Chapter 4

Consumption Dependent Changes in Reward Value: A Framework for Understanding Addiction

Gene M. Heyman

Introduction

The title of this conference, *Choice, Behavioural Economics, and Addiction*, and the content of the papers suggest that addiction entails voluntary drug use. Although all of the speakers seem to share this assumption, it is at odds with how many outside of the boundaries of this conference talk and think about addiction. Addiction is widely understood as a destructive form of drug use, and in accordance with this understanding the standard definition of addiction, as documented by the dictionary, is "compulsive" drug use, where "compulsive" is defined as driven by an "irresistible" force (see, e.g. Oxford English Dictionary, 3rd ed.; American Heritage Dictionary, 3rd ed.). In support of "common sense," it is not obvious that individuals would repeatedly take drugs voluntarily if the drug effects were seriously self-injurious, and, according to standard usage, an act cannot be both "voluntary" and "compulsive." Hence, the idea that guides this conference, that drug use in addicts is voluntary, requires some explanation.

But these discrepancies could be ignored if it were just a matter of "scientific" vs. "everyday" word usage. However, many scientists also define addiction as compulsive drug use (e.g. Koob 2000; Volkow & Fowler 2000). From these articles, it is not clear if the term "compulsive" has simply become a synonym for "strong preference." However, at least some leading experts accept the standard definition of "compulsion" as "irresistible." For example, in the journal *Science*, Alan Leshner, the recent director of the National Institute on Drug Abuse, wrote that addiction begins as voluntary drug use but then becomes involuntary and should be considered a chronic illness, like diabetes or hypertension (Leshner 1997). Jellinek (1952), who championed the disease model of alcoholism more than 50 years ago, made similar arguments about alcoholics. His ideas have become widely accepted by journalists, clinicians, and at least some scientists. For example, media reports on problem drinking usually contain the catch-phrase, "the disease of alcoholism,"

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and editorials in the scientific journal *Alcoholism: Clinical and Experimental Research* promote the view that alcoholism is a disease (which implies involuntary or irresistible drinking (e.g. Erickson 1998)). Thus, the issue of whether it is legitimate to assume, as have the conferees, that addiction entails voluntary drug use needs to be addressed. Indeed in this paper this question takes precedence in regard to order of presentation.

The second section introduces a choice-based analysis of addiction. The analysis builds on a paper by Herrnstein & Prelec (1992). This paper introduced a simple but fundamental distinction regarding whether the behavior to be explained is a single choice leading to a particular outcome or a series (distribution) of choices leading to a disposition or state. In the arena of eating, an example of the former is the decision to have, say, a Chinese meal or an Italian meal, whereas an example of the latter is an extended diet resulting in weight loss. The distinction, as will be shown, leads to a proof that in repeated choice situations an individual can choose the lowest overall reinforcement rate (e.g. Heyman & Herrnstein 1986). Or put another way, from the idea of distributed choice, it is possible to derive addiction.

The second section ends with a description of an experiment based on the distributed choice theory of addiction (Heyman & Dunn 2002). The study compared drug users and non-drug users in series of two-choice tests. One choice was better from the perspective of the current trial, whereas the other choice was better from the perspective of two or more consecutive trials. This dilemma, it is argued, is analogous to the problem facing an addict who is trying to quit using drugs. The subjects in the study varied in regards to their history of illicit drug use, and this difference turned out to be correlated with performance in the experimental procedure. As the history of illicit drug use increased, a tendency to treat the experimental procedure as a simple, non-repeating, one-choice situation increased.

The third, and last, section of this paper evaluates the generality of the idea that consumption-based changes in reward value yield choice dilemmas. This section is based on the elementary observation that, since consumption dependent changes in reward value are common (e.g. satiation and tolerance), then choice dilemmas of the sort that face the addict (and the subjects in the experimental procedure) must be common. The section ends with a brief discussion of why drug-related choice dilemmas are more difficult than the choice dilemmas that attend conventional rewards, like food or sex.

An Overview of Addiction: Compulsion or Ambivalence?

The goals of this section are to provide a checklist of the behaviors that a model of addiction should predict and to answer the question of whether drug consumption in those who meet the criteria for addiction is compulsive or voluntary. The empirical material includes the American Psychiatric Association's definition of addiction, estimates of the time course and recovery rates for addiction, and psychosocial correlates of recovery. The criterion for determining whether drug consumption is voluntary will be the degree to which it is influenced by the factors that influence decision making. These factors include new information, insights, values, incentives, and rewards. For example, when an individual can be persuaded to behave in some specified way by such interventions as new information, new personal values, legal sanctions, or, more generally, by rewards and punishments, then that behavior

is, according to this argument, voluntary. In contrast, when a behavior persists more or less at the same rate regardless of these same factors, then that behavior is deemed to be involuntary.

The distinction can be captured by a thought experiment. Imagine what would be involved in trying to persuade someone not to wink and not to blink. Although the topographies are roughly similar, it is quite plausible that rather modest social sanctions, such as a frown or simply turning away, would discourage further winks, whereas plausibility similarly suggests that a blink, say in response to a blast of air directed to the eye, could not be dissuaded by any amount of money or training. Of course, drug use is not as simple, topographically, as is the exercise of the eye, and with the greater topographic complexity come three problems. First, complex acts like the maintenance of an addiction will entail voluntary and involuntary elements. For example, hedonic motives, such as the desire to feel better or calmer, likely reflect states that vary widely as a function of innate differences. Second, the degree to which an act can be influenced by contingencies must vary along dimensions that have yet to be established. For example, it is possible that behaviors that are less susceptible to environmental contingencies come with their own built-in, virtually immediate rewards (e.g. sexual behaviors). Third, it may often be difficult to distinguish the influence of a contingency and the influence of a change in disposition. For example, someone who lowers their body temperature by means of a swim in ice-cold water has not really *learned* to lower their body temperature — rather they have learned to place themselves in a situation that elicits a change in body temperature.

Although each of these points deserves attention, we need not wait for further research to come to a conclusion about the influence of ideas, values, and consequences on drug use. As is shown next, there is little question that a wide range of rather ordinary persuasive influences can significantly modify the level of drug use in addicts (individuals who meet the criteria for "substance dependence").

It may also be useful to point out what do not count as criteria for the distinction between voluntary and involuntary behavior. I am not asking whether addictive drugs change the brain. Of course they do, but this does not discriminate addictive drug use from any experience that alters behavior. Similarly, the question is not whether there is a biological predisposition for addiction. Most likely there is a biological predisposition for most if not all voluntary behaviors. People are born with musical, athletic, and intellectual talents that help guide their careers, just as some are born with a predisposition for alcoholism (e.g. Cloninger 1987; Pickens *et al.* 1991). Put somewhat differently, that drug use is voluntary does not preclude biologically-oriented addiction research. Indeed, according to the approach advocated here, the difference between voluntary and involuntary behavior is at root biological: the neural bases of voluntary behavior are more susceptible to the influence of contingencies and learning, whereas the neural bases of involuntary behaviors are less susceptible to these factors.

Thus, the question to ask is: "does drug consumption in addicts systematically vary as a function of its consequences?" Can new information, values, laws, and incentives bring drug use to a halt in someone who meets the criteria for addiction? And, conversely, does drug consumption persist when the consequences, as framed by the user, favor persistence? If the answers to these questions are "yes" then, according to the persuasion criterion, addiction is a case of voluntary drug consumption.

The American Psychiatric Association Criteria for Drug Dependence

The American Psychiatric Association publishes a diagnostic manual for identifying psychiatric disorders (e.g. APA 1994). One of the purposes of the text is to provide clinicians and researchers with reliable criteria for identifying psychiatric disorders (see, e.g. Spitzer *et al.* 1979). For "substance dependence," the APA term for addiction, the reliability ratings are consistently among the highest of any psychiatric disorder. Sometimes overall agreement levels reach above 95% using conventional concordance measures (e.g. Helzer *et al.* 1985). Consequently, the APA criteria have become widely accepted as the defining characteristics for drug use problems and, as such, they also make a good starting point for any review of the nature of addiction.

According to the manual, the "essential feature" of *substance dependence*:

> is a cluster of cognitive, behavioral, and physiological symptoms indicating that the individual continues use of the substance despite significant substance-related problems. There is a pattern of repeated self-administration that usually results in tolerance, withdrawal, and compulsive drug-taking behavior (176).

Following this general statement is an account of the criteria for identifying *tolerance*, *withdrawal*, and *compulsive* and a list of seven signs or symptoms. As neither tolerance nor withdrawal are necessary or sufficient, the pivotal term is "compulsive." The manual identifies compulsive drug use in the following way:

> The individual may take the substance in larger amounts or over a longer period than was originally intended (e.g. continuing to drink until severely intoxicated despite having set a limit of only one drink) . . . Often there have been unsuccessful efforts to decrease or discontinue use . . . The individual may spend a great deal of time obtaining the substance, using the substance, or recovering from its effects . . . Despite recognizing the contributing role of the substance to a psychological or physical problem (e.g. severe depressive symptoms or damage to organ systems), the person continues to use the substance. The key issue in evaluating this criterion is not the existence of the problem, but rather the individual's failure to abstain from using the substance despite having evidence of the difficulty it is causing (178–179).

The seven signs and symptoms come with the rule that if three occur within a 12-month period then the individual meets the criteria for substance dependence. The list includes items from the above passage and tolerance and withdrawal (APA 1994: 181).

Compulsion or Changes in Preference?

As a diagnostic tool for researchers and clinicians the APA account has proven itself many times over (Robins & Regier 1991; Warner *et al.* 1995). However, when it comes to

defining "compulsive," the manual uses behavioral criteria that do not require the dictionary definition of "irresistible" or involuntary. For instance, the manual states that to drink more than was initially intended is a sign of compulsion. Yet, it is an everyday experience that our predictions about our future voluntary acts — such as how much we will work, watch television, or talk on the phone — are consistently and repeatedly wrong. Once engaged in an activity, it is commonplace to find that it is more interesting or satisfying than we thought it would be. However, this does not mean that we would not have stopped had the incentives changed. Similarly, there is a non-compulsive interpretation of relapse. If a currently abstinent ex-drug user enters a setting in which his or her drug of choice is readily available, then the context for the decision to indulge or abstain may shrink from what is good overall to what is good for the next few moments. Since one cigarette does not cause cancer and one shot of heroin does not condemn the user to a "junkie life style," a person can quite correctly reason that "since it's just for one last time," the drug is the best choice. However, a series of "one-last times" turns into a relapse. In this example, the process includes reason, a shortsighted time horizon, and incentives. There is nothing compulsive in deciding that, as measured over the next few moments, the drug is better than not having the drug. In sum, the APA's approach to defining "compulsion" deviates from the dictionary account, and it is ambiguous in that the behavioral examples are open to a decision analysis as well as the conventional "compulsive" interpretation.

More on the Nature of Addiction: Supplementing the APA Account

The argument so far is intuitive. We can imagine that the APA symptoms reflect an ambivalent attitude toward drug use, but we can also imagine that they are the signs of a compulsion. The correlates of recovery provide the decisive data, but first it would be useful to say something about recovery itself. Is it common, and if so, how long does addiction usually last?

On the Duration of Addiction: General Population Surveys Show that Most Addicts Recover

The introduction to many scientific papers on addiction includes the phrase: "addiction is a chronic relapsing disorder," or words to that effect. Although these papers usually do not attempt to support this assertion with reference to the clinical literature, the claim that addiction is typically a chronic disorder has empirical support. Addicts in treatment often continue to use drugs (e.g. Condelli *et al.* 1991; Kidorf & Stitzer 1993) and, following treatment, relapse is more common than long-term abstinence (e.g. Hunt *et al.* 1971; Wasserman *et al.* 1998). Thus, on the basis of the clinical literature, the claim that addiction is a "relapsing disorder" or even a "relapsing disease" is plausible.

However, in the most extensive survey of psychiatric disorders among the general public, most people who met the criteria for addiction to an illicit drug did not seek treatment (Anthony & Helzer 1991). This is significant because when the population of addicts is expanded to include those who did not seek treatment — and hence is more representative — recovery not relapse is the rule. For example, in the most recent, large,

national survey of psychiatric disorders that selected subjects independently of whether they sought treatment, addiction had the highest recovery rate of any psychiatric disorder (Warner *et al.* 1995) Approximately 76% of those who met the criteria for dependence on an illicit drug at some point in their life, no longer did so. It might be argued that the methods of these large, national surveys are too crude to provide reliable or valid results. But, small-scale intensive ethnographies of heroin and cocaine users that selected subjects on criteria other than clinic attendance lead to the conclusion that for most people addiction is a limited disorder, often ending in their early 30s (e.g. Biernacki 1986; Robins 1993; Robins & Murphy 1967; Waldorf *et al.* 1991). (Interestingly, the national surveys indicate that duration of heavy use for the two legal addicting drugs, alcohol and tobacco, persists longer than does heavy use of the illicit addictive drugs (e.g. Helzer *et al.* 1991).)

According to the evidence, recovery from addiction is common, expert opinion notwithstanding. Consequently, it is reasonable to ask about the correlates of recovery. Do they include the factors that influence voluntary behavior? Or will they support the view that addiction is a form of compulsive behavior, on the order of, say, compulsive hand washing, or the "involuntary" movements and vocalizations that identify Tourette's syndrome?

The Correlates of Recovery: Ideas, Incentives, and Values

One of the distinctive characteristics of voluntary action is that it is highly susceptible to the influence of ideas, especially when the ideas are backed by larger social trends. For example, over the last twenty years or so, the concept of "natural food" has altered the eating and shopping habits of millions of people. Do similar trends apply to drug consumption among addicts?

Most regular smokers meet the criteria for "cigarette addiction," and according to a recent text, many experts in addiction count cigarette smoking as one of the most addictive forms of drug consumption (e.g. Gahlinger 2001). Smoking is legal and despite recent prohibitions, it probably remains the most public addiction. People smoke at or near work, at home, in bars, at parties, at the beach, and according to the ads, even while on horseback. Smoking is part of the culture. Thus, if addicted smokers are actually voluntary smokers, they should be influenced by new ideas about smoking, especially when these ideas are reinforced by other cultural trends. As is demonstrated next, the history of smoking shows the predicted pattern.

With the invention of a cigarette-making machine in the late 19th century, cigarette smoking gradually spread, first among men and then among women. By about 1955, more than 60% of American males and more than 30% of American females were regular smokers (e.g. Giovino *et al.* 1995). But since 1964, the trend has reversed. Over half of those who were ever regular smokers have quit, and currently less than a quarter of the U.S. adult population smokes (e.g. Smith & Fiore 1999). The turning point was the publication of the Surgeon General's Report on the health risks of smoking (USDHHS 1964). The report's fundamental message was that smoking increased the likelihood of a variety of life-threatening illnesses, including cancer. This information was not new, as claims that smoking jeopardized health date as far back as 1604 (King James I, *A Counterblaste to Tobacco*). Rather what was new was the credibility of the data. There were 387 pages of graphs, tables, and statistics, and a supporting cast of scientists that numbered in the

hundreds. For anyone who took science seriously, it was difficult to dismiss the possibility that smoking markedly increased the chances of serious illness.

If drug use in addicts is subject to the influence of ideas and values, then the Surgeon General's Report should have led to a decrease in smoking among regular smokers, especially among those who had been trained to respect research and new information. The accompanying graph (Figure 1) tests this idea (USDH&HS 1990, 1994). On the *x*-axis is the year, starting with the year after the Surgeon General's Report. On the *y*-axis is the proportion of smokers who have quit as a function of education level. The steeper the slope, the greater is the change in the probability that a smoker has quit. Since 1964 the overall proportion of smokers who have become ex-smokers has greatly increased. But, as predicted, cessation has increased faster for those who are more educated, and, as a result, educational achievement has become an increasingly stronger predictor of who smokes.

Incentives Decrease Drug Use in Addicts

In the laboratory, the study of voluntary behavior has largely been the study of the influence of rewards and punishment on responding (e.g. Mazur 2002; Skinner 1953). Thus, if drug consumption among addicts is voluntary, it should be susceptible to the influences of reward and punishment. Under a variety of conditions, money and various tangible rewards have reduced or eliminated drug use in smokers (Stitzer *et al.* 1986), cocaine addicts (Higgins *et al.* 1994), and alcoholics (e.g. Bigelow & Liebson 1972). In one of the more realistic studies, severe alcoholics were given a free drink and then offered incentives for not taking a second drink (Cohen *et al.* 1971). The procedure was highly effective at inducing a bout of heavy drinking. For example, the larger the priming drink, the more likely a binge. However, for every priming dose there was an incentive that would promote self-control. With a drink in hand and one under the belt, money persuaded "out of control" drinkers to contain themselves. (However, it may still be the case that under non-laboratory conditions, most serious drinkers are better off as teetotalers than as social drinkers.)

Values and Recovery from Addiction

Autobiographical accounts of recovery often tell of a pivotal emotional experience that sets in motion a chain of events that leads to recovery (e.g. Waldorf 1983). An interesting and overlooked source of these stories is an article published in 1983 by Jorquez. One of the interviewees is Wendy. She places the first steps of her recovery to a solitary sunset and a powerful urge to become a responsible person. She writes that:

> One evening . . . I climbed on this rock, and just sat there alone waiting for the sunset . . . Then I snapped . . . "What am I doing? God did not put me here on earth to be using heroin!" For the first time I felt guilty about being a user. I began to have these powerful feelings for my parents to be proud of me again. And I thought about my son and my responsibilities to him. I stayed clean for about two weeks that time (Jorquez 1983: 353).

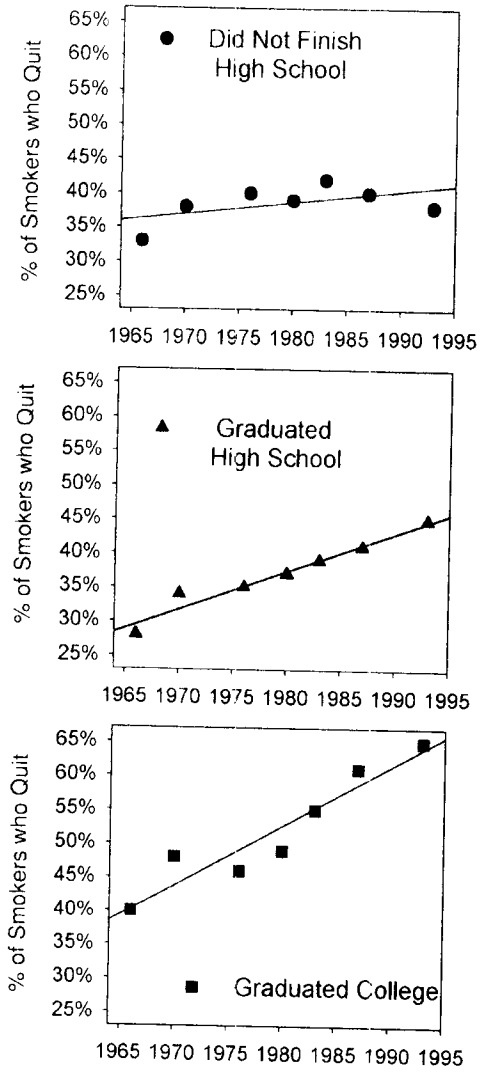

Figure 1: The information in this graph was obtained from the 1990 Surgeon General's Report (U.S. Department of Health & Human Services 1990) and the *Morbidity and Mortality Weekly Review* (U.S. Department of Health & Human Services 1994). These results were initially gathered as part of the NHIS survey on smoking. Ever smoking was defined as smoking 100 or more cigarettes. Quitting was determined by the question "Do you currently smoke?" Although, there was no attempt to validate the respondents' answers, experts in smoking epidemiology believe that the results of this survey are valid. Internal consistency in the data support this belief.

Over a two-year period Wendy gradually moved from heavy drug use to abstinence and had not used drugs for about two years at the time the article was published. For the entire sample in this study the average time since last use was about 6.5 years. An ethnography that used systematic interview methods supports Wendy's version of recovery (Waldorf 1983). In a population of 100 recovered heroin addicts, the most frequently cited reason for the transition from heavy heroin consumption to abstinence was an event that led to feelings of regret about addiction or the junkie lifestyle.

Summary: On the Correlation Between Behavior and Word Usage

This review reveals that new information, incentives, and values can markedly reduce the level of drug consumption in individuals who were daily drug users and who would meet the APA criteria for addiction (for a more complete account of this literature, see Heyman 2001). This point becomes important by contrast. New scientific insights, monetary pay-offs, and religious beliefs have so far proven to have little or no influence on disorders such as schizophrenia and Tourette's syndrome. Thus, by the "persuasion" criterion, addiction entails voluntary drug use and Tourette's syndrome entails involuntary ticking. (Of course, as indicated earlier, not all contingencies will reduce drug use, and, conversely, not all contingencies will have no effect on Tourette ticking.) In support of this distinction and general approach, everyday language conforms to this analysis. Although voluntary behavior is defined in terms of the exercise of the "will," the legal system excuses just those acts that are least susceptible to contingencies: accidents, acts committed by the immature, and acts committed by the insane. Consequently to apply the label "compulsive" to addiction is to ignore: (1) much of what is known about drug use; (2) much of what is known about non-drug related psychiatric disorders; and (3) everyday experience as embodied in language.

Distributed Choice and Addiction

In a paper on the nature of choice, Herrnstein & Prelec (1992) introduced an elementary yet illuminating classification scheme. They pointed out that some choices are distinct and unitary, whereas other choices are aggregates of "many smaller decisions, distributed over a period of time." In the first case, the decision has a relatively well-bounded endpoint; in the second case, a series of decisions establishes a disposition or state. For example, at a particular time and place, a consumer can buy an exercise machine. But to be physically fit, the consumer will have to repeatedly decide to use the exercise machine. The purchase requires but one decisive choice. In contrast, fitness reflects many choices, no one of which is decisive. Herrnstein and Prelec aptly called the second case "distributed choice." Its relevance to this paper is that addiction is an instance of distributed choice. One Friday night binge does not turn a social drinker into an alcoholic. Similarly, for the alcoholic, one weekend of sobriety does not turn him or her into a teetotaler. Rather, alcoholism and abstinence (or controlled drinking) are states that reflect the cumulative effects of many small decisions, and, as with fitness, no one decision is decisive.

The Implications of Distributed Choice and their Application to Addiction

The distinction between distributed and unitary choice is a byproduct of the ideas and experimental results associated with Herrnstein's matching law (Herrnstein 1970, 1990), especially the research that focused on the relationship between matching (defined below) and the economic theory that individuals make choices so as to maximize overall reward or utility. Scores of papers have been written on this issue (see Herrnstein 1990; Heyman 1982; Rachlin *et al.* 1988; Vaughan 1981), but the key ideas as they apply to addiction can be captured in a few paragraphs and a simple graph. (As distributed choice is a quantitative concept, it falls along a continuum with unitary choices. This issue has not been analyzed or investigated and is ignored in this paper.)

Distributed Choice and Consumption Dependent Changes in Value

When a good or activity is chosen or consumed repeatedly, there is the opportunity for its value to change as a function of how often it has been chosen or consumed. For instance, one of the properties of the substances and activities that maintain appetitive behavior (including addictive drugs) is that they either decrease (tolerance) or increase (sensitization) in value as they are consumed. Moreover, with addictive drugs, there are also consumption dependent changes in the value of competing non-drug activities. These interactions are both direct and indirect. Intoxication and withdrawal directly follow drug use and interfere with many conventional activities, thereby undermining their value. Social stigma and legal difficulties are less direct costs that also decrease the value of competing activities. For example, an arrest record decreases employment opportunities, and this, in turn, may increase the likelihood of drug use.

Consumption Dependent Changes in Value Create Ambiguous Environments

Consumption dependent changes in reward value are familiar. We all know about satiation, tolerance, and sensitization. But this familiarity has not led to an appreciation of the implications of these processes for theories of choice and more generally for the understanding of addiction and other self-destructive appetites. The key implication is ambiguity. In situations in which there are consumption dependent changes in reward value there is the strong likelihood that there will be two or more competing reward contingencies. For each contingency, a different response strategy maximizes reward. Thus, assuming reward maximization, consumption dependent changes in reward value create choice dilemmas, or, put slightly differently, they render the environment ambiguous as to which action is "best." An example is given in Figure 2. It shows the reward contingencies for several simple distributed choice experiments, including the one presented in this paper (see also Rachlin & Siegel 1994).

In both panels, the x-axis depicts the number of choices out of the last ten that were for option A, and the y-axis represents the reward value (or utility) associated with each choice. However, for the left and right panels, the domains for calculating value differ. In the left

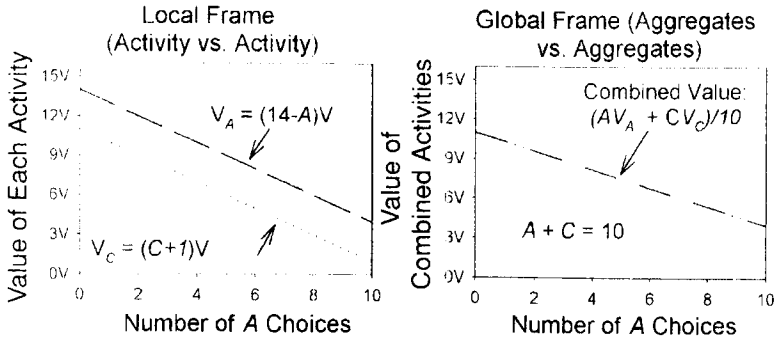

Figure 2: A simple distributed choice "experiment." On the x-axis is the number of choices for alternative A in the most recent 10 trials. On the y-axis in the left panel are the local reward rates. On the y-axis in the right panel is the overall rate of reinforcement, counting rewards from alternative A and alternative B. Note that the best choice in the left panel is A, whereas the best choice in the right panel is B. However, as described in the text, the reward functions in the left and right panels are the same. The different outcomes are due to different ways of framing the choices.

panel, reward value is calculated in terms of each activity taken separately. For example, the input for the value of activity A is restricted to behavior at A and similarly for activity C: $V_A = (14 - A)V$ and $V_C = (C + 1)V$. This seems a natural enough way to compare the value of competing activities. However, it is not the only possible way to approach the problem.

In the right panel, reward value is calculated in terms of each of the possible combinations of activities. That is, instead of comparing activity A to activity C, the right panel compares aggregates whose elements are A and C. For example, the y-axis shows the values of an aggregate of 4 As plus 6 Cs vs. an aggregate of 6 As and 4 Cs. This way of displaying the choices reflects the implicit, but usually overlooked, fact that from a distance two competing entities can be seen as elements of a combination, and if the relative frequencies of the elements change, then the characteristics of the overarching combinations change. Consequently, the domain for the y-axis entails all 11 possible combinations and is referred to as the "global" reward (or utility) rate. Put another way, the decision as to which option to choose in the left panel requires simply checking the height of each option at the moment of choice, whereas the decision as to which option to choose in the right panel requires checking the heights of all possible combinations of options yet encountered: $(V_{A+B} = (AV_A + CV_C)10)$.

The difference in the frame of reference turns out to be important. For example, given the choice rule "Always choose the best alternative," the two ways of organizing the choices yield exactly opposite courses of action. From the perspective of local reward rates, the value of activity A, V_A, is always larger than the value of the competing activity, V_C. Hence an individual with this frame of reference will always choose activity A. But A-choices drive down the future value of both options (A and C), and a series of 10 A choices will drive both local reward rates to their lowest possible level. Nevertheless, if the choice is framed in terms of the local rates, the predicted equilibrium point is exclusive preference for activity A. This is what the logic of "doing what is best" demands.

In the right panel the negative sloping diagonal line traces out the value of the eleven possible combinations of drug and non-drug choices. For example, the y-value that corresponds to the leftmost point on the x-axis gives the value of 0 As and 10 Cs, whereas the y-value that corresponds to the rightmost point on the x-axis, gives the value of 10 As and 0 Cs. Choice distributions with more C-activity choices are associated with higher global reward rates. Thus, from a global perspective, C choices should increase, reaching the limit of 10 C choices in a row. This is just the opposite of what the local frame of reference predicts. Also note that if choice is under the control of global reward rates, logic says choose the C activity even though the A activity provides a larger reward on the current trial (which is the frame of reference for local reward rates). For both panels of the graph, the mathematical functions relating value to choice are the same (e.g. $V_A = (14 - A)V$ and $V_C = (C + 1)V$, where $A + C = 10$), and the choice rule is the same: "Choose the option with the highest value." The difference is in how the options are framed.

The message of this example is that consumption dependent changes in reward value create situations in which there are conflicting behavioral outcomes as a function of how reward contingencies are framed. One implication of this point is that the contingencies of reward, the bedrock of behavioral analysis, are ambiguous. This observation will be returned to at the end of this paper.

But perhaps this conflict is only theoretical. If individuals steadfastly adhered to a local or global perspective, the ambiguities of alternative reward functions would remain latent and not a real problem. For instance, in economics textbooks, the universal assumption is that choices are framed in terms of the global reward (utility) rates. The textbook graphs invariably show consumers choosing between "market baskets" that each contain different combinations of the same sets of goods (e.g. Frank 1991; Nicholson 1985; Samuelson 1970). These graphs correspond to the right panel of Figure 2, and economics texts and papers do not discuss the possibility of alternative ways of framing choices. Like economists, psychologists have generally ignored the problem that reward contingencies are inherently ambiguous. Texts on learning and motivation assume one reward contingency per situation. And even Herrnstein & Prelec (1992) graphed reward functions in ways that hid the full extent of the potential dilemma. They always plot the local and global functions along the same x-axis. For example, imagine the two panels of Figure 2 collapsed along a single x-axis. This is misleading and does not seem sensible as each function applies to a different domain, as described earlier.

Implicit in the practices of economists and experimental psychologists is the assumption that frame of reference is static. Accordingly, the ambiguity demonstrated by Figure 2 is a theoretical but not a real problem. However, two rather elementary observations suggest that economists and psychologists are leading their students astray. First, everyday experience suggests that when individuals step back to analyze choice situations, they often adopt a global perspective. A good example of this is the analysis of choice in economics, as just described. In the texts consumers choose between aggregates of goods, called "market baskets." But, in laboratory studies of behavior that provide choices with direct consequences, the local framework predicts the pattern of choices. This generalization rests on logic and observation.

The logical implication of control by local reward rates is that choice proportions will approximate reward proportions. (See, for example, a paper by Herrnstein (1990) for a

proof of this statement.) This equality of choice and reward proportions is known as the "matching law," and literature reviews show that matching is the expected outcome in most laboratory experiments (e.g. Herrnstein 1990; Williams 1988). Moreover, matching occurs for all species yet tested (including humans) and for a wide array of laboratory and non-laboratory environments. In other words, it is highly likely that those who assume a global framework when donning their analytical hats switch to a local framework when facing actual choices. Or, put yet another way, the frame of reference for decision-making is dynamic and situation-dependent. This conclusion, as is shown next, leads to an account of individual differences in susceptibility to the addictive properties of drugs.

Distributive Choice and Addiction

The left side of Figure 2 describes Herrnstein & Prelec's (1992) primrose path theory of addiction. Let *A* stand for an addictive drug and let *C* stand for competing non-drug activities, and assume that the subject is governed by the local rates of reward (as experiments suggest is usually the case). For example, imagine that the left panel represents the reward contingencies for a heroin addict. The downward slopes reflect the observations that heroin use reduces its own value (e.g. tolerance) and also the value of competing conventional activities (e.g. the impact of intoxication on professional responsibilities). However, since the local reward rate for heroin never falls below that of the conventional competition, heroin has the higher reward value and is invariably chosen — the primrose path to addiction.

However, this is just half the story. Addiction also entails attempts to curtail drug use and periods, perhaps brief, of abstinence. The motivation for abstinence follows immediately from the right panel. If the heroin addict frames his or her choices in terms of the combined benefits and costs (e.g. the heroin addict life-style vs. a conventional life-style), the graph says that the preferred course of action is non-drug activity. Thus, the two panels of Figure 2 generate an addictive pattern of heroin use — periods of heavy use followed by abstinence, followed by periods of heavy use, etc. Also notice that the global framework sets the criterion for determining whether behavior is excessive. For instance, from the perspective of the global framework, heroin use is excessive because it persists yet lowers overall reward rates. In contrast, from the local framework, there is no level of heroin consumption that is excessive.

Conditions that Influence the Frame of Reference

According to this analysis, whether drug consumption persists or desists depends on the factors that establish the frame of reference. Restricting the discussion to laboratory studies, there are but three experiments that explicitly tested conditions that might influence whether choice was guided by the local or global reward values. Two experiments varied stimulus conditions, one with humans and the other with pigeons. In the human study, the temporal pattern of the inter-trial intervals influenced whether choices proceeded according to a local or global framework. When trials were presented in clusters of three, global choices increased (Kudadjie-Gyamfi & Rachlin 1996; Rachlin & Siegel 1994). When there

was no discernible overarching temporal pattern, local choices persisted. In the experiment with pigeons, the introduction of a stimulus (a light) increased the frequency of global choices (Heyman & Tanz 1995). When the pigeons responded so as to maximize reward, from the perspective of the global strategy, a light went on. The pigeons learned to respond so as to keep this light on. But in sessions in which the light was not available, the subjects responded according to the local rates of reward (as predicted by the matching law). The third study addressed drug use and frame of reference directly (Heyman & Dunn 2002). It tested the hypothesis that individual differences in decision making help explain individual differences in illicit drug use. It will be described in some detail, as it provides a test of the distributed choice approach to addiction.

An Experimental Test of the Hypothesis that Individual Differences in a Laboratory Distributed Choice Procedure Predicts Differences in Drug Use

Most people who experiment with illicit drugs do not go on to become regular users (Anthony & Helzer 1991; SAMHSA 2001), and recall that among those who do become regular users, there is wide variation in the duration of the disorder (see Section 1 of this paper and Heyman 2001). Epidemiological research shows that these differences are correlated with a variety of factors, including employment history, education level, the percentage of fat in the diet, the likelihood of using car seat belts, exercise patterns, divorce rate, delinquency, and the absence of additional psychiatric disorders (e.g. Abood & Conway 1994; Anthony & Helzer 1991; Hersch & Viscusi 1998; Robins & Murphy 1967). These correlates suggest a general and enduring approach to distributed choice problems. For instance, the likelihood of a car accident on any particular drive (say, going to the super market) is vanishingly small. Hence, from a local perspective, it is reasonable to suppose that the comfort of not wearing a seat belt has more value than wearing one (counting the effort of putting them on as a cost). However, from a global perspective, seat belts save lives. Thus, the correlation between seat belt wearing and not smoking (Hersch & Viscusi 1998) suggests the possibility of a general disposition for a more local or more global frame of reference. The experiment, described next, evaluated this line of thought. It tested whether individual differences in a laboratory distributed choice task predicted differences in illicit drug use.

The purpose of the experiment (Heyman & Dunn 2002) was to test whether performance in a simple, computer-based distributed choice game predicted drug use history. The game was played on a laptop computer. There were two choices. One button was the best choice from the perspective of the current trial (the local solution) and the other button was the best choice from the perspective of two or more trials (the global solution). As in the contingencies outlined in Figure 2, the button that was the best local solution decreased future benefits for both options and led to a lower overall rate of reward. In contrast, the button that corresponded to the global solution increased future benefits and led to a higher overall rate of reward. Also, as in Figure 2, the changes in reward value were a linear function of previous choices. However, the averaging window was not ten responses but just two. This is the smallest possible temporal horizon for a distributed choice problem.

The details of the contingency included the following relations. Each choice had two programmed consequences: it earned a nickel and it determined the length of the delay

until the next choice trial. Longer delays meant longer waits or dead time until the next choice trial, and since the session lasted a fixed period (five minutes), longer wait times also meant lower rates of reward. Thus, at each trial the local solution produced the shortest wait time on the current trial, but increased the wait times for both alternatives on the next trial. In contrast, the global solution produced the longest wait time for the current trial, but reduced wait times on the next trial. These wait times were not especially long, for example the longest was 14 seconds. However, they were noticeable, and in pilot tests subjects stated that they did not like to wait for the next trial to start.

Over the course of the experimental session, subjects played five different distributed choice games. In each game, the absolute inter-trial wait times were varied so that differences between the local and global solutions would vary. We did this to test the prediction that preference for the local solution would increase as the immediate advantage of the local solution increased. For example, in one game a switch from the global to the local solution always reduced the current wait time by 3.0 seconds, whereas in another game the decrease was twice as large, 6.0 seconds. If subjects preferred shorter wait times (as expected) then preference for the local solution should be greater in the 6.0-second game. Other features of the procedure included a battery of cognitive tests and questionnaires regarding drug use and social-economic status.

Subjects were selected with the goal of producing a wide range of drug use histories. Illicit drug users were recruited from the North Charles Center for the Addictions and McLean Hospital's Alcohol and Drug Abuse Treatment Unit. The North Charles clinic provides counseling services and methadone for individuals who are dependent on opiates (usually heroin). The McLean drug treatment clinic is primarily a non-residential day program that provides counseling and daily drug screening. For the McLean patients, the primary drug of abuse was usually cocaine. Control subjects were recruited by newspaper ads from neighborhoods near the methadone and McLean clinics. The majority of control and drug clinic subjects were white and had graduated high school.

The basic finding was that there was a correlation between drug use history and performance in the distributed choice game. Drug clinic subjects were more likely to favor the local solution and control subjects were more likely to favor the global solution.break Figure 3 shows these results on a game-by-game basis.

Details of the graph reveal that differences between clinic subjects and controls did not emerge straight off, but took time to develop. That is, they were a function of experience with the procedure. We also found that quantitative differences in the games made a difference. In games in which the immediate advantage of the local solution was larger, subjects were more likely to choose the local solution (e.g. Game 4), and in games in which the immediate advantage of the local solution was smaller, subjects were more likely to choose the global solution (e.g. Game 3).

Were the Differences in Game Performance Related to Differences in Drug History or the Correlates of Drug History?

The two groups differed in terms of several important demographic characteristics. Drug clinic subjects left school earlier, had lower incomes, and lower IQs (101 and 114,

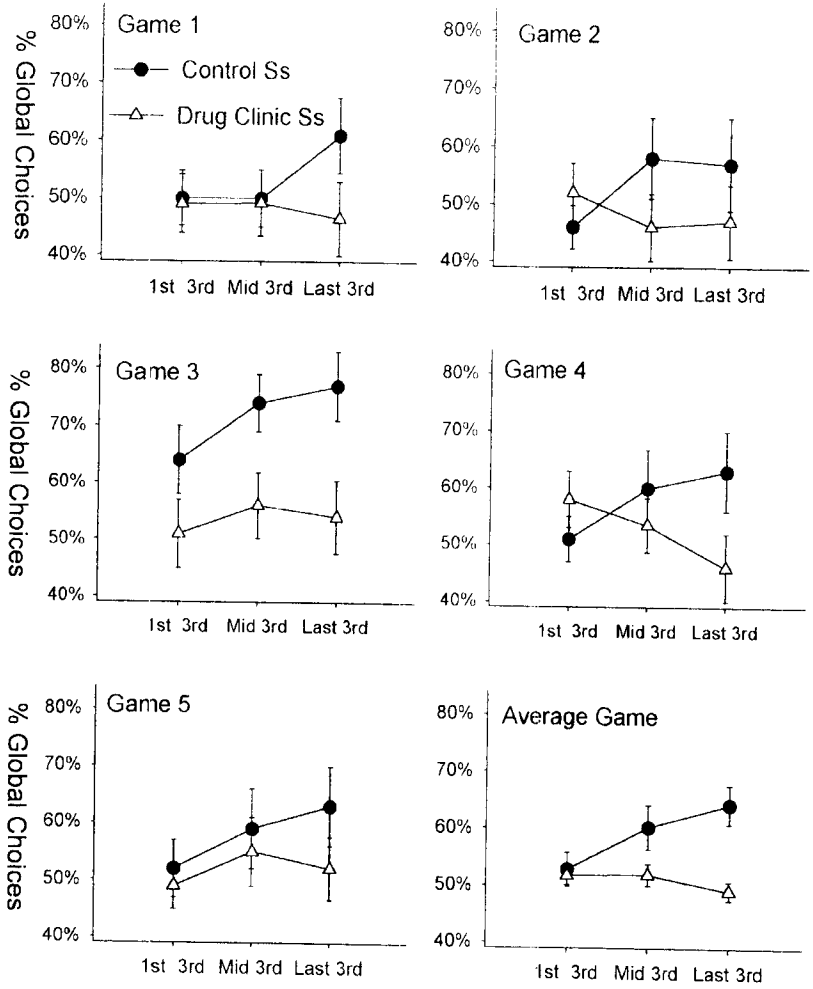

Figure 3: A summary of the distributed choice experiment (Heyman & Dunn 2002). On the x-axis session trials are divided into three consecutive blocks. Each block was composed of about 13–15 trials. On the y-axis is the percentage of global choices for each block of trials. The control subjects, filled circles, generally made more global choices than the drug clinic subjects (open triangles). In each of the five games, differences between control and drug clinic subjects emerged as a function of exposure to the game. The games differed in terms of the magnitude of the advantage of switching from the global to the local (see Heyman & Dunn 2002).

respectively). We used analysis of covariance to analytically control for education and IQ differences. The results showed that group differences in game performance did not depend on group differences in IQ or educational achievement. In other words, although there were group differences in academic achievement and its correlates, these differences

were not strongly correlated with performance in the distributed choice task. On the other hand, the correlations among the psychosocial variables, e.g. IQ, education, and income, were robust and significant. That is, the sample was not too small to detect robust correlates of IQ and education.

The experiment was based on the idea that differences in how individuals approached a laboratory distributed choice problem would be correlated with their history of illicit drug use. The assumptions leading to this hypothesis were that drug use is an example of a distributed choice dilemma, and that there are enduring individual differences in how people approach distributed choice problems. The experimental results supported the assumptions and hypothesis.

Limitations of the Experiment

This experiment is the first attempt to determine whether individual differences in distributed choice are related to individual differences in drug use. Consequently, the generality of the results are unexplored and confounding factors remain unanalyzed. Some of the issues that require attention include the following.

The drug clinic subjects had been using heroin and/or cocaine for an average of about 10 years. But as noted in the review of the addiction literature, there is much individual variation in the duration of addiction. Thus, it is possible that a bias toward local solutions in the computer game does not distinguish addicts from non-addicts, but instead distinguishes long-term drug users from the rest of the population, including those individuals who were addicted for a few years and then quit. Second, the drug users were recruited from treatment centers. Bob Schuster (personal communication, March 2002) suggested that treatment seeking might reflect a global perspective. Possibly, then, long-term drug users who were not in treatment might show even greater preferences for the local solution than the clinic subjects who participated in this study. In other words, the current results may underestimate the range of performances that would have been obtained had we tested a population of drug users who did not seek treatment. Third, the differences in performance may reflect a correlate of drug use, but not drug use itself. For example, drug users who seek treatment are about twice as likely to be afflicted with additional psychiatric disorders than drug users who do not seek treatment (e.g. Regier *et al.* 1990). Thus, preference for local solutions could be causally linked to psychiatric distress rather than to addiction. Finally, it is not known if preference for the local solution among illicit drug users is a consequence of drug use or reflects qualities that preceded and perhaps abetted long-term drug use. In sum, the experimental results point to new and interesting questions, which, if answered, would markedly increase our understanding of drug use and of decision-making.

A Graphic Test of the Claim that Competing Local and Global Equilibriums are a General Problem for Appetitive Behavior

According to the discussion that introduced the experiment, motivated behavior typically involves consumption or choice dependent changes in reward value and thus motivated

behavior typically entails the possibility of two or more ideal choice strategies, depending on the frame of reference. This next section of the paper explores this claim by means of graphs. In two graphs there are consumption dependent changes in reward value, and, for comparison, there is a graph in which reward value remains constant, independently of changes in consumption levels.

The three pairs of graphs show the predicted behavioral outcomes for the local and global frame of reference for three conditions. For the top and middle pair, the local rate of reward for alternative *A*, which is meant to represent an addictive-substance, decreases as a function of consumption (e.g. tolerance). In the bottom panel, both local reward rates are constant and unaffected by consumption. As before, the choice rule for the left panels is "select the local rate of reward that is best," whereas, the choice rule for the right panels is "select the distribution of activities that is best."

In the top panel, the reward value of *A* decreases rapidly as a function of consumption and then replenishes rapidly while the subject is engaged in behavior *B*. The mathematics are based on an analysis of a commonly used reward schedule (the variable-interval, Heyman 1979, 1982; Heyman & Luce 1979), but here it is assumed that reward value changes as a function of internal processes, such as satiation, tolerance, and deprivation. For example, during consumption bouts, satiation and tolerance lead to a decrease in reward value, and then when consumption comes to a halt, deprivation sets in, thereby driving reward value back to an initial asymptotic level.

Given these dynamics and the rate constants for the changes in value, the local rate perspective in the top pair of panels predicts a strong preference for the addictive substance (*A choices* = 76%), whereas the global rate perspective predicts an equilibrium point with an equally strong preference for the non-addictive substance (*B choices* = 77%). For someone whose preferences were controlled by the global framework, any preference for *A* in excess of 23% is excessive. Hence, a person under the control of the local contingencies is consuming the addictive substance at about three times the rate that they should. Conversely, from the perspective of the local framework, someone stuck in the global framework is favoring the smaller reward over the larger reward.

In the middle panel, the local and global equilibrium points differ but not by as much as in the top panel. The predicted outcomes are a 24% preference for the addictive substance when the frame of reference is local, and a 7% preference for the addictive substance when the frame of reference is global. The local and global solutions are closer together because the addictive substance replenishes and habituates more slowly (relative to the addictive substance in the top panel).

In the bottom panel, the local and global perspectives predict the same outcome so that ambiguity is not possible. Here, though, there are no consumption dependent changes in reward value.

The graphs suggest several new generalizations for cases in which there are consumption dependent decreases in reward value. (1) When the origins and slopes of the reward functions differ, the local and global equilibrium points will differ. In these cases, the local equilibrium will involve overindulgence in the appetite that has the higher initial value (at a consumption level of zero). (2) The magnitude of the difference between the local and global equilibriums varies systematically as a function of quantitative differences in the competing reward functions. (3) When the rates of tolerance are the same for both options,

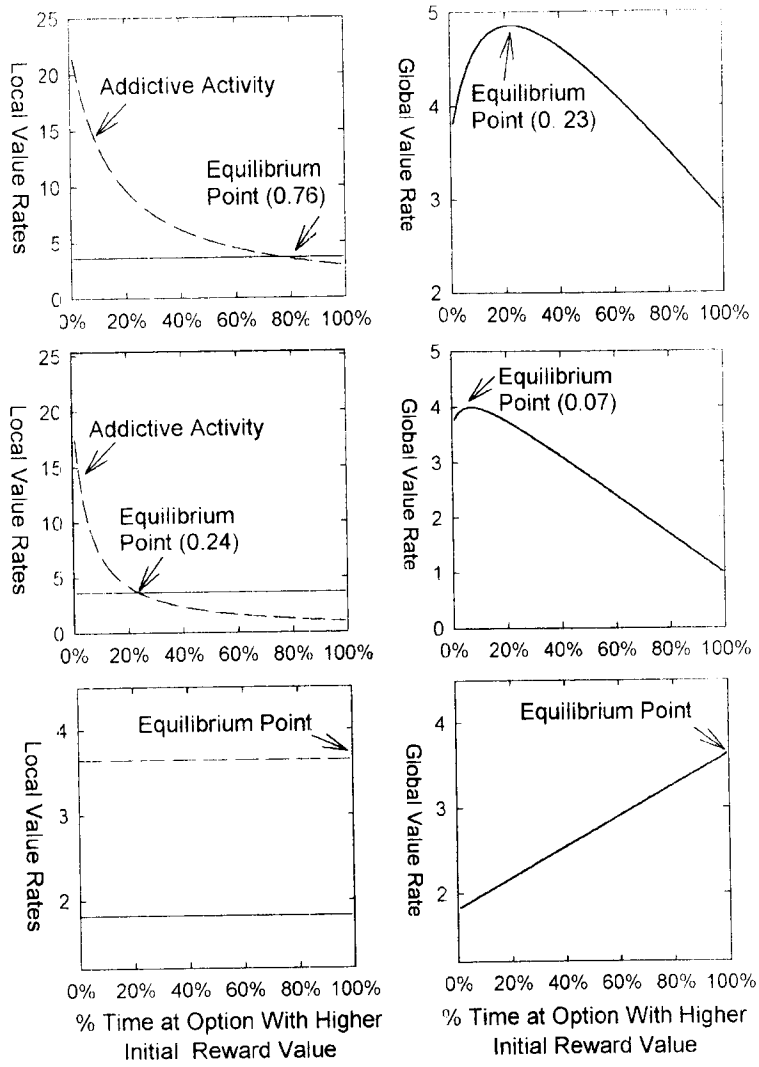

Figure 4: Each pair of panels shows the local and global reward rates for a choice between two alternatives. For the addictive activity, reward value decreased as a function of consumption, and replenished as a function of time spent in the competing activity. The rates of decline and replenishment mimic those associated with the reward dynamics of variable interval schedules (see, Heyman 1982 for the equations), but in this graph the curves identify tolerance and the loss of tolerance. In the top panel the rates of tolerance and loss of tolerance are three times greater than in the middle panel. In the bottom panel consumption does not alter reward rate and consequently the local and global frame of reference lead to the same pattern of choices: exclusive preference for the non-drug activity.

as in Figure 2, the relationship between the initial values will determine the relationship between the local and global equilibrium points.

If Consumption Dependent Changes in Reward Value Set the Stage for Addiction, Then Why are Some Substances Much More Likely to Become the Focus of an Addiction Than Others?

Although consumption dependent changes in reward value accompany virtually all appetitive activities, appetitive problems are much more likely with drugs than with other substances and activities. This outcome follows from the graphs. For instance, appetitive goals that reinforce a local perspective or that are accompanied by an especially large difference between the local equilibrium point and the global equilibrium point will be more problematic. Drugs that are recognized as addictive meet these conditions. Intoxication and other drug effects enhance the local perspective or create a more extreme local equilibrium. Some of the key observations that support these conclusions include the following points.

By definition, intoxication entails a state in which normal mental faculties are compromised. This should decrease the likelihood of a more global, encompassing perspective. In contrast, other rewards, even somewhat problematic ones, such as food, do not alter judgment. Various drug effects undermine conventional activities. For instance, intoxication and withdrawal interfere with many conventional responsibilities, thus making the heavy drug user less susceptible to the rewarding effects of conventional activities. This produces the downward sloping reward functions of Figures 2 and 4, and the greater the downward slope of the competing reward function, the greater the preference for the addictive activity, all else being equal. In contrast, many conventional goals increase the reward value of competing activities. For instance, success in one's profession often leads to outcomes, such as committee assignments and invitations to give talks that compete with professional achievement. Somewhat similarly, the satiating mechanisms associated with drug use are relatively weak in comparison to those associated with primary conventional rewards. Food makes you full and exercise tired. In contrast, there are no similar direct satiating mechanisms for most addictive drugs. To be sure, one can get full on alcohol, but with distilled drinks it is possible to become extremely intoxicated well before one is bloated on drink. Parallel contrasts between addictive drugs and conventional activities extend to withdrawal, and indirect effects such as stigma. However, without going into details, it should be clear that many of the behavioral effects of addictive drugs reinforce the choice dilemma that is posed by consumption dependent changes in reward value. Of course, for each drug the story will be somewhat different (e.g. cigarettes are addictive but not intoxicating), and a more complete account will include these details.

A Brief Evaluation of Other Choice Theories of Addiction

At this conference, presenters have focused on four choice models of addiction: hyperbolic discounting (Ainslie 1975; Rachlin & Green 1972), the Becker–Murphy economic analysis

(1990), Rachlin's substitution theory (1997), and Herrnstein & Prelec's primrose path theory (1992). Although these four approaches have rather different histories and focus on different aspects of behavior, they can be compared in terms of how well they correspond to the APA account of addiction presented at the beginning of this paper.

The hyperbolic model can explain impulsivity and ambivalence (e.g. Ainslie 1975). However, it does not have terms for representing consumption dependent changes in value. Consequently, it is really more appropriate for modeling one-shot, non-repeating choices, whereas, as emphasized in this paper, addiction entails a series of choices. Ainslie has dealt with this by considering the implications of a series of delayed choices, which he represents as a series of overlapping hyperbolic discount curves. However, in Ainslie's graphs reward value does not change as a function of consumption. This may be realistic for some goals but not for those involving drugs.

Becker & Murphy's "reward model" and Rachlin's substitution model share a number of common properties and will be discussed together. The equations explicitly represent consumption dependent changes in value. However, they assume that for each environment there is but one reward function. Consequently, these models entail no criterion for defining excessive consumption, and similarly there is no formal way of representing ambivalence and relapse. These are not really models of addiction. Rather, they are equations that generate extreme but unambivalent preferences. For example, an individual who behaved according to the rules of Rachlin's substitution theory or Becker & Murphy's rational choice model has no reason (within the boundaries of the model) to regret their behavior. In contrast, a person who comes under the control of global contingencies will regret choices made according to a local frame of reference.

This paper is an elaboration of Herrnstein & Prelec's distinction between unitary and distributed choices and their primrose path theory of addiction (the left panel of Figure 2). The ideas emphasized here, such as consumption-dependent changes in reward value, competing value functions, an ambiguous environment, frame of reference, and local and global choice equilibriums are concepts that have their basis in the distinction between unitary and distributed choices. However, these ideas are at best a framework for understanding addiction. They provide a general approach for understanding addiction. What is needed next is integration at the conceptual level with other theories that have sought to explain the persistence of drug use despite aversive consequences (e.g. Koob & LeMoal 2000; Robinson & Berridge 1993), and a more detailed account of how the specific inputs to drug use, such as cravings, intoxication, and changes in brain function, influence the decision to use or forgo drugs. Some of these inputs affect the relative value of the drug (e.g. craving) and others may affect decision-making itself (see, e.g. Grant *et al.* 2000; Volkow *et al.* 1991).

Common Misunderstandings of Choice-Based Analyses of Addiction

Choice-based accounts of addiction are easily misunderstood. The common criticisms are that they "amount to blaming the victim," "they ignore biology," and they are "contradicted by the success of pharmacological treatments." Although these criticisms reflect important and influential ideas about the nature of behavior and the ethics of treatment, they will only be touched on briefly in this paper.

Choice in a Deterministic World

If choice is part of the natural world, then the rationale for helping individuals make better choices must be similar to the rationale for ameliorating any natural process, as, say, when we search for a cure for cancer. In both cases, the goal is to help create a better world and to make a difference. However, there are differences, and in general the politics of correcting voluntary behavior will likely prove to be more complicated than the politics of non-voluntary disorders. For instance, it is often not clear as to which institutions are responsible for problems that involve choice. In the case of criminal acts there has been a long-standing debate as to whether criminals and society would be better served by rehabilitation or by punishment. A similar debate attends drug use. It is not clear whether punishment should play a role in "drug treatment," or whether the stigma that is associated with voluntary disorders plays a useful or harmful role. For instance, it is often overlooked that ex-addicts often point out that the desire to lead a more productive life that their parents and/or children could take pride in led them to quit using drugs (e.g. Jorquez 1983; Waldorf 1983).

A corollary of the idea that drug use in addicts is subject to the influence of its consequences is that in principle there exist circumstances such that quitting is not possible. For example, consider individuals with the following characteristics: (1) they can imagine that sobriety would help create a better overall life-style; but (2) they have no conventional alternatives that provide as much reward value in the short term as does drug intoxication; and (3) they have no techniques for escaping the local reward rates. Under these conditions, drug use persists — voluntarily but inescapably. However, this imagined situation might have no real life counterpart. Even heavy drug users are not intoxicated all the time, leaving a temporal window for strategies that will counter the influence of the drug. For instance, during periods of sobriety, the heroin addict or alcoholic can make arrangements that prevent contact with the drug (for other examples of these strategies, see Ainslie 1975).

The Emphasis on Choice Denies the Importance of Biology

The idea that drug use among those who are addicted is a matter of choice is often understood as a denial of the biological bases of addiction. However, if psychological processes are seen as a product of evolutionary processes, then there is no conflict. Put most generally, the difference between voluntary and involuntary behavior is in the "wiring." The biology of voluntary behavior allows for the influence of experience, and, in particular, it allows reward contingencies to shape behavior. In contrast, the biology of involuntary behavior does not permit the direct influence of reward contingencies. Thus, the question is not whether drugs alter the brain, but whether they alter the brain in ways that leave drug use immune to the influence of incentives, new information, and the various factors that normally influence choice. The review of the correlates of recovery presented in Section I of this paper shows that the answer to this question is "no."

Although a wide array of findings support the view that drug addicts remain voluntary drug users, even after decades of drug use (see, e.g. Jorquez 1983), the literature, including the experiment presented in this paper, shows that there are biases in decision making associated with drug use. Several researchers have presented data that suggest that these

biases are associated with the functioning of the prefrontal cortex (e.g. Everitt *et al.* 2001; Grant *et al.* 2000), and it is plausible that addictive drugs, especially stimulants, undermine the functioning of brain regions important in the cognitive functions that contribute to decision making (Volkow *et al.* 1991). Thus, the toxic effects of addictive drugs may promote further drug use by undermining cognition in ways that promote the control of local reward functions.

Psychopharmacological Correlates of Recovery

Clinical research shows that pharmacological treatments have increased the likelihood of successful and long-lasting abstinence in some heroin addicts and smokers (e.g. Dole & Nyswander 1967; Fiore *et al.* 1994). This is not discrepant with the conclusion that those who meet the criterion for addiction actually choose to continue to use drugs and could be persuaded to stop. Indeed, as the distinction between voluntary and involuntary behavior is fundamentally a matter of biology, voluntary behavior must be as subject to pharmacological manipulations as is involuntary behavior. In support of this point, a common property of successful biological treatments for addiction is that they directly or indirectly reduce the reward value of the drug. For example, methadone blocks the rush that accompanies heroin injections and nicotine replacement techniques (e.g. the patch) indirectly decrease the reward value of cigarettes by attenuating withdrawal symptoms. Given the relativity of reward, these treatments can be described as pharmacological methods for increasing the relative reward value of competing non-drug activities, which is the strategy employed in the successful incentive-based drug treatment programs (e.g. Higgins *et al.* 1994). In other words, clinicians have two general methods for altering the addict's preferences: behavioral and pharmacological.

The Future and Limits of Strictly Behavioral Accounts

The experimental results demonstrate that individual differences in decision making are correlated with individual differences in drug use. These differences reflect educational influences, basic cognitive processes, and the biological mechanisms that mediate cognition. These observations imply that at least some of the variance in decision-making is correlated with cognitive factors that are beyond the scrutiny of behavioral methods and with biological factors that are well beyond the influence of reward contingencies. That is, a strictly behavioral account of addiction is necessarily incomplete. What will be needed are techniques that can uncover individual differences in cognitive functioning and individual differences in the biology of voluntary behavior. Put another way, we now have a reasonable outline of the contingencies that apply to drug use, and it is time to make similar progress in the understanding of the factors that determine which contingencies come to control individual behavior. In particular, it would be especially useful and especially interesting to better understand why under similar circumstances some individuals excessively consume drugs, as predicted by the local reward rates, and others eschew or moderately consume drugs, as predicted by the global reward rates.

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