pointless. What if the destiny revealed was instead that she was never to smoke again after today? Here, too, there seems to be little incentive to turn down the cigarette - it would be harmless. Fixing future smoking choices in either direction evidently makes smoking the dominant current choice. Only if future smoking is in doubt does a current abstention seem worth the effort. But its importance cannot come from any physical consequences for future choices; hence the conclusion that it matters as a precedent. Indeed when Kirby and Guastello (2001) merely suggested to student subjects that the subjects' current choices might serve as predictions of their future choices, preference for larger-later alternatives increased, although not as much as when the experimenters bundled the choices directly.

Thus subjects in amount-versus-delay experiments who seem to have markedly shallower discount curves for a particular reward, as compared with other kinds of reward or other subjects, may actually have been evaluating this reward as a member of a broader category. Such evaluation will have made her choice predict, and thus depend on, future rewards that may overshadow the reward literally at stake. She will then seem more patient with this reward than with other kinds, and more patient than younger or otherwise less skilled subjects for whom the reward at hand dominates the choice.

3. Addictive choices do not depend on the proximity of temptation

As hyperbolic mechanisms for addictive choices get proposed, they are often criticized for seeming to force the choice into a Ulysses-and-the-Sirens mold.

Clinicians are well aware that the precipitant for a relapse is not always, or even usually, a sudden coming into close proximity with a tempting opportunity. Rather lapses are apt to follow a significant event, good or bad, in the person's day, and be explained by the person herself with a more-or-less plausible rationalization.

But although this pattern would not be seen in a naive subject trying to control temptation by prior commitment, it is exactly what we would expect in someone struggling to use the willpower mechanism we have just described. In principle, personal rules make it possible for a person never to prefer small early alternatives at the expense of the series of larger later ones. She may be able to keep temptations close at hand without succumbing to them. However, although she may always prefer a series of larger later rewards to the small early one at hand, she must even more strongly prefer to have both. The danger is no longer one of the poorer reward coming so close that she will suddenly choose it, but of her finding a credible distinction between this choice and the other members of the series that form the stake of her private side bet. Proximity is still a contributor to her temptation, of course, but the deciding factor is no longer whether a prior commitment is too weak but whether a tentative loophole currently looks to her like she could get away with it. The person will not experience this situation as the exotic voyage past some Siren or other, but as a simultaneous struggle between two ways of conceiving a choice. Her rules have enabled her to live in close proximity to her temptations, but while she is there the struggle will be continuous rather than episodic. Lapses will occur through loopholes, variously clever and inept, rather than through a global shift of preference in favor of the forbidden activity. A person is apt to express preference for the course of action required by her rule even as he is evading it, as Sjoberg and Johnson (1978) found in their study of smoking lapses.

Among other things, intertemporal bargaining allows people to establish personal rules for valuation of money and other important goods. A person who works in finance will surely be forced to rule that she will calculate value according to exponential curves, for instance, or she will lose out to competitors who do. However, the shallower she makes this artificial curve, the more she risks that at some point her expected reward from obeying this curve will not be enough to overcome spikes of temptation, which are still governed by her underlying hyperbola. Ruling that she should not discount future goods at all would be still harder, and thus riskier.

It seems to be possible to shield rules against imminent temptation by defining them so that investment decisions are not weighed against your strongest temptations. As Shefrin and Thaler (1988) have pointed out, people assign their wealth to different "mental accounts" such as current income, current assets, and future income. These accounts seem to represent personal rules for how readily the money they govern may be used to satisfy immediate wants. In effect, the person draws boundaries where she thinks they will never demand so great an act of abstention that she will prefer to abandon them by spending money from the asset account (“breaking into capital”), or borrowing against future income. We believe that people are apt to have a fourth account to the left of Shefrin and Thaler's three: a category for comparatively small windfalls like gifts or prizes, or money earned under exceptional circumstances like the pay as experimental subjects. Money in this category is beyond the protection of rules, as Thaler (1990) reports noticing personally when it was suggested to him that he spend $300 in football winnings

evenly over his expected lifetime. Only in this account are the person's valuations of single choices apt to be governed by the hyperbolic formula for single cases.

4. People may come to feel imprisoned by their self-control, while a hyperbolic shape seems to predict that avoiding temporary preferences will always increase long range reward.

Intertemporal bargaining is still not a complete solution. Until Victorian times philosophers regarded willpower as an unmixed blessing. It was Kierkegaard who first pointed out that it could become a prison (May 1958). His heirs, the existentialists, continue to identify an "idealistic orientation" which, although it inhibits the pursuit of transient pleasure, makes a person "inauthentic" (Kobasa and Maddi 1983). The most obvious side effect of an iron will is compulsiveness, arguably also a plague that grows proportionally as a society gets more sophisticated at self-control. Most psychotherapy deals with problems concerning overcontrol, described for instance by psychoanalysts as a punitive superego, by cognitive therapists as overgeneralization and magnification, and by gestalt therapists as dependence on cognitive maps (many summarized in Corsini 1984), rather than the simple inability to give up an impulse.

The intertemporal bargaining hypothesis predicts just such a potential for personal rules to grow pathologically. Reliance on this bargaining causes a decision to be worth as much or more as a precedent than it is in its own right. This does not necessarily imply that it is the wrong decision. On the contrary, you would think from the logic of summing discount curves that judging choices in whole categories rather than by themselves would have to improve your overall rate of reward (Figure 2a). Cooperation in a repetitive prisoner's dilemma would have to serve the players' long range interests, or else they would abandon it. How, then, can this cooperation ever become a prison?

The likeliest answer is that in everyday life a person can discern many possible principles in a given situation; and the way of grouping choices that finally inspires intertemporal cooperation need not be the most productive, because of the selective effect of distinctness: Personal rules operate most effectively on distinct, countable goals. Thus, to a person who is afraid of her spontaneous wishes, a rule to maximize foreseeable wealth or to never spend money unnecessarily will be more reassuring than the assortment of softer rules and social incentives by which people usually arrange to control their spending. Likewise, a person who is chronically afraid that she will get too angry will make or adopt narrow rules for conduct rather than relying on vague rules like putting herself in the other person's shoes. In such cases the person often knows that she is impairing her long range effectiveness, but cannot give up the guarantee that explicit rules supply.

So cooperation among successive motivational states does not necessarily bring the most reward in the long run. The mechanics of policing this cooperation may produce the intrapsychic equivalent of regimentation, which will increase your efficiency at reward-getting in the categories you have defined, but reduce your sensitivity to less well-marked kinds of reward. Even short of frank compulsiveness, the systemization that lets rules recruit motivation most effectively may undermine our longest range interests.

The attempt to optimize our prospects with personal rules confronts us with the paradox of definition - that to define a concept is to alter it, in this case toward something more formalized. If you conclude that you should maximize money you

become a miser; if you rule that you should minimize your vulnerability to emotional influence, you will develop the numbing insensitivity that clinicians have named alexithymia (Nemiah 1977); if you conclude that you should minimize risk, you become obsessively careful; and so forth. The logic of rules may come to so overshadow your responsiveness to experience that your behavior becomes formal and inefficient. A miser's strict rules for thrift make her too rigid to optimize her chances in a competitive market, and even a daring financier undermines the productiveness of her capital if she rules that she must maximize each year's profit (Malekzadeh and Nahavandi 1987). Similarly, strict autonomy means shielding yourself against exploitation by others' ability to invoke your passions; but alexithymics cannot use the richest strategy available for maximizing emotional reward, the cultivation of human relationships (Ainslie 1995). Likewise, avoidance of danger at any cost is poor risk management.

In this way people who depend on willpower for impulse control are in danger of being coerced by logic that does not serve what they themselves regard as their best interests. Concrete rules dominate subtle intuitions; and even though you have a sense that you will regret having sold out to them, you face the immediate danger of succumbing to short-range urges like addictions if you do not. If you have not learned ways of categorizing long-range rewards that permit them to dominate systematic series of mid-range rewards, your mid-range interests will make you compulsive.

The proneness of intertemporal bargainers to fall into compulsions may explain some hitherto perplexing characteristics of addictive behavior. The robustness of suboptimal rules may sometimes let addictions serve long range interests. Better to be fat, you might think, than anorectic. Your will may become so confining that a pattern of regular lapses actually makes you better off in the long run. The lore of addictionology often attributes bingeing to a patient's inhibitedness in the rest of her life; her general overcontrol is said to set up periodic episodes of breaking loose. The model of intertemporal bargaining predicted by hyperbolic discount curves provides a specific rationale for this pattern: Rules that eliminate any large source of emotional reward will create a proportional motive for you to bypass or break those rules. If those rules have, in William James' phrase, "grown too narrow for the actual case" (James 1890: 209), even your long range interest will lie in partially escaping from them. Thus personal rules that serve compulsion range interests can create alliances between long and short range interests. The person's occasional binge comes to serve as a corrective to the comparative sterility of such rules, a means of providing richer experiences than these rules allow while its transient nature still limits the damage it does. The longest range interest of an alcoholic who is too rigid when sober may be to tacitly foster the cycle of drunkenness and sobriety, rather than be continuously imprisoned by her rules.

Alcoholics are sometimes described who become nicer, or more genuinely creative, or more fully human when drunk. Furthermore, some addicts plan binges in advance. Such people may believe that their binges are undesirable - indeed, "rationality" will almost certainly dictate such a belief - but the therapists they hire find them mysteriously unresponsive to treatment. The patient who arranges for drinking several days in advance - who goes off the disulfiram that commits her to sickness if she drinks, for instance, or who brings bottles to her rehabilitation program for later use - cannot simply be yielding to a short range impulse. This is behavioral evidence that

she experiences a rational plan like giving up drinking as a compulsion which, even at a distance, appears to need hedging, although she may be unable to report any such thing.

This phenomenon suggests why a simplistic policy of "the more willpower, the better" contradicts the experience of many addicts. To them, more willpower means less of the human qualities they value most in themselves. They are able to listen to reason only when reason, represented by personal rules, stops starving their own longest range prospects for emotional reward.

5. Some discount rates in humans are appear to be negative - that is, delayed rewards may be valued more than immediate ones.

A finding that might seem to strike at the heart of an internal marketplace model of choice is a preference for *more* delayed goods and *less* delayed punishments. It is not difficult to find human self-reports of preferences that seem to reflect such negative discounting. Subjects say that they would rather have $1,000,000 tomorrow, rather than immediately (Rachlin *et al.* 2000), and most would prefer that a kiss with the movie star they find most attractive be delayed rather than immediate (Loewenstein 1987). Elsterand Loewenstein call such reverse discounting "savoring"; the process of "deriving positive utility from anticipation of desirable events" (Elster and Loewenstein, 1992: 224). A related observation is that, when deciding on a sequence of rewards of various magnitudes, subjects generally prefer ascending order rather than the descending order predicted by a positive temporal discounting. One study had subjects imagine that they had won a prize of three free meals at three different restaurants: one mediocre, one quite good, and one world-class. The dinners were to be scheduled to occur on the first of the month over each of the next three months, with the only choice being their order. The modal response is to choose the sequence of ascending superiority (Loewenstein and Prelec 1993). Except in cases where there is a strong expectation that outcomes will generally descend (such as health across one's lifetime; Chapman 2000), people typically prefer to save the best for last.

As the Victorian economist Jevons said, "There is little doubt that, in minds of much intelligence and foresight, the greatest force of feeling and motive is what arises from the anticipation of the future" (Jevons, 1871: 40 quoted by (Elster and Loewenstein 1992: 223) The reason for savoring is clearly to increase pleasure. Utility theory has had little to say about the relationships of external events to the experience of pleasure, but there is at least some popular recognition that managing pleasure can be a matter of managing appetite. Our culture warns us not eat dessert first or read ahead in a novel; indeed it often recommends "working up" an appetite. It has not told us why such practices should make a difference. However, the phenomenon of hyperbolic discounting suggests a hypothesis not only about savoring but about appetite generally. This is the broader problem of premature, discussion of which will suggest a rationale for savoring."

6. The most constant rewards often lose their rewarding power, even after periods of nonoccurrence when appetite should be fresh.

Rationality turns out to be less a matter of comparing the sizes of goods than of avoiding seductive derailments. The will, looked at as an intertemporal bargaining strategy, has costs of its own that detract from its value in achieving rationality. It is also limited in scope; purely mental options like paying attention and recalling

memories, for instance, are probably chosen too quickly to be evaluated as precedents, and thus cannot be well controlled by will. This is a particularly serious limitation in a wealthy society, where physical needs are satisfied readily and most effort goes into pursuing various kinds of emotional satisfaction. The problem that hyperbolic discounting creates here is premature satiation; the solutions people find are apt to be even more costly, and seemingly irrational, than the compulsiveness that comes with willpower.

Hyperbolic discounting can be expected to attenuate many kinds of emotional satisfaction, according to the following logic:

- Rewards that are freely available will be limited by how much appetite you have for them, which often depends on deferring consumption of them.
- Hyperbolic discounting makes you innately impatient to increase your rate of consuming a reward, which often moves you to satiate your appetite for it prematurely (Figures 3a and 3b).
- You can pace your consumption of physical rewards through personal rules, but this will not work for rewards like the emotions, that depend only on attention.
- To the extent that you cannot keep your attention from anticipating a familiar sequence of events, this familiarity alone will dissipate your appetite. The only protection from anticipation is for the events to be surprising.
- Premature satiation therefore weeds out emotions not cued by events that are adequately surprising.

FIGURES 3a AND 3b ABOUT HERE

The impatience for knowledge that is so adaptive in hostile environments spoils the enjoyment of sustained success, as emotion researcher Sylvan Tomkins noted:

> "The paradox is that it is just those achievements which are most solid, which work best, and which continue to work that excite and reward us least. The price of skill is the loss of the experience of value-- and of the zest for living" (Tomkins 1978: 212).

In the absence of some factor that refreshes available appetite, ethologist Konrad Lorenz said:

> "The normal rhythm of eating with enjoyment after having become really hungry, the enjoyment of any consummation after having strenuously striven for it, the joy in achieving success after toiling for it in near-despair - in short the whole glorious amplitude of the waves of human emotions, all that makes life worth living - is dampened down to a scarcely perceptible oscillation between scarcely perceptible tiny displeasures and pleasures. The result is an immeasurable boredom." (This is because) "… the mechanisms equilibrating pleasure and displeasure are thrown off balance because civilized man lacks obstacles which force him to accept a healthy amount of painful, toilsome displeasure" (Lorenz 1970: 355-6, 357).

Failure of appetite is familiar enough, but without hyperbolic discounting to explain why people don't accept that "healthy amount of painful, toilsome displeasure" it has not made motivational sense. Premature satiation emerges as a pervasive impulse that is increasingly important as a society gets efficient at satisfying appetites. Where willpower can be effective, as in the timing of consuming externally supplied goods, we would expect people to develop personal rules for cultivating appetite. In effect: 'save the best for last,' 'don't take vacation days until you must use them or lose them,' 'don't consume something until you start to get diminishing returns from anticipation." The need to defend appetites from premature satiation explains the savoring that human subjects so often manifest, an apparent reversal of discounting that is actually a response to discounting. Where willpower cannot be effective, as when the goods are entirely emotional and appetite can be spoiled by mere anticipation, we are apt to see people adopt strategies that peg their emotions to surprises-- gambling in its many, often subtle, forms-- consideration of which is beyond the scope of this chapter (see Ainslie 2001: 161-97).

Converse to the problem of premature satiation is the problem of dread, the tendency of anticipated pains to have more impact than imminent pains with the same dimensions. The majority of normal human subjects choose an immediate shock over an equally intense delayed shock[5] (Cook and Barnes 1964; Hare 1966a), and this tendency was most apparent when larger shocks were used (Hare 1966b). Similarly negative discount rates in the domain of hypothetical losses have been observed in at least a portion of subjects (Loewenstein 1987; Chapman 1996; Chapman *et al.* 2001; van der Pol and Cairns 2001). Presumably, a week's postponement of a colonoscopy leaves us with both the pain of the procedure, plus the additional aversiveness of seven days of dread. Humans' preference for more immediate aversive outcomes over less immediate ones has no documented analog in the Skinner box; like savoring, it seems to require a capacity for self-control. The phenomenon being controlled - the urge to rehearse the anticipated pain despite resulting distress in the present - is no more likely to respond to willpower than is premature satiation of anticipated emotional pleasure. The only discipline possible for the will is to hasten the cause of the distress and "get it over with."

Conclusions

Delay has a profound effect on the value of expected reward. In animal subjects the form of this effect is a highly reliable hyperbola. However, it is not likely that discount rates derived from human experiments can similarly assess a core aspect of motivation - that is, something limbic and uncomplicated by cognition and culture. The fact that discount rates in standard human experiments are so much lower than in animal experiments is a *prima facie* reason to suspect interposed cultural and cognitive layers of processing The negative discount rates found in humans but not lower animals using some rewards and aversive experiences, and humans' reported preferences for ascending rewards when choosing a series also point toward interposed control processes. In any case, the low correlation between discount rates across domains, noted earlier, indicates that delay experiments provide a highly imperfect measure of a person's general delay sensitivity.

Accordingly some authors are pessimistic about the existence of an underlying innate discount function, Indeed there is a movement to give up on the idea of constructing a general model of intertemporal choice. Roelofsma and Read write:

> "The study of intertemporal choice is currently undergoing a change in emphasis, as has already occurred in the study of decision making under risk and uncertainty. Rather than searching for the holy grail of a single utility function, researchers now take the more pragmatic view that preferences are constructed based on the circumstances of their expression" (Roelofsma and Read 2000: 172).

But this pessimism is premature. Although experiments elicit human behaviors toward delayed reward that are as variable as those in real life, there is good reason to believe that much of this variability results from exactly those strategic responses that are predicted by hyperbolic discounting. There are now good data supporting the intertemporal bargaining model of will, which transforms the task of impulse control from one of prior commitment to one of dealing with potential rationalizations. Furthermore, predicted problems with the use of will match clinical problems that are actually observed, including addicts' frequent rejection of binding commitments to sobriety. And the possibility of strongly motivated premature satiation of appetite provides what we believe to be the first explicit motivational theory for both the decline of emotional reward with familiarity and human countermeasures like savoring and gambling.

This is to argue that the preference patterns that have been described as anomalies for a theory of hyperbolic discounting are actually consistent with, and even predictive of, the implications of this theory. Hyperbolic curves cannot be substituted simply for exponential curves in an otherwise unchanged theory of maximizing expected utility. Hyperbolae imply temporary preferences that demand strategic responses, which with experience will elaborate a fabric of incentives much like that which interpersonal bargaining games have woven in societies. The addictions we deal with as therapists are embedded in this kind of incentive structure, and confront us with corresponding subtleties.

Notes

1. Most typically in behavioral economic experiments, the best fit discount parameter k (from Equation 1 or some variant) is used as the measure of individual discount rate. Myerson and colleagues have recently argued that area under the discount curve makes for a less theoretically loaded measure (Myerson *et al.* (2001).)

2. To save money, some experimental procedures use probabilistically real money. Subjects may be given their selected preference for just one trial, chosen randomly after the experiment (Richards *et al.* 1999; Crean *et al.* 2000).

3. At least one study reported that smokers had *lower* temporal discount rates (Chesson and Viscusi, 2000). This study used complex stimuli, requiring subjects to both choose and provide indifference amounts between some amount of money delivered at a set time and another amount of money that would be delivered at one of two possible times, according to some specified probability. The study yielded several findings that are counter to other reported studies - lower temporal discounting in 1) smokers, 2) lower income subjects, 3) younger subjects, and 4) subjects with the most education.

4. The terms of the prisoner's dilemma must be modified slightly to deal with the fact that future selves cannot retaliate strategically against past selves (see Ainslie 2001: 90-4).

5. Interestingly, subjects with antisocial personality disorder, relative to normals, had a greater preference to choose more delayed shock (Hare 1966a).

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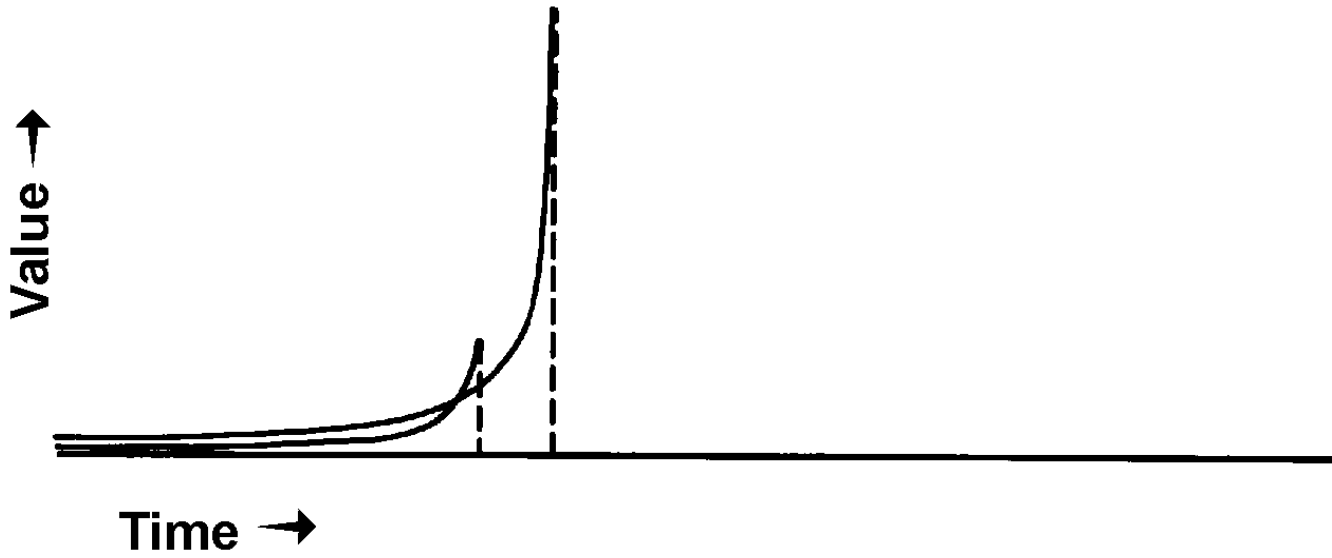
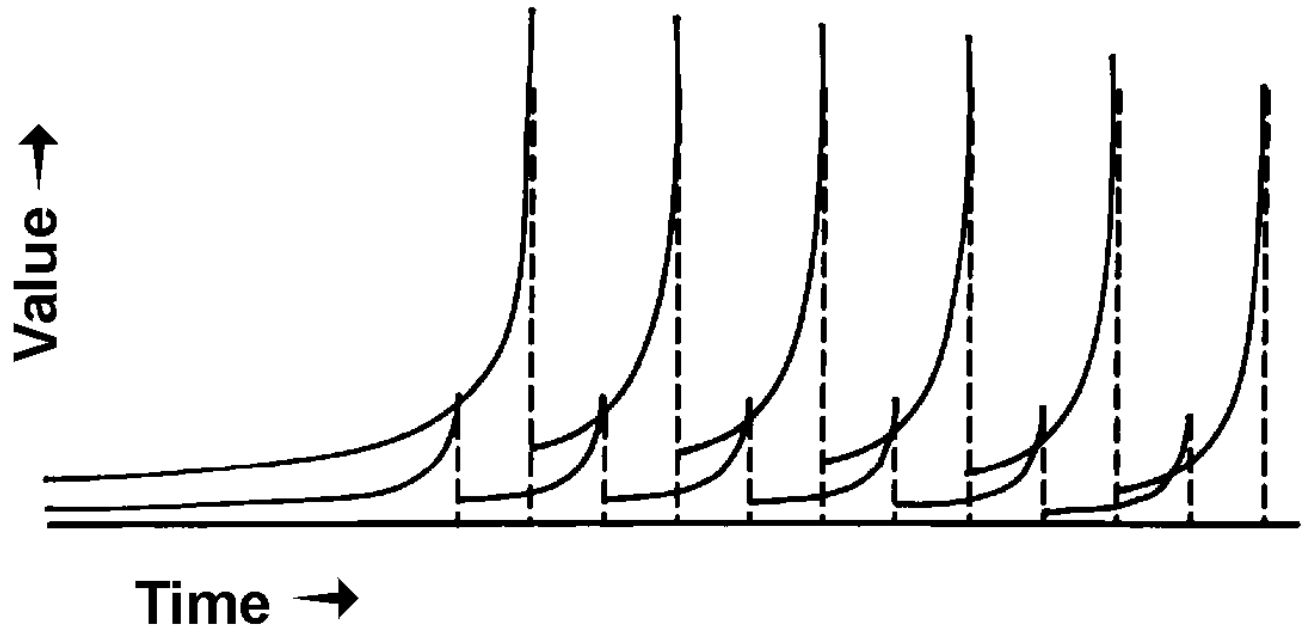
Figure 1



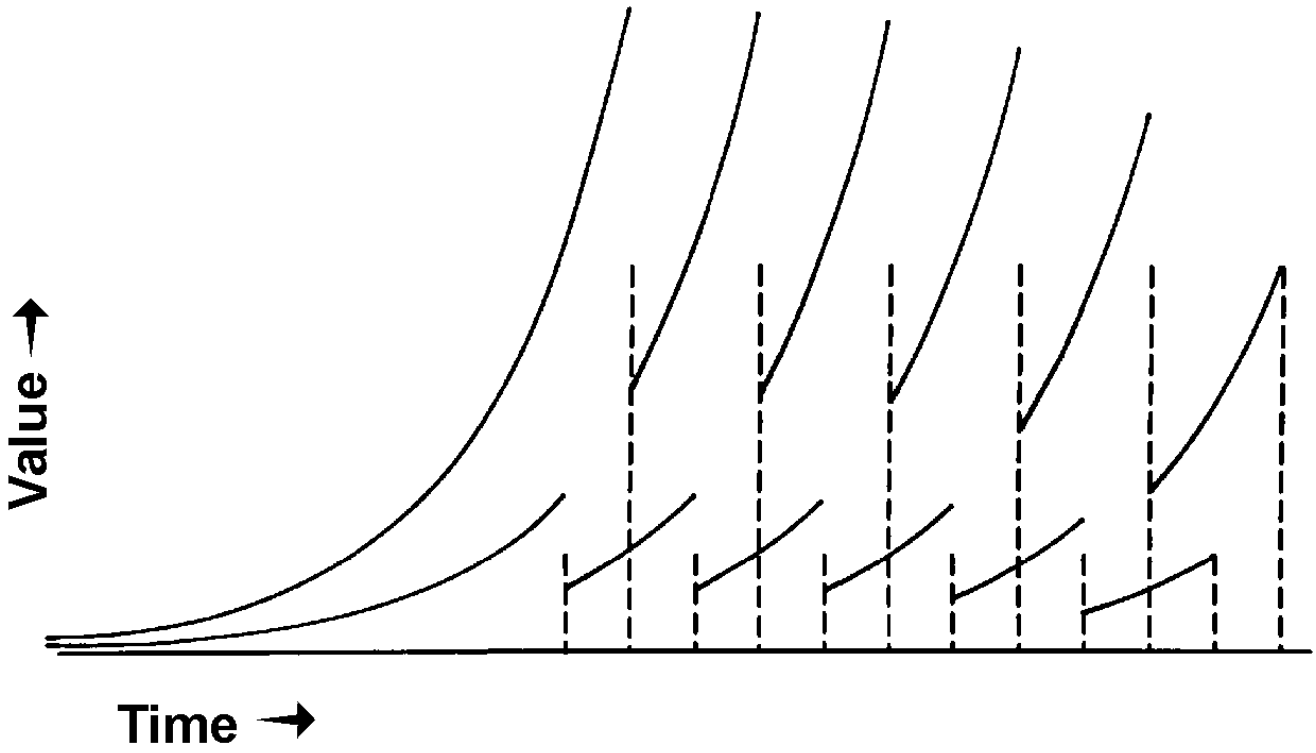
Hyperbolic discount curves from two rewards of different sizes available at different times (vertical dashed lines). The smaller-earlier reward is temporarily valued higher (preferred) for a period just before it's available, as shown by the portion of its curve that projects above that from the later-larger reward.

Figure 2a



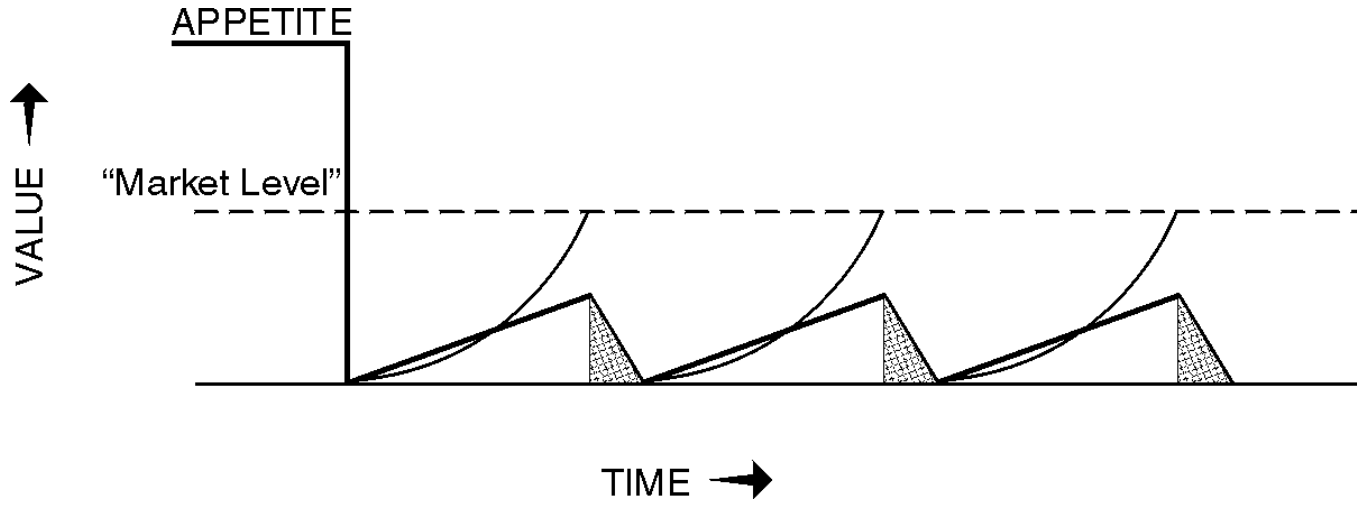
Summed hyperbolic curves from a series of larger-later rewards and a series of smaller-earlier alternatives (vertical dashed lines). Each curve depicts the summed discounted values of all future (more to the right) rewards in the series. As the series gets longer and the summed curves peak higher above the current rewards, the initial period of temporary preference for the series of smaller rewards shrinks to zero. (Compare the top of the first short vertical dashed line with that of the last vertical dashed lines). The curves from the final (right-hand) pair of rewards are the same as in Figure 1.

Figure 2b



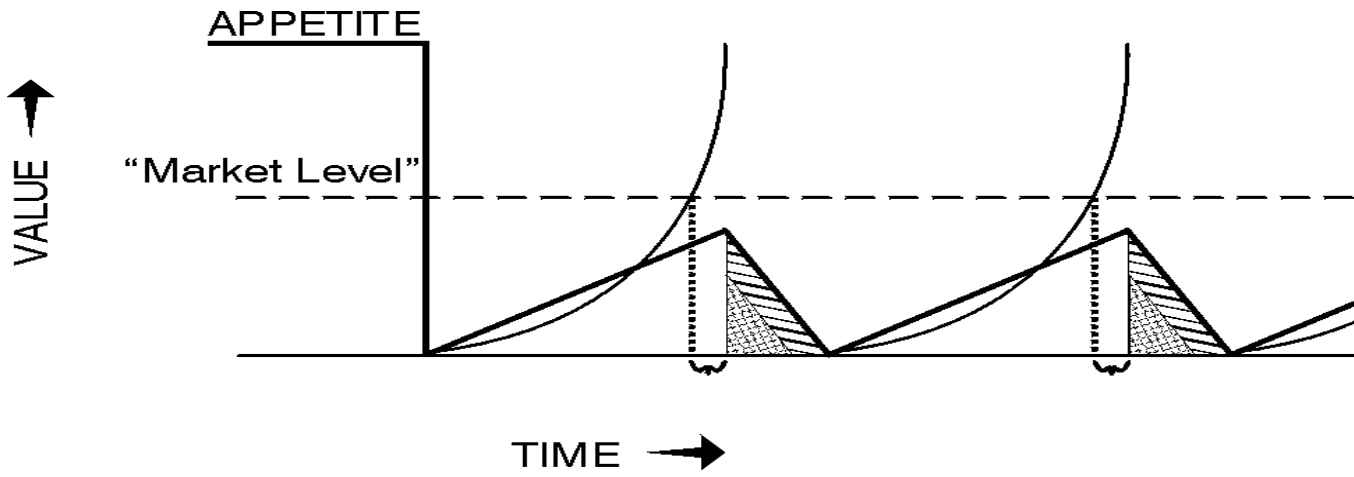
Summed exponential curves from the same series of paired alternative rewards (vertical dashed lines). Summing increases their heights as the series get longer (more to the left), but does not change their *relative* heights. (This would also be true if the curves were so steep that the smaller, earlier rewards were preferred; but in that case summing would add little to their total height, anyway, because the tails of exponential curves are so low.)

Figure 3a



Cycles of growing reward potential (rising straight lines) and actual consumption (gray areas) leading to satiety. Consumption begins when discounted value of expected consumption reaches the competitive market level. Hyperbolic discount curves of the total value of each act of consumption decline with delay from its anticipated onset (right to left as delay increases).

Figure 3b



Increased reward (stripes) resulting from increased appetite when there is an obligatory delay in the moment of starting consumption from the moment of choice ("{" brackets); the choice to consume occurs when the discounted value of the delayed consumption reaches the market level.