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CONCEPTUALIZING ADDICTION

Toward a behavioral economic understanding of drug dependence: delay discounting processes

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Abstract

Behavioral economics examines conditions that influence the consumption of commodities and provides several concepts that may be instrumental in understanding drug dependence. One such concept of significance is that of how delayed reinforcers are discounted by drug dependent individuals. Discounting of delayed reinforcers refers to the observation that the value of a delayed reinforcer is discounted (reduced in value or considered to be worth less) compared to the value of an immediate reinforcer. This paper examines how delay discounting may provide an explanation of both impulsivity and loss of control exhibited by the drug dependent. In so doing, the paper reviews economic models of delay discounting, the empirical literature on the discounting of delayed reinforcers by the drug dependent and the scientific literature on personality assessments of impulsivity among drug-dependent individuals. Finally, future directions for the study of discounting are discussed, including the study of loss of control and loss aversion among drug-dependent individuals, the relationship of discounting to both the behavioral economic measure of elasticity as well as to outcomes observed in clinical settings, and the relationship between impulsivity and psychological disorders other than drug dependence.

Introduction

Behavioral economics is 'the study of the allocation of behavior within a system of constraint' (Bickel, Green & Vuchinich 1995, p. 258) and examines conditions that influence the consumption of commodities, including drugs of dependence. Fundamental to this discussion, behavioral economics provides two concepts that may be instrumental in understanding drug dependence. The first concept is *elasticity of demand* that refers to the proportional change in consumption resulting from a proportional change in price (Bickel, Madden & Petry, 1998). *Inelastic consumption* refers to decreases in consumption that are proportionally less than increases in price, while *elastic consumption* refers to decreases in consumption that are proportionally greater than increases in price. Studies have demonstrated that cigarettes among cigarettes smokers and heroin among heroin-dependent individuals are less sensitive to price or more inelastic than other reinforcers (Petry & Bickel, 1998; Bickel & Madden, 1999; Jacobs & Bickel, 1999).

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The second concept of significance in understanding drug dependence is that of how delayed reinforcers are discounted. The concept of discounting is what this paper will address specifically. Discounting of delayed reinforcers refers to the observation that the value of a delayed reinforcer is discounted (reduced in value or considered to be worth less) compared to the value of an immediate reinforcer. Indeed, to the extent that most individuals would prefer a reinforcer now rather than that same reward later, the discounting of delayed reinforcers is intuitive (Kirby, 1997). This concept may play a central role in understanding two types of behavior that are important elements of drug dependence. First, the notion of discounting of delayed rewards provides an explanation of impulsivity, a type of behavior typically exhibited by the drug dependent. *Impulsivity* has been defined as the selection of a smaller more immediate reward over a larger more delayed reward (self-control has be defined as the opposite; Logue, 1988; see Evenden, 1999 for other definitions of impulsivity). Impulsive choices are made frequently by drug-dependent individuals. For example, drug-dependent individuals, as indicated by DSM-IV diagnostic criteria, often forgo or reduce occupational or recreational activities in order to use drugs. That is, drug-dependent individuals select relatively brief, but immediately available, bouts of drug intoxication or relief of transient withdrawal symptoms over a variety of prosocial, but often deferred, rewards (Madden *et al.*, 1997). Similarly, intravenous drug users, in the pursuit of immediate rewards, may opt to share hypodermic needles instead of deferring drug use until they have time to disinfect the needles or obtain clean needles (e.g. Schuster, 1988; Magura *et al.*, 1989; Normand, Vlahov & Moses, 1995). However, other than noting that drug-dependent individuals exhibit what may be deemed impulsive behavior (Logue, 1995), and that they score higher than controls on standardized measures of impulsivity (e.g. Alcock & Grace, 1988; Rosenthal *et al.*, 1990), research has only just begun to compare the prevalence or the degree of impulsivity across the different types of drug-dependence disorders. A central concern of this research is whether drug-dependent individuals are equally impulsive on all choices (consistent with an enduring trait or characteristic) or whether their choices vary with the type of reinforcer.

Secondly, another aspect of drug dependence, which we will argue is closely related to impulsivity, is referred to as 'loss of control'; that is, drug-dependent individuals may state a preference for the larger, more delayed reward, yet none the less later choose the smaller, more immediate reward, thus demonstrating a reversal in preference. The difference between loss of control as indicated here and impulsive behavior is that with loss of loss of control, preference changes, while with implusivity, preference may be consistently exhibited for the smaller reward. For example, drug-dependent individuals may express a strong preference for employment or participation in relationships with family and friends over drug use, yet a short time later they may use drugs instead of going to work or spending time with their family. Similarly, injection-drug users may express a strong preference for using clean needles, yet they will share needles when offered the opportunity to use drugs (e.g. Abdul-Quader *et al.*, 1987). Also (to the consternation of treatment providers), many drug-dependent individuals participate voluntarily in outpatient drug-treatment programs, but continue to abuse drugs (Milby, 1988). Some of these patients declare a preference for not using drugs upon entering treatment, but none the less relapse to drug use at some later point in treatment, indicating a reversal in preference. Some attempts have been made to understand loss of control scientifically (e.g. Tiffany, 1990), but those efforts are far from definitive, and to our knowledge no single approach has been offered to account for both loss of control and impulsivity.

In this paper, we propose to examine the discounting of delayed reinforcers in order to understand the impulsivity and loss of control exhibited by the drug dependent. To accomplish this purpose, we will (1) review economic models of delay discounting, (2) review the empirical literature on the discounting of delayed reinforcers in the drug dependent, (3) review the empirical literature on personality assessments of impulsivity in the drug-dependent, and (4) discuss future directions for the study of discounting, including the study of loss of control and loss aversion among drug-dependent individuals, the relationship of discounting to both the behavioral economic measure of elasticity as well as to outcomes observed in clinical settings and the relationship between

impulsivity and psychological disorders other than drug dependence.

Economic models of delay discounting

Among the most developed accounts of delay discounting are those provided by economics (e.g. Lancaster, 1963; Meyer, 1976; Fishburn & Rubinstein, 1982). Economic models, including the rational theory of addiction (Becker & Murphy, 1988), assume that delayed rewards are discounted *exponentially*; that is, for each unit of time that constitutes the delay to delivery, the value of a reward decreases (or is discounted) by a fixed proportion (Kirby, 1997). *Exponential discounting* may explain impulsive behavior by assuming a large discounting rate (e.g. temporal myopia). However, under most conditions such discounting predicts that an individual's preference should remain constant over time and will not reverse (Ainslie & Haslam, 1992). Therefore, economic approaches, assuming rational behavior, do not always account for the preference reversals that are evident in the behavior of drug-dependent individuals (i.e. loss of control). Additionally, exponential discounting has not been empirically supported by behavioral research conducted in nonhuman and human subjects. Instead, these studies demonstrate that delay discounting is hyperbolic (Ainslie, 1992; Ainslie & Haslam, 1992).

Hyperbolic discounting refers to the devaluation of delayed rewards proportional to their delay (Ainslie, 1992); that is, for each unit of time that constitutes the delay to delivery, the reward's present value decreases by an increasingly smaller proportion (Kirby, 1997). Hyperbolic discounting is illustrated by the hypothetical data displayed in Fig. 1. Figure 1 shows the value of two rewards plotted as a function of time to those rewards. One reward is a sooner smaller magnitude reward of $100, and the other a delayed, larger-magnitude reward of $200. Note that these two rewards are separated by 2 years. The two curves indicate the present value of the rewards as a function of time to their availability. Importantly, they are hyperbolic in shape and cross each other. Thus, in this example, $200 has greater value to a subject than $100 (e.g. self-controlled choice) at time-point 1 that is 6 years prior to the availability of $100. However, as the $100 becomes more immediately available at time-point 2, the value of the rewards reverse and the $100 has greater value (i.e. impulsive choice). This reversal in preference occurs even though the objective magnitude of the rewards ($100 vs. $200) and the time between their availability (2 years) remains constant. Hyperbolic discounting of delayed rewards suggests that when the events in question are temporally distant, choices are made that could be referred to as 'self-controlled', 'rational' and consistent with the objective magnitude of the rewards (e.g. 'I want to work, be with my family, and not use drugs'). However, as the smaller-sooner reward becomes available, preference reverses resulting in a choice that could be described as 'impulsive', 'irrational' and inconsistent with both the objective magnitude of the rewards and the prior expressed preference. Note that this account of preference reversals could potentially be criticized to result from experimenter-induced demand characteristics or simply reflect verbal behavior as opposed to actual choices. However, preference reversals have been demonstrated frequently in analogous situations with non-humans (e.g. Green *et al.*, 1981). None the less, hyperbolic discounting appears to account for both loss of control and impulsive behavior.

Studies examining delay discounting in human subjects typically employ procedures similar to those used in psychophysical experiments (Richards *et al.*, 1997). Psychophysical procedures typically present a participant with a standard stimulus and then also present them with a stimulus that is adjusted until the two stimuli are considered equivalent by the participant (Stevens, 1975). Similarly, procedures used in delay discounting experiments present subjects with a choice between a standard larger-later reward (e.g., $1000 delivered in 1 year) and an immediate reward whose magnitude is adjusted until the participant subjectively considers the two rewards to be of approximately equal worth (e.g. Green, Fry & Myerson, 1994). This point of equivalence is the *indifference point* for that particular delay interval. When indifference points are obtained for a variety of delays, then an *indifference curve* may be plotted (similar to those plotted in Fig. 1). The importance of indifference curves is that they permit the shape of the function to be empirically determined, and the rate that delayed rewards are discounted to be empirically derived.

The discounting rate can be calculated by

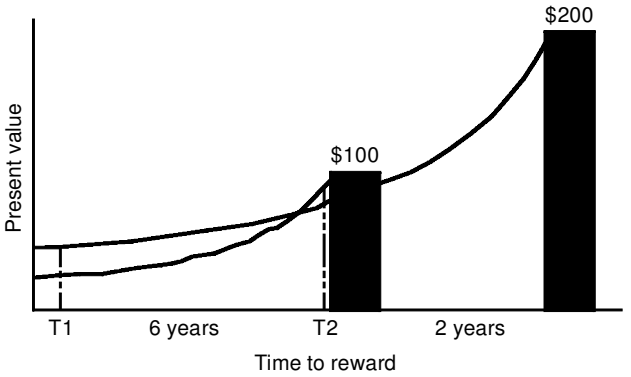

Figure 1. *Present value of delayed rewards (i.e. the value of the reward in terms of money presently available) as a function of increasing delays to reward delivery. Discounting functions are hyperbolic in shape, which predict preference reversals from T1 to T2.*

application of the following hyperbolic equation developed by Mazur (1987):

$$v_d = \frac{V}{(1 + kd)}$$

In the above equation, v_d is the present discounted value of a delayed reward (i.e. the indifference point), V is the objective value of the delayed reward, k is an empirically derived constant proportional to the degree of delay discounting (i.e. discounting rate) and d is delay duration. Empirically determined indifference curves have been demonstrated to be hyperbolic and the hyperbolic equation has been found to model the discounting function accurately (accounting for more than 85% of the variance) when food and water are used with non-humans (Richards *et al.*, 1997) and real and hypothetical money are used with humans (Rachlin, Raineri & Cross, 1991; Green *et al.*, 1994; Kirby & Herrnstein, 1995; Myerson & Green, 1995; Kirby, 1997; Madden *et al.*, 1997; Richards *et al.*, 1999).

Delay discounting and drug dependence: review of empirical studies

We are aware of 10 studies that have explored the relationship between delay discounting and drug dependence. Two studies examined delay discounting of hypothetical monetary rewards in participants who were heavy vs. light drinkers, and problem vs. light drinkers (Vuchinich & Simpson, 1998). The heavy and problem drinkers were college students not in treatment. Separate indifference curves were derived from choices made by problem, heavy and light drinkers. Relative to the light drinkers, heavy and problem drinkers showed higher rates of discounting; that is, heavy and problem drinkers devalued delayed rewards more than did light drinkers. Moreover, the hyperbolic equation described above accounted for significantly more variance than the exponential function developed via economic approaches. In another study (Ainslie & Haendel, 1983) the delay discounting of a heterogeneous group of substance-abusing inpatients vs. employees of that inpatient unit were examined. Results indicated that the substance abusers discounted hypothetical monetary rewards to a greater extent did than employees.

In two additional studies (Madden, Bickel & Jacobs, 1999; Madden *et al.*, 1997), delay discounting by opioid-dependent patients in treatment was compared to that of community volunteer controls matched on age, gender, education, income and IQ. In these studies, participants chose between hypothetical monetary rewards available immediately or following a delay. Delayed rewards were $1000, and the immediate-reward amount was adjusted until choices reflected indifference. This process was repeated at each of seven delays (1 week to 25 years). The opioid-dependent participants were also given a second series of choices between immediate and delayed heroin, using the same procedures (the amount of heroin was adjusted using street values, such that the dollar amount of the delayed heroin was $1000). Across the

opioid-dependent and control participants, the hyperbolic discounting equation accounted for between 80% and 99% of the variance. As is evidenced in Fig. 2 (Madden *et al.*, 1997), the rate of discounting monetary rewards was significantly greater for the opioid-dependent than for normal participants. For example, to reduce the subjective value of $1000 by 60% required a delay of 1 year for the opioid-dependents and a delay of 5 years for the controls (a five-fold difference). Within the opioid-dependent sample, the discounting of heroin was significantly greater than the discounting of money. Specifically, heroin lost 60% of its value at a 1-week delay (a 52-fold difference compared to monetary choices). These findings demonstrate that the magnitude of discounting is not invariant, but rather is dependent upon the type of rewards available. Moreover, these results demonstrate that the procedures used to estimate delay discounting could be modified to use drugs as a reward.

These observed differences between opioid-dependent individuals and matched controls in rates of discounting delayed rewards were also evident in the sixth study, in which real rewards were available to participants (Kirby, Petry & Bickel, 1999). In this study, opioid-dependent people and community controls (matched on several demographic characteristics, including age, education and IQ) made choices between smaller immediate and larger delayed monetary rewards, in which they had a 1 in 6 chance of winning a reward they selected on a randomly chosen trial. Results indicated that the delay discounting rates of heroin-dependent individuals were about twice that of control participants.

Another study (Odum *et al.*, 2000) investigated whether risky needle-sharing behavior among substance abusers may be related to the discounting of the value of delayed outcomes. In this study, the discounting rates of delayed hypothetical monetary and heroin outcomes were compared among in-treatment opioid-dependent individuals who agreed that they would share a needle with a friend when injecting drugs in a scenario where a sterile needle was not available and those that indicated they would not share a needle in such a scenario. As in previous studies all participants, irrespective of group, discounted delayed heroin more steeply than delayed money. Additionally, those participants who indicated that they would share a needle discounted delayed monetary rewards more steeply than those who indicated that they were unwilling to share a needle. Indeed, $1000 lost 50% of its value after a delay of 5 years and 1 month for the non-sharing and sharing groups, respectively. These results suggest that extreme delay discounting may be indicative of potential problems for both substance abuse and risky injection practices among injection drug users.

Another study (Petry & Casarella, 1999) assessed discounting of delayed monetary rewards by problem gambling substance abusers compared to that of non-problem gambling substance abusers. Discounting of delayed rewards of both of these groups of substance abusers was also compared to that of non-substance abusing control participants. Substance abusers discounted delayed monetary rewards at higher rates than non-substance abusers. Additionally, problem-gambling substance abusers discounted delayed monetary rewards at higher rates than non-problem gambling substance abusers. Indeed, discounting rates of substance abusers with problem gambling were over three times greater than discounting rates of their non-problem gambling substance-abusing counterparts. Thus, substance abuse and comorbid gambling problems interacted additively in affecting discount rates.

Two additional studies examined impulsivity among cigarette smokers. In the first of these studies (Mitchell, 1999), impulsivity among regular and never smokers was examined using the delay discounting procedure in which participants chose between small, immediate and large delayed rewards. At the end of the experiment, participants had the opportunity to win one randomly selected reward that they chose during the discounting task. Participants also completed several additional personality and behavioral measures of impulsivity. Results indicated that smokers were significantly more impulsive than never smokers on the delay discounting and other behavioral tasks, as well as the majority of the personality scales. In a second, related study (Bickel, Odum & Madden, 1999), discounting of delayed hypothetical monetary rewards was examined among current, never and ex-smokers of cigarettes. Current smokers discounted the value of delayed cigarettes more steeply than delayed monetary rewards, suggesting that cigarette smoking is characterized by a rapid loss of subjective value for delayed outcomes, particularly

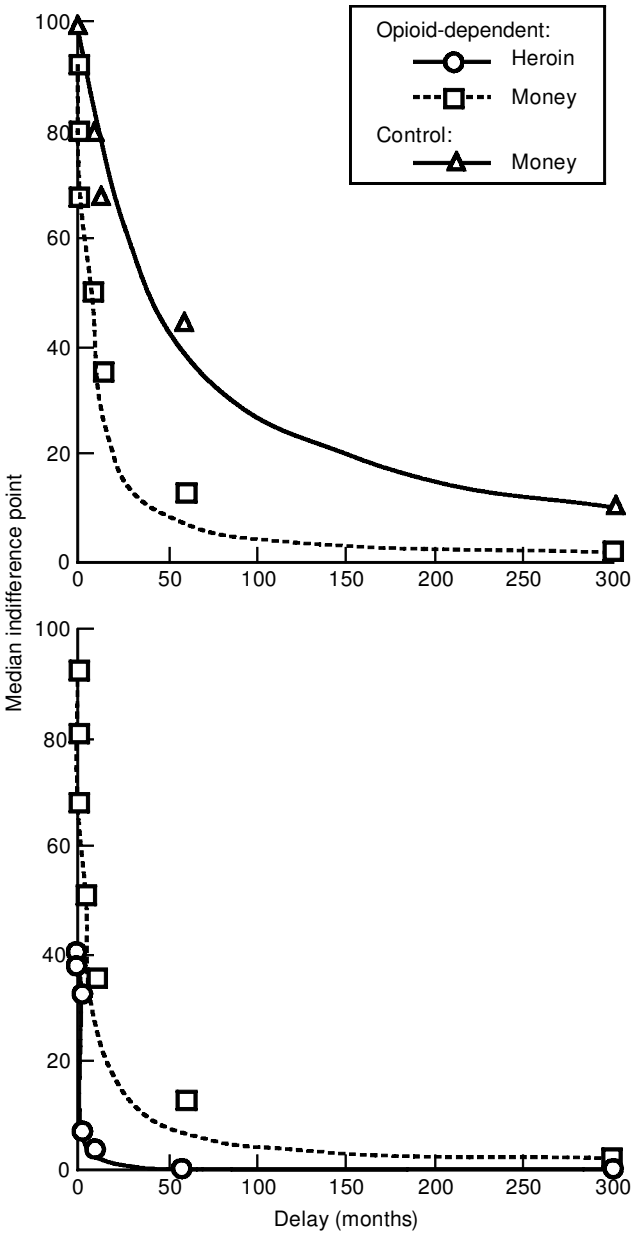

Figure 2. *Median indifference points between large delayed and small immediate heroin and monetary rewards. Opioid-dependent and control participants' monetary choice data are shown at the top, whereas the bottom shows opioid-dependent participants' monetary and heroin choice data. Indifference points reflect the present value of the larger, more delayed rewards (i.e. the value of the delayed rewards in immediate-reward units). So that heroin and monetary rewards could be compared on a common axis, the vertical axis shows the percentage of the large delayed reward (this transformation did not affect the delay-discounting parameter estimates). Reprinted with permission from Madden,* et al., *1997.*

for the drug of dependence. These findings demonstrate further that the magnitude of discounting is dependent upon the type of rewards available. Additionally, current smokers discounted the value of delayed money more than individuals in the other two groups; however,

never- and ex-smokers' discounting rates did not significantly differ from one another. The similar discounting rates observed with never- and ex-smokers suggest that cigarette smoking may involve a reversible increase in discounting rates.

Concerns about using hypothetical rewards

One potential shortcoming for many of the studies described above is that they used hypothetical rewards. As a result, perhaps the results are spurious and not representative of choices made between actual outcomes. This concern is similar to ones that may pertain to measures of drug craving or other phenomena that rely exclusively on self-reports; however, delay discounting procedures which use hypothetical rewards and delays differ on one important factor. Namely, unlike other self-report measures, a single equation has been shown to accurately measure indifference curves with hypothetical and actual outcomes. If the results from studies with hypothetical rewards were completely spurious, one would not expect the hyperbolic equation to account for the results obtained (e.g. Mazur, 1987; Myerson & Green, 1995). Overall, results from studies with humans using hypothetical rewards are quantitatively similar to the delay discounting functions obtained when humans and nonhumans choose between actual immediate and delayed rewards (Mazur, 1987).

A recent review suggests that differences between actual and hypothetical rewards may be one of degree rather than form of the discounting function (Kirby, 1997). This review compared discounting rates derived from the hyperbolic equation across human studies that used actual or hypothetical rewards. Two differences were noted: first, the dollar amounts used in studies with actual money were less than studies using hypothetical monetary rewards. Secondly, the discount rates were higher with actual than with hypothetical rewards. Thus, whether differences in the discount rates are due to the magnitudes of the rewards employed, or to use of actual vs. hypothetical outcomes, cannot be discerned. Nonetheless, the review by Kirby suggests that these procedures appear to measure the same process, but may be biased towards less discounting when hypothetical outcomes are used relative to actual outcomes (i.e. actual outcomes were discounted more). These results are important because they indicate that studies that use hypothetical rewards can be expected to provide an estimate of discounting, though the discount rate may be an underestimate. The extent of such a bias could be clarified by a study comparing delay discounting for actual and hypothetical rewards within subjects.

In general, although choice behavior that is assessed in simulation paradigms which employ hypothetical rewards and delays may not be a perfect substitute for observations of behavior in actual situations, such research may provide a useful supplement to laboratory-based research. First, the simulation procedures used to assess temporal discounting have been based on laboratory procedures, thus allowing the results of the simulations to be interpreted using terms and concepts that have been empirically validated in laboratory settings. Additionally, the use of hypothetical rewards and delays may enable the assessment of choice behavior in scenarios not amenable to study using actual rewards and delays. For example, the use of money in laboratory settings with humans is usually confined to a small range of values (e.g. cents or dollars) and can not practically cover higher values (e.g. hundreds or thousands of dollars) which may be employed in simulated settings and which may meaningfully impact choice behavior. Additionally, laboratory research enables the study of choice behavior over relatively short periods of time (e.g. minutes or hours) but can not assess such behavior over long time intervals (e.g. days, years or decades), as is possible when simulation procedures are used. Thus, the use of hypothetical rewards and delays enables the study of choice behavior in a time- and cost-effective manner relative to studies using actual rewards, which may be logistically difficult or impossible to conduct under certain conditions.

Questionnaire measures of impulsivity

Typically, impulsivity in drug-dependent individuals has been measured with methods other than those used in delay discounting studies. These methods may be broadly termed 'personality assessments' and include such instruments as the Eysenck Impulsivity Questionnaire, the Eysenck Impulsiveness–Venturesomeness–Empathy' questionnaire, the Barratt Impulsiveness Scale, the Stanford Time Perception Inventory and the Future Time Perspective.

The Eysenck Impulsivity Questionnaire is one

subscale of the Eysenck Personality questionnaire (Eysenck & Eysenck, 1978). Previous research has shown that medical students who reported less use of cannabis, alcohol or other drugs were less impulsive on this measure than medical students who reported more drug use (Golding & Cornish, 1987). Hospitalized male and female substance users were shown to be more impulsive than historical controls used to standardize the scale (Rosenthal *et al.*, 1990). Moreover, in that same report, cocaine users were significantly more impulsive than alcohol or opioid users. Additionally, inpatient substance abusers were found to score significantly higher on this measure relative to inpatient control participants (King *et al.*, 1990). In our laboratory, opioid-dependent patients were more impulsive on this scale than matched controls (Madden *et al.*, 1997), and smokers were shown to be significantly more impulsive than never-smokers (Mitchell, 1999) and ex-smokers (Bickel *et al.*, 1999).

The Eysenck 'Impulsiveness–Venturesomeness–Empathy' questionnaire (IVE; Eysenck & Eysenck, 1978; Eysenck & McGurk, 1980) contains three subscales: (1) IMP which measures impulsiveness as defined as a failure to evaluate risk, (2) VENT which measures behavior in which risk is perceived by an individual but yet accepted by the individual, and (3) EMP which measures an individual's ability to express empathy. Prior research has demonstrated that opioid-dependent individuals reliably score higher on the IMP and VENT subscales relative to matched control individuals, although scores between the two groups are similar on the EMP subscale (Kirby *et al.*, 1999).

The Barratt Impulsiveness Scale (BIS; Barratt, 1985; Patton *et al.*, 1995) includes three subscales, each of which are assumed to measure three subtraits of impulsiveness. The three subscales assess 'nonplanning', 'cognitive impulsiveness' and 'motor impulsiveness', respectively. Opioid-dependent individuals have been shown to have consistently higher scores on all three subscales of the BIS relative to matched control individuals (Kirby *et al.*, 1999). Additionally, smokers have been found to be more impulsive on many items on the BIS relative to those who have never smoked (Mitchell, 1999). The three subscales have recently been revised to assess acting without thinking, careful planning, and 'future-oriented coping stability', respectively (Barratt, 1994); however, to our knowledge, the revised scale has not been employed with drug-dependent populations.

The Stanford Time Perception Inventory (STPI; Zimbardo, 1992) has four subscales: Future-Orientation, Past Orientation, Present-Hedonism, and Present-Fatalism. To our knowledge, only one study compared opioid-dependent individuals and controls on this measure (Petry, Bickel & Arnett, 1998). Control subjects scored significantly higher on the Future-Orientation scale compared to opioid-dependent participants, and the latter scored significantly higher on the Present Hedonism scale and on the Present Fatalism scale than normal controls. The two groups did not differ on the Past-Orientation scale.

The Future Time-Perspective (FTP) measures individuals' ability to conceptualize future personal events (Wallace, 1956). Central to these tasks are estimates of individuals' personal events (e.g. number of years until being married) and the ordering of those events. One study reported that alcoholics had significantly shortened FTPs relative to matched control participants (Murphy & DeWolfe, 1986). A study of opioid-dependent individuals reported significantly shorter future-time perspectives than high-school students, who served as controls (Manganiello, 1978), but the lack of an appropriate control group limits conclusions drawn from this study. Alvos, Gregson & Ross (1993) found that treated drug users demonstrated significantly longer FTP compared to currently injecting heroin addicts. Finally, we compared 34 opioid-dependent individuals with 59 non-drug controls matched on sex, age, years of education and IQ (Petry, Bickel & Arnett, 1998). Consistent with previous studies, we found opioid-dependent individuals in treatment had significantly shorter FTPs than controls. To illustrate the magnitude of this effect, consider the responses to one of the FTP tasks where subjects are asked to finish a story that began 'After awakening, Bill began to think about his future. In general, he expected to …' The mean response of opioid-dependent participants referred to a future of 9 days, while the mean responses of controls referred to a future of 4.5 years.

Although some of these studies that employed personality assessments of impulsivity with drug-dependent populations used less than optimal control groups, they provide none the less evi-

dence of impulsivity among drug-dependent individuals. Additionally, in the few studies where both personality assessments and delay discounting procedures have been employed, impulsivity scores on several personality assessments have been shown to be positively correlated with discounting parameter scores (k) (Madden *et al.*, 1997; Kirby *et al.*, 1999; Richards *et al.*, 1999), and the magnitude of these correlations are typically within the range of correlations that are usually reported between behavioral and self-report measures of impulsivity (Gerbing, Ahadi & Patton, 1987; Logan, Schachar & Tannock, 1997). The use of multiple assessments of impulsivity, including delay discounting procedures in future research efforts, will enable the determination of the concordance between, and utility of, these various measures. Moreover, use of delay discounting procedures as well as personality assessments of impulsivity may increase our understanding of impulsivity, by enabling an experimental analysis of the variables affecting discounting as well as a description of the behavioral process that results in impulsivity and loss of control. By identifying such behavioral processes, delay discounting may also suggest potential interventions for modifying impulsivity and self-control failure. Additionally, results from the discounting task may be used as an outcome measure to assess the efficacy of interventions designed to promote self-control training.

Future directions for the study of discounting

Potential future directions for the study of the discounting of delayed reinforcers include exploring (1) two interesting phenomena closely related to discounting, (2) the relationship of discounting to both the behavioral economic measure of elasticity as well as to outcomes observed in clinical settings and (3) the relation between impulsivity and other psychological disorders. We will consider each in turn.

Two phenomena related to discounting

The first phenomenon related to discounting that we will discuss is preference reversal. *Preference reversal*, as we reviewed briefly above, refers to a shift in preferences over time from the larger delayed reward to a smaller more immediate reward (and vice versa) and is predicted by crossing hyperbolic discounting curves. Preference reversals have been demonstrated with non-humans and humans selecting among a variety of reinforcers (see Ainslie & Haslam, 1992, for a review). For example, preference reversals have been observed in non-humans selecting between different amounts of food (Rachlin & Green, 1972; Navarick & Fantino, 1976; Ainslie & Herrnstein, 1981; Green *et al.*, 1981), in humans choosing between hypothetical amounts of money (Thaler, 1981), in undergraduates selecting different durations of playing a video game (Miller & Navarick, 1984), or different durations of turning off a noxious noise (Solnick *et al.*, 1980; Navarick, 1982), and in women deciding upon anesthesia for childbirth (Christensen-Szalanski, 1984). In each case, as the events became temporally proximal, preferences reversed. Preference reversals demonstrate that preferences stated earlier, when outcomes are remote, may be inconsistent with later preferences, when the outcomes are more immediately available.

Although preference reversals appear related to the loss of control phenomenon, only one study has examined this in substance abusers. Ainslie & Haendel (1983) examined preference reversals for money in a heterogeneous group of substance-abusing inpatients. Subjects could choose to receive money now or receive 25% more money by waiting 3 additional days. They were also given the identical choice with a 7-day wait added to both alternatives. Thus, the objective magnitude of the rewards, and the delay between them (3 days), were constant. Thirteen of the 18 subjects demonstrated preference reversals. Whether the proportion of subjects reversing their preferences is more or less than would be observed in matched controls, however, is unknown.

The second phenomenon related to hyperbolic discounting of delayed rewards is referred to as the *sign effect.* The sign effect refers to the observation that rewards are discounted at a higher rate than are comparably valued losses (e.g. Thaler, 1981); that is, the value of a $10 reward delivered in 1 week is discounted more than is the value of a $10 fine collected in 1 week. This loss aversion phenomenon where gains are discounted more than losses has been empirically demonstrated in normal human populations (MacKeigan *et al.*, 1993; Chapman, 1996). However, exceptions have been reported; that is, some studies have reported that losses are discounted more so than gains (Shelley, 1994).

Some evidence suggests that alcohol- and opioid-dependent individuals are insensitive to immediate small magnitude punishers (e.g. Petry *et al.*, 1998). If drug-dependent individuals were insensitive to small immediate losses, or showed less of a sign effect than normals, then the plethora of social and behavioral problems evident in some forms of drug dependence may be understood better (e.g. family, occupational, legal and health problems of opioid-dependent patients). For example, these numerous problems may result from drug-dependent individuals preferring not to address immediate problems until they become much larger at a later time. Moreover, if lower sensitivity to immediate smaller-punishers is combined with a preference for smaller, more-immediate gains, this response style could result in a number of self-selected problems and may have important implications for understanding why drug-dependent individuals often engage in a plethora of risky behavior.

The relationship of discounting to other behavioral economic measures and clinical outcomes

Other potential important directions in research on delay discounting include understanding its relationship to elasticity of demand and whether it may be meaningfully related to clinical outcomes that characterize the phenomenon of drug dependence.

Consumption of the drug of dependence by drug-dependent individuals has been shown in a limited number of studies to be more inelastic (less sensitive to price) relative to other commodities (Petry & Bickel, 1998; Bickel & Madden, 1999; Jacobs & Bickel, 1999). In the studies reviewed above, the drug of dependence also tended to be discounted to a greater extent than other commodities. These findings raise the question of whether these two characteristics of inelasticity of demand and extreme discounting may contribute to a behavioral definition of drug dependence; that is, perhaps, drug dependence could be considered as a joint function of (1) being willing to pay high prices for the drug relative to other reinforcers and (2) strongly discounting the drug reinforcer (the drug is preferred immediately). Indeed, discounting and elasticity could be thought to interact in the following way: if a particular commodity, a drug, is discounted to a large extent, then by definition, there is limited inter-temporal substitution between present and future consumption. With limited inter-temporal substitution, then the present source of drug is functionally the only source of drug. If the present source of drug is functionally (because of discounting) the only source of drug, then higher prices should be paid to obtain that commodity.

If this speculation were to be confirmed empirically, then it would provide a reinforcement-based account of drug abuse that is not open to the same criticism that is often raised against a reinforcement approach; namely, that reinforcement is not a sufficient condition to account of drug dependence because a person for whom alcohol is reinforcing (e.g. likes to drink a few beers at the weekend) cannot on that basis be distinguished from an individual who finds alcohol reinforcing and meets DSM-IV criteria for alcoholism. If these two behavioral economic factors contribute to drug dependence, then this more elaborated reinforcement model of drug dependence may be able to meaningfully distinguish the recreational drug user from the drug dependent user based on the individualís elasticity of demand for the drug and discounting of the drug. However, more research will be needed to examine the nature of the relationship between these two measures elasticity of demand and discounting of delayed reinforcers in individuals who are drug dependent.

In considering the discounting of delayed reinforcers, an important concern is whether this measure is related to observed clinical outcomes for drug dependent individuals. As reviewed here, we know that individuals with alcohol problems, opioid-dependent individuals and cigarettes smokers discount delayed rewards more than matched control participants; however, we do not know whether (1) children/adolescents who discount delayed rewards more are more likely to become drug dependent relative to those who discount delayed rewards to a lesser extent, (2) discounting predicts the effects of treatment (e.g. are those with lower discounting rates more likely to respond to treatment efforts?), (3) discounting can be used as an outcome measure to assess the effects of a treatment, (4) changes in discounting can be a target of therapeutic efforts and (5) discounting relates to biological markers of impulsivity (e.g. reduced serotoninergic neurotransmission). The answers to these questions are important in order to fully understanding discounting and its relationship to

clinical outcomes. The only limited information we have of relevance to this issue is that ex-smokers discount in a fashion similar to matched non-smokers (Bickel *et al.*, 1999), suggesting that high discounting rates by smokers may be reversible. Moreover, this observation is supportive of the notion that discounting may be related to the effects of abstinence, yet, although encouraging, this information alone does not answer the above questions. Only future research efforts will enable a systematic examination of these issues.

Relationship between impulsivity and other psychological disorders

In this paper, we have examined the discounting of delayed rewards in order to understand the impulsivity and loss of control exhibited by drug-dependent people. An expanding scientific literature suggests that impulsivity may be evidenced in numerous and various problem behaviors in addition to drug-dependence.

For example, several studies have underscored the relationship between impulsivity and delinquent behavior (e.g. Davids, Kidder & Reich, 1962; Davids & Falkof, 1975; Landau *et al.*, 1975; Trommsdorff, 1994). Both behavioral and psychometric measures of impulsivity have been strongly correlated with the development of delinquent behavior (White *et al.*, 1994), and a lack of self-control has been proposed as a hallmark characteristic of criminal behavior (Gottfredson & Hirschi, 1990). Additionally, impulsivity has been implicated in behavioral problems ranging from depression, suicidality, aggression, gambling, excessive spending (as opposed to saving money), eating and failure to exercise (e.g. Neville, 1980; Hewitt & Flett, 1993; Lowe & Eldredge, 1993; Logue, 1995; Cherek *et al.*, 1997; Steel & Blaszczynski, 1998; Cherek & Lane, 1999).

Additionally, a substantial amount of research suggests that many types of psychological disorders do not occur in isolation but rather tend to co-occur (for a review, see Bickel & Marsch, 2000). That is, many such problem behaviors tend to cluster together, such that individuals who exhibit one type of problem behavior tend to exhibit a behavioral repertoire of engaging in several types of myopic or short-sighted behavior. Such behavioral clustering has been shown to occur between criminal behavior and drug use, family violence, job instability and failed marriages in adults, and between conduct problems, drug and alcohol use, high rates of television viewing and low rates of exercise in adolescents (e.g. Rydelius, 1983; Donovan & Jessor, 1985; Gottfredson & Hirschi, 1990; Livingston, 1996; Lytle & Roski, 1997; Coogan *et al.*, 1998). Similarly, various types of alcohol and drug use have been shown to frequently co-occur with high risk sexual behavior and gambling, as well as with depression and other psychiatric disorders, including personality and eating disorders (e.g. Lacey & Moureli, 1986; Dulit *et al.*, 1990; Donoghoe, 1992; Lowe & Eldredge, 1993; Grant, 1995; Barber *et al.*, 1996; Brown *et al.*, 1996; Klerman *et al.*, 1996; Vitaro *et al.*, 1998).

These findings suggest that, although drug dependence and other disorders are often studied independently as if each represents a unique problem, these disorders may share at least one common feature, namely impulsive behavior. Nevertheless, the majority of this research investigating the relationship between impulsivity and problem behaviors other than drug dependence has largely employed the use of paper-and-pencil self-report measures of impulsivity. Use of the delay discounting procedure in future research efforts to assess impulsive behavior in these varied populations may enable the systematic analysis of the variables affecting the nature and degree of impulsivity exhibited by these populations. Additionally, the delay discounting methodology may aid in identifying structural links between drug dependence and various psychological disorders.

Conclusion

In this paper we have illustrated how the economic concept of discounting may be useful in understanding the impulsivity evident in drug-dependent individuals and how such an approach may provide a means of understanding loss of control over drug use. The research reviewed here suggests that drug-involved and drug-dependent individuals show substantial discounting relative to matched control non-drug users. The research also suggests that other measures of impulsivity appear to be concordant with the discounting measure. One value of examining impulsivity as discounting is that it enables the study of the behavioral process that has

broad generality and permits experimental analyses of its determinants. Important questions remain to be addressed, however. In addition to the those reviewed above, there remains the question of whether different reinforcers continue to be discounted at different rates and whether interventions designed to reduce discounting of one reinforcer will lead to change in the discounting of other reinforcers. None the less, this paper illustrates an economic concept that can be used to understand important aspects of drug dependence. The challenge, of course, is to understand whether such insights can provide novel suggestions for effective therapeutic interventions for drug dependence. If the suggestions that come from this perspective prove effective, then behavioral economics may positively contribute to the understanding and treatment of drug dependence.

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