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Heroin Addicts Have Higher Discount Rates for Delayed Rewards Than Non-Drug-Using Controls

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Fifty-six heroin addicts and 60 age-matched controls were offered choices between monetary rewards ($11–$80) available immediately and larger rewards ($25–$85) available after delays ranging from 1 week to 6 months. Participants had a 1-in-6 chance of winning a reward that they chose on one randomly selected trial. Delay-discounting rates were estimated from the pattern of participants' choices. The discounting model of impulsiveness (Ainslie, 1975) implies that delay-discounting rates are positively correlated with impulsiveness. On average, heroin addicts' discount rates were twice those of controls ($p = .004$), and discount rates were positively correlated with impulsivity as measured by self-report questionnaires ($p < .05$). The results lend external validity to the delay-discounting rate as a measure of impulsiveness, a characteristic associated with substance abuse.

Individuals who abuse drugs persistently choose the relatively immediate and short-term rewards of drug use over a variety of delayed larger rewards. The positive effects associated with drug use, such as pleasant feelings, euphoria, and relief from withdrawal or dysphoria, occur within minutes or even seconds of drug ingestion. However, the negative effects of drug use are usually delayed in time relative to short-term benefits and often have a gradual onset (Heyman, 1996; Petry, Bickel & Arnett, 1998). The long-term consequences of drug abuse include loss of employment, poor relationships with family, legal difficulties, and premature death from overdose, AIDS, and other contagious diseases. It is implicit in voluntary participation in treatment programs for substance abuse that drug abusers value the long-term rewards of abstinence over the short-term rewards that maintain their addiction. Even so, many drug users, with the best of intentions of remaining abstinent, persist in using drugs and express regret over their choices.

A possible explanation for drug users' persistent choices to use drugs despite the long-term consequences is in the degree to which future outcomes impact their current decisions. *Delay-discounting* refers to the reduction in the present value of a future reward as the delay to that reward increases. The more remote a future reward is, the lower its present value, and, therefore, the less likely the reward is to be chosen among current alternatives. The *discount rate* determines the steepness of the reduction in present value with increases in delay. Individuals have different discount rates (Kirby, 1997), and the higher the rate at which a person discounts future rewards, the lower the present values of future rewards and the less impact those rewards will have on current choices. In this paper we compare delay-discounting rates for opioid-dependent individuals with those of non-drug-using controls.

The delay-discounting model of impulsiveness (Ainslie, 1975, 1992; Rachlin, 1974) defines an impulsive choice as the choice of a smaller, sooner reward over a larger, later reward, when the larger reward would have been chosen at sufficiently longer delays to both rewards. Such preference reversals can arise naturally from the form of the delay-discounting functions for a pair of rewards, as illustrated in Figure 1. The vertical lines show the values at the point of receipt of a smaller, sooner reward (point B) and a larger, later reward (point C), whose values are both discounted with delay. (Avoidance of delayed losses can be modeled in a similar fashion.) At sufficient delays to both rewards (prior to point A) a person may prefer the larger reward, as implied by the higher, dashed curve representing the present value of that reward in the figure. However, as both rewards approach in time, preference may reverse (at point A) such that the person temporarily prefers the smaller reward. The interval during which the smaller reward is temporarily preferred (between points A and B) can be thought of as a "window of vulnerability" during which opportunities to choose the smaller reward will result in an impulsive choice. The duration of this window and the difference in value between the two rewards within the window will vary depending on the individual's discount rate.

Previous research using real rewards has shown that people's preferences typically do reverse with changes in

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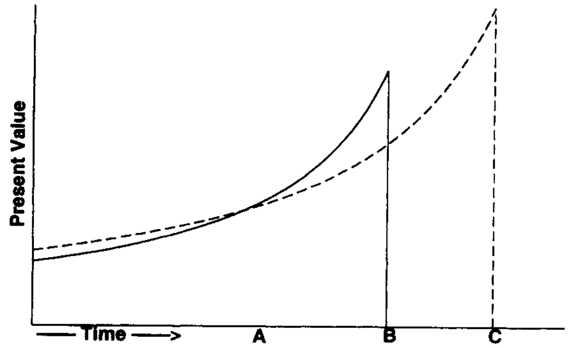

Figure 1. Present, discounted values of two delayed rewards as a function of delay. B indicates the point of receipt of a smaller, sooner reward, and C indicates the point of receipt of a larger, later reward. With the passage of time, preference reverses from the larger to the smaller reward at point A.

delay in the manner assumed by the discounting model (Kirby & Herrnstein, 1995). Research using real rewards has also shown that people's discounting curves are well-described by a hyperbolic function, which is a form that allows the discounting curves for two rewards to cross in the manner illustrated in Figure 1 (Kirby, 1997; Kirby & Maraković, 1995). One hyperbolic function that fits the existing data very well is the following (Mazur, 1987):

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

where V is the present value of the delayed reward A at delay D, and k is a free parameter that determines the discount rate. (All delays below are measured in days, and the values of k are scaled accordingly.) As k increases the person discounts the future more steeply. Increasing k increases both the duration of the window of vulnerability and the magnitude of the person's preference for the smaller reward within this window. Therefore, k can be thought of as an *impulsiveness parameter*, with higher values corresponding to higher levels of impulsiveness (Herrnstein, 1981).

One previous study has examined differences in discount rates between heroin addicts and non-drug users. Madden, Petry, Badger, and Bickel (1997) offered participants a series of choices between hypothetical monetary rewards available immediately or delayed in time. The median estimated discount rate (k) for the heroin addicts was 0.220, which was dramatically higher than that for the controls, 0.027. In addition, Madden et al. questioned the heroin addicts about their preferences for amounts of heroin available immediately and larger amounts available after a delay. They found that heroin addicts discounted heroin rewards much more steeply than monetary rewards, with a median discount rate of 4.170 for heroin. Thus, heroin addicts revealed discount rates consistent with higher levels of impulsiveness than controls in their choices involving hypothetical money, and even higher levels of impulsiveness when the choices involved hypothetical amounts of drugs.

The purposes of the present study were (a) to determine whether heroin addicts discounted delayed rewards at higher rates than non-drug users when real monetary rewards were at stake, and (b) to assess the external validity of delay-discounting rates as measures of real-world impulsiveness.

Method

Participants

Participants in the patient group were 56 opioid-dependent individuals enrolled in the Substance Abuse Treatment Center at the University of Vermont, an outpatient clinic that provides counseling and buprenorphine (an alternative to methadone, which is a mixed-opioid agonist/antagonist with a long duration of action and few subjective drug effects in opioid-tolerant individuals; Bickel & Amass, 1995) and naltrexone (an opioid antagonist that prevents relapse to opioid abuse). The patients had been regular heroin users for an average of 8.3 years. The 60 participants in the control group were recruited by a newspaper advertisement. Respondents were selected from telephone pre-screening such that as a group they were matched as closely as possible to the general demographic characteristics of the heroin abusing population, including age, gender, and education. Only respondents who reported no previous or current history of alcohol or illicit substance abuse were invited to participate.

Patients were typically given a battery of tests, including those reported below, upon admission to the clinic. All patients enrolled in the clinic were administered the monetary-choice questionnaire during one of three testing periods conducted over the course of a year. At the time they were given the monetary-choice questionnaire, patients had been in treatment between 2 days and 21 months, with a median of 51 days. Controls completed the questionnaires during participation in a three-hour-long assessment study (Madden et al., 1997; Petry et al., 1998). All participants signed written, informed consent forms for participation. Some participants in both groups received cash rewards based on their choices on the monetary-choice questionnaire.

Summary statistics for the demographic and IQ variables are shown in Table 1. Full-scale IQ (FSIQ) scores were estimated from the information, vocabulary, picture completion, and block design tests of the Wechsler Adult Intelligence Scale, Revised (Wechsler, 1981). The two groups were reasonably matched on age and FSIQ. Patients were significantly lower than controls in education and in legal income. Addiction Severity Index scores (ASI; McClellan et al., 1985) for the patient group are shown in Table 2.

Materials and Procedures

The monetary-choice questionnaire was based on one developed by Kirby and Maraković (1996). Participants were presented a fixed set of 27 choices between smaller, immediate rewards (SIRs) and larger, delayed rewards (LDRs). For example, on the first trial participants were asked "Would you prefer \$54 today, or \$55 in 117 days?" The participant indicated which alternative he or she would prefer to receive by circling the alternative on the questionnaire. The values used in all 27 trials are shown in Table 3. The order of the questions on the questionnaire is shown in the first column. The order was contrived such that trial order did not correlate with the SIR or LDR amounts, their ratio, their difference, the delay to the LDR, or the discount rate corresponding to indifference between the two rewards.

Both groups of participants were guided through the instructions by a research assistant who was familiar to them but who was blind to the discount rate estimation procedure used for the questionnaire. To encourage accurate responding, all participants were given a 1-in-6 chance of receiving the reward that they chose on one of the trials. Prior to completing the questions, all participants read the following instructions (the statements enclosed in brackets were included only for the patients):

> Please take the choices seriously: they may be for *REAL MONEY*. After you complete the questionnaire, you will roll a die. If it comes up a six (6), then you will win one of your 27 choices. The numbers of the questions below are written on a piece of paper in a bag [behind the dispensary]. If you roll a six, you will get to pick a number from the bag. The number you pick corresponds to the amount of money you will win; you will win whatever you chose on that particular question. For example, if you pulled the number 9 from the bag, you would win whatever you answered to question #9 below. If you had circled the smaller reward (the $78 today reward), you would get $78 as soon as you selected that choice from the box. If you chose the delayed reward on that question ($80 in 162 days), you will get $80 162 days from now. We would contact you [and/or a designated friend of yours] at the time your payment came due, and we will ask you if you prefer to return to the clinic to collect your money or if you want us to mail you a check.

The instructions continued with the admonition "To make sure that you get a reward you prefer, you should answer *every question* as though it were the one you will win." At the end of the questionnaire the patients were asked to provide contact information for themselves, and/or one or more friends who would be able to find them and who could be contacted at any time a delayed reward might be due. This procedure was successful, in that all patients and controls who were due to receive delayed rewards actually received their rewards in cash in the number of days specified. After reading the instructions, participants were questioned to ensure that they understood the instructions. Any questions were clarified prior to beginning the questionnaire.

Table 1
Summary Statistics for Demographic Variables

Group	Age (years)	Education (years)	Income ($)	FSIQ
Addicts				
M	35.8	12.6	8,740	98.5
SD	7.8	1.8	9,148	15.5
Mdn	35.5	12.0	6,600	93.0
IQR	31–42	12–14	2,697–11,640	88–102
Controls				
M	35.4	13.5	13,694	103.5
SD	10.5	1.4	10,769	14.9
Mdn	35.0	13.0	13,110	100.5
IQR	26–44	12–14	5,260–20,490	93–112
Tests of differences between patients and controls				
t	0.25	3.01	3.86[a]	1.73
p	.80	.003	.0002	.09
d	0.05	0.56	0.72	0.33

Note. Standard deviation refers to population estimate. For columns 1–3, $df = 114$; for FSIQ, $df = 108$. FSIQ = full-scale IQ; IQR = interquartile range.
[a]The *t* test for the income variable used log(income + 1).

Table 2
Addiction Severity Index Statistics for Patients

Scale	*M*	*SD*	*Mdn*	IQR
Medical	.31	.33	.18	0–.56
Employment	.62	.32	.63	0–1.0
Alcohol	.12	.18	.06	0–.15
Drug	.37	.09	.36	0–.42
Legal	.30	.24	.25	0–.50
Family/social	.29	.21	.24	0–.43
Psychiatric	.33	.22	.37	0–.48

Note. Standard deviation refers to population estimate. IQR = interquartile range.

Participants also completed two widely used self-report inventories that measure different subscales of impulsiveness. One was the I-5 questionnaire (Eysenck & Eysenck, 1978; Eysenck & McGurk, 1980). This questionnaire contains three subscales: IMP, which measures impulsiveness related to a failure to evaluate risk (e.g., "Do you generally do and say things without stopping to think?"); VENT, which measures venturesomeness, or a type of behavior in which risk is consciously perceived and accepted (e.g., "Would you enjoy parachute jumping?"); and EMP, which is an empathy scale that was included to add variety to the I-5 questionnaire ("Do you get very upset when you see someone cry?"). The other questionnaire was the Barratt Impulsiveness Scales, Version 10 (BIS-10; Barratt, 1985). This questionnaire contains three scales related to impulsiveness: nonplanning (e.g., "I am more interested in the present than the future"); cognitive impulsiveness (e.g., "I make up my mind quickly"); and motor impulsiveness (e.g., "I do things without thinking"). Scores on both questionnaires have been shown to correlate with a wide variety of impulsive behavior (for the Eysenck scales, see, e.g., Kennedy & Grubin, 1990; McCown, 1989; Stein et al., 1995; for the Barratt scales see, e.g., Barratt, 1994; Carlton & Manowitz, 1994; O'Boyle & Barratt, 1993; Stein, Hollander, Simeon, & Cohen, 1994).

Discount Rate Estimation Procedure

An estimate of a participant's discounting-rate parameter (k in Equation 1) can be made from the participant's pattern of choices across the 27 questions on the monetary-choice questionnaire. For example, question 19 (the fourth trial from the bottom in Table 3) offered participants a choice between "$33 today" and "$80 in 14 days." A participant with a discount rate of 0.10 would be indifferent between these two rewards. Therefore, if a participant chose the immediate reward on this trial, then one could infer that this person had a discount rate greater than 0.10. Question 4 (the bottom trial in Table 3) offered participants a choice between "$31 today" and "$85 in 7 days." A participant with a discount rate of 0.25 would be indifferent between these two rewards. Therefore, if the same participant chose the delayed reward on this trial, then one could infer that this person had a discount rate less than 0.25. Taking the two trials together, this person would have a discount rate between 0.10 and 0.25, and the midpoint of this interval is an estimate of the person's k value. We used the geometric mean to avoid underweighting the smaller of the two rate parameters. In the example, this yields $k = 0.16$.

The 27 choices define ten ranges of discount rates, eight of which are bounded above and below (as in the example) and two of which represent the endpoints (choices of all 27 immediate rewards or all 27 delayed rewards). Based on participants' choices of the immediate reward across trials, we assigned each participant a k value

Table 3
Choice Trial Values, Their Associated Discount Rates (k), and the Proportions of Participants Choosing the Delayed Reward on Each Trial

	Reward values						Addicts			Controls		
Order	SIR	LDR	Delay[a]	*k* at indiff.	*k* rank	LDR size	S	M	L	S	M	L
13	$34	$35	186	.00016	1	S	0			0		
1	$54	$55	117	.00016	1	M		4			2	
9	$78	$80	162	.00016	1	L			4			2
20	$28	$30	179	.00040	2	S	2			0		
6	$47	$50	160	.00040	2	M		0			2	
17	$80	$85	157	.00040	2	L			0			0
26	$22	$25	136	.0010	3	S	4			0		
24	$54	$60	111	.0010	3	M		0			5	
12	$67	$75	119	.0010	3	L			5			3
22	$25	$30	80	.0025	4	S	7			3		
16	$49	$60	89	.0025	4	M		9			10	
15	$69	$85	91	.0025	4	L			7			20
3	$19	$25	53	.0060	5	S	21			22		
10	$40	$55	62	.0060	5	M		13			20	
2	$55	$75	61	.0060	5	L			39			33
18	$24	$35	29	.016	6	S	18			30		
21	$34	$50	30	.016	6	M		34			52	
25	$54	$80	30	.016	6	L			41			67
5	$14	$25	19	.041	7	S	43			72		
14	$27	$50	21	.041	7	M		55			85	
23	$41	$75	20	.041	7	L			68			90
7	$15	$35	13	.10	8	S	68			90		
8	$25	$60	14	.10	8	M		82			93	
19	$33	$80	14	.10	8	L			89			100
11	$11	$30	7	.25	9	S	93			100		
27	$20	$55	7	.25	9	M		91			98	
4	$31	$85	7	.25	9	L			89			100

Note. k at Indiff = the value of the discount rate at which the immediate and delayed rewards are of equal value according to Equation 1; k Rank = trials with the same values of *k* grouped in ascending rank order; SIR = smaller, immediate reward; LDR = larger, delayed reward; S, M, and L = the small, medium, and large delayed reward categories, respectively.
[a]Delays are in days.

corresponding to the geometric midpoint of one of the eight ranges or one of the two endpoint values. Because participants' choices are not always perfectly consistent with any single value of *k*, the parameter estimates could not be made by simply looking for a switch from the immediate to the delayed rewards moving down Table 3. Instead, each participant was assigned a *k* value that yielded the highest proportion of choices consistent with that assignment. That is, for each participant we computed the proportion of that person's choices that were consistent with assignment to each of the 10 values of *k* defined by the questionnaire (bounded or unbounded), and the participant was assigned to the value that yielded the highest consistency among his or her choices. Consistency here is a relative rather than an absolute measure, with the discount rate that yields the highest relative consistency across trials providing the best estimate of the participant's *k* value. When two or more values yielded equal consistency, the participant was assigned a value corresponding to the geometric mean of those values.

Previous studies using real rewards (Kirby, 1997; Kirby & Maraković, 1995, 1996) and hypothetical rewards (e.g., Benzion, Rapoport, & Yagil, 1989; Green, Fristoe, & Myerson, 1994; Green, Fry & Myerson, 1994; Raineri & Rachlin, 1993; Thaler, 1981) have shown a *magnitude effect* on discount rates. Specifically, people's discount rates decrease as the amounts of the rewards increase. To examine this effect in this study, the delayed rewards used in the questionnaire were grouped into three reward sizes, small ($25 to $35), medium ($50 to $60), and large ($75 to $85). Within each category, trials were constructed to correspond to each of the nine levels of impulsiveness. For example, the bottom three trials in Table 3 show delayed rewards in each magnitude group, with immediate rewards and delays chosen such that the discount rate at indifference for all three trials is $k = 0.25$. The reward-size categories are listed in column 7, and the rank order of their discount rates are shown in column 6. The discount rate estimation procedure described above was repeated for the 9 trials within each reward-size category. In this way, each participant could be assigned a separate *k* value for small, medium, and large delayed rewards.

Results

Discount Rates

The distributions of *k*s were approximately normalized using the natural log transformation. Across all reward magnitudes, the (geometric) mean *k* for the controls was 0.013 and the mean *k* for the patients was 0.025, which were reliably different, $t(114) = 2.95$, $p = .004$, Cohen's $d = 0.57$. There was only one outlier in the overall distribution, which was a case in the control group (k = 0.00063). Excluding this participant, the mean for the controls increased slightly to 0.0135, but remained reliably smaller than the mean for the patients, $t(113) = 2.78$, $p = .006$, $d = 0.54$. Histograms of the distributions of Ln(k) values for both groups are shown in Figure 2.

Correlations Between Discount Rates and Demographic Characteristics

Across groups, discount rates were not reliably correlated with any of the demographic variables shown in Table 1. The largest correlations were with age, education, and FSIQ, all with $rs \leq .13$, $ps \geq .15$. Within the patient group, the largest correlation was with FSIQ, $r = -.14$, $p = .34$. Within the control group, there was a significant correlation with age, $r = -.30$, $p = .02$, but this correlation would not be considered reliable after adjusting for the number of tests performed. Interestingly, the correlations between k and income were quite low, with $r = .06$ for the patients, $r = .03$ for the controls, and $r = .04$ overall.

To examine the difference in discount rates between patients and controls, controlling for the effects of age, income, education, and IQ, an analysis of variance was performed including those variables as covariates. (Income was normalized prior to these analyses using $\log_{10}$[income + 1], with the 1 added because of the zero values.) The adjusted mean discount rate for the controls remained the same, and the adjusted mean for the patients decreased slightly to 0.022. These means remained reliably different, $t(102) = 2.26$, $p = .03$, $d = 0.44$. Thus, the difference in discount rates between patients and controls cannot be accounted for by these other variables.

For the patients, the correlation between k and days in treatment was $r = -.04$, which was not reliable, $p = .78$. (For log days in treatment, the correlation with k was $r = .08$, $p = .58$.)

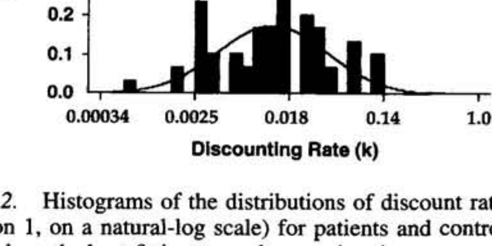

Figure 2. Histograms of the distributions of discount rates (k in Equation 1, on a natural-log scale) for patients and controls. The curves show the best-fitting normal approximations.

Self-Reported Impulsiveness

Summary statistics for the subscales of the I-5 and the BIS-10 are shown in Table 4. Patients were reliably higher on all of the impulsiveness subscales, all $ps \leq .0001$. Importantly, patients scored similarly to controls on the EMP (empathy) scale of the I-5, showing that heroin addicts do not simply differ from non-drug users on every dimension. The largest difference was on the IMP scale of the I-5, on which patients and controls differed by nearly 2 standard deviations.

Table 4 also shows the correlations between the self-report impulsivity scales and k. All of the correlations are reliable, $p < .05$ (unadjusted), except for the correlation with motor impulsiveness on the BIS-10. The largest correlations are with IMP on the I-5 ($r = .27$) and nonplanning on the BIS-10 ($r = .25$), which are similar in the content of their items. The magnitudes of these two correlations are within the range that is typically found between behavioral and self-report measures of impulsiveness (see, e.g., Gerbing, Ahadi, & Patton, 1987; Logan, Schachar, & Tannock, 1997; White et al., 1994).

Magnitude Effect

Figure 3 shows the mean estimates of k for both groups as a function of the magnitude of the delayed reward. The linear decrease in k as amount increased was highly reliable overall, $t(114) = 7.69$, $p < .0001$, $r = .58$, as well as for each group separately. All pairwise differences in k between reward magnitudes (horizontal comparisons in Figure 3) were highly reliable overall, and within each group, all $ps < .0001$. The departures from linearity were not reliable, and neither the linear nor the nonlinear trends differed between patients and controls, all $ts < 1$.

The patients had reliably higher values of k than controls at each of the three reward sizes (vertical comparisons in Figure 3), all $ps \leq .02$. These differences were similar across the three reward magnitudes, yielding nearly parallel lines in Figure 3, with no overall or simple interactions, all $ts < 1$.

The last six columns in Table 3 show the proportions of participants choosing the delayed reward on each trial. The first three of these columns correspond to the small, medium and large rewards, respectively, for the patients, and the last three correspond to the small, medium and large rewards, respectively, for the controls. Moving down each column, one can see that the proportion of participants choosing the delayed reward increases nearly monotonically in every column.

Consistency

The consistency measure represents the percentage of participants' choices that were consistent with their assigned discount rate. For the rate assignment based on all 27 trials the mean choice consistency was 94% for the patients and 96% for the controls. These means were significantly different, $t(114) = 2.39$, $p = .02$, $d = 0.45$.

Although the patients as a group were not as consistent as

Table 4
Summary Statistics for Self-Reported Impulsiveness Measures and Their Correlations With the Discount Rate (k)

	Measure					
	I-5			BIS-10		
Group	IMP	VENT	EMP	Nonplan	Cog	Motor
Patients						
M	14.7	10.7	13.5	25.6	19.6	19.9
SD	4.3	3.2	3.3	7.3	5.6	7.3
Controls						
M	6.5	7.7	13.3	17.5	15.3	13.6
SD	4.1	3.8	3.0	6.0	5.9	6.0
Tests of differences between patients and controls						
$t(114)$	10.51	4.48	0.32	6.50	3.93	5.06
p	<.0001	<.0001	.75	<.0001	.0001	<.0001
d	1.97	0.84	0.06	1.22	0.74	0.95
Correlations with Ln(k)						
$r =$	.27	.19	−.19	.25	.19	.11
$p =$	.004	.04	.04	.006	.04	.23

Note. The I-5 is the impulsiveness questionnaire developed by Eysenck and Eysenck (1978). BIS-10 is the 10th revision of the Barratt Impulsiveness Scales (Barratt, 1985). IMP = impulsiveness subscale; VENT = venturesomeness subscale; EMP = empathy subscale; Nonplan = nonplanning subscale; Cog = cognitive impulsiveness subscale; Motor = motor impulsiveness subscale.

the controls, the difference was small. A consistency of 94% indicates that we were able to assign a discount rate to the patients such that less than 2 out of the 27 trials were inconsistent with the assigned rate. Furthermore, this consistency measure is artificially low because it ignores the magnitude effect, that is, it assumes a single discount rate for all reward magnitudes. If one computes consistency based on separate discount rates within reward magnitude categories, the mean consistency increases to 97% for the patients and 99% for the controls. This increase in the level of consistency when the magnitude effect is taken into account is consistent with the results in Kirby and Maraković (1996).

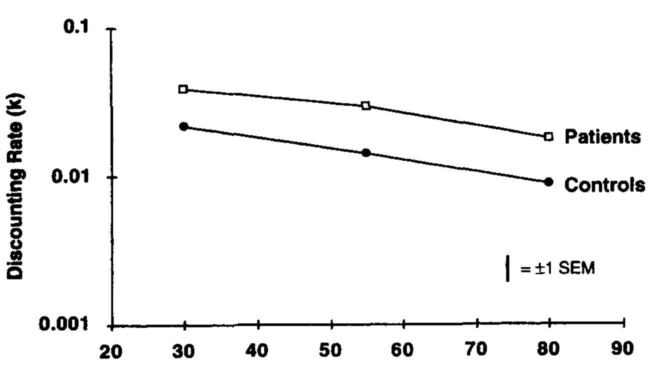

Figure 3. Mean discount rate k (on $\log_{10}$ scale) as a function of delayed reward magnitude for patients and controls. The vertical line shows the length of 2 standard errors of the mean (±1 *SEM*) based on the variance around the separate means. (The *SE*s for all conditions are too similar to distinguish visually.)

There were no significant differences among the mean consistencies for the three reward magnitudes, all ts < 1.

It is important to note that consistency was not correlated with k, either across or within groups, all ps $\geq .42$. This indicates that the observed differences in k are not artifacts of differences in consistency. Inconsistency tends to produce ties between different discount rates in accounting for a given participant's choices. In such cases, the tied ks are averaged together to give an overall estimate. Therefore, inconsistency tends to assign participants to intermediate discount rates that have little influence on the group means. This was the case, for example, with the group of the 5 most inconsistent participants in the patient group. Excluding them from the analysis of the discount rates left the mean unchanged at the reported accuracy. In addition, we recomputed all of the statistical tests above, limiting the data to only those participants in both groups who had 100% consistency. The mean differences in k between groups changed only slightly overall and within all three magnitudes, and all differences remained significant.

Across the demographic and self-report variables, only FSIQ correlated with consistency after adjusting for the number of tests performed, $r = .33$, $p = .005$. However, the correlations with education, I-5 IMP, and BIS-10 nonplanning and cognitive impulsiveness were all greater than .20, and had unadjusted p values less than .05.

Discussion

The data indicate that, on average, patients had discount rates about twice as high as those of the controls ($k = 0.025$ vs. 0.013). Concretely, this means that for the average heroin addict in this population $50 would lose half of its value if delayed by about 40 days, whereas for the average control \$50 would require a delay of about 77 days to lose half of its value. The two populations overlapped substantially, as illustrated in Figure 2. By comparison, for a sample of 528 undergraduates at a highly selective liberal arts college who were given a similar questionnaire (Kirby & Maraković, 1996), the mean value of k was 0.007, or about half the value for the controls in the present study. For the average student in that sample \$50 would lose half of its value if delayed by about 143 days. Clearly, with either comparison group, heroin addicts discounted delayed rewards at meaningfully higher rates.

Patients and controls also differed significantly in impulsiveness as measured by two standard self-report questionnaires, the Eysencks' I-5 and the BIS-10. Importantly, discount rates were significantly correlated with both self-report measures, and the sizes of these correlations were in the typical range for correlations between self-report and behavioral measures of impulsiveness. Impulsiveness is a multidimensional construct, and the precise characterization of the sub-dimensions of impulsivity is an ongoing endeavor, with estimates of the number of sub-dimensions ranging from two (e.g., IMP and VENT in the I-5) to fifteen (Gerbing et al., 1987). Although we cannot yet characterize the position of delay-discounting rates within this multidimensional framework, the correlations with self-report measures observed here support the external validity of the delay-discounting rate as an indicant of one or more of the sub-dimensions of impulsiveness. These correlations are also consistent with our inference that the difference in discount rates between the heroin addicts and non-drug users reflects, at least in part, differences in their levels of impulsiveness.

This inference is also supported by the fact that the differences in discount rates between patients and controls cannot be explained by differences in IQ, education, age, or income. Nor can the difference be accounted for by differences in choice consistency. Patients and controls were highly consistent in their choices between immediate and delayed rewards, and consistency was not correlated with discount rates.

The magnitude effect, that larger rewards are discounted at lower rates, is very important here because the similarity of this effect across groups indicates that patients are just as sensitive to the amounts of the rewards as are controls. Furthermore, the size of the observed magnitude effect implies that most patients took into account both the amounts of the rewards and the delays to those rewards in making their choices, as assumed by Equation 1. The discount rates estimated from the questionnaire based on Equation 1 are highly correlated with the sizes of the SIRs, the differences between the two rewards, the ratios of the two rewards, and the delays to the LDRs. Thus, it is possible for participants to achieve very high, even perfect, levels of consistency by basing their choices on threshold values of either the amount or delay variables alone. However, each one of these strategies can be ruled out as entirely accounting for the difference in estimated impulsiveness between patients and controls:

1. Choosing an SIR above a certain threshold (e.g., always choosing the SIR when it is greater than \$20), regardless of the size of the LDR or its delay, can be ruled out because it predicts a large magnitude effect in the wrong direction—with larger delayed rewards being discounted at higher rates than smaller delayed rewards.

2. Choosing the LDR if the ratio of the LDR to the SIR exceeds a threshold (e.g., always choosing the LDR when it is more than twice as large as the SIR) can be ruled out because the ratios that were used are nearly uncorrelated with the magnitude of the LDR (r = .04). Therefore, the way that the trials in the questionnaire are contrived, the strategy predicts no magnitude effect across the range of ratios that was used.

3. Choosing the LDR if the difference in magnitude between the LDR and SIR exceeds a threshold (e.g., always choosing the LDR when it is more than \$10 over the SIR) can be ruled out because the LDR-SIR differences increase across LDR magnitudes, which means that a given difference threshold will result in more LDR choices as the LDR increases. This predicts a magnitude effect vastly larger than the one observed. That is, for all but a small minority of participants, the difference thresholds required to produce the observed discount rates would yield magnitude effects much larger than those observed.

4. Choosing the SIR if the delay to the LDR exceeds a threshold (e.g., always choosing the SIR when the delay to the LDR is greater than 21 days) can be ruled out because it ignores the amount of the LDR, and therefore, it predicts no positive magnitude effect. For the majority of possible thresholds it even predicts a slightly negative magnitude effect because the delays tended to be longer for the larger LDR trials, meaning participants using this strategy would be less likely to wait in those trials, implying greater impulsiveness.

Therefore, none of these threshold strategies can account for any substantial portion of the data. The data may reflect a mixture of any or all of these strategies, but the data indicate that the majority of participants in both groups took both amounts and delays into account in making their choices, and the similarity of the magnitude effect in the two groups suggests that patients were no more prone than controls to use threshold strategies.

One way that patients and controls may have differed that could not be controlled is in their estimates of the probabilities of actually obtaining the delayed rewards. Every effort was made to assure patients and controls that their rewards would be delivered as promised, and in fact, all patients and controls who won rewards did receive their rewards on the due dates. Patients were very familiar with the clinic and staff, and knew exactly when, where, and to whom to return to collect a delayed reward. In contrast, controls only visited the clinic once. So it is possible that patients did not have lower expectations of receiving the delayed rewards than did controls. However, if patients' expectations about the likelihood of receiving the rewards were lower than those of the controls, this would have the effect of reducing the expected value of the delayed rewards, independently of the effects of delay-discounting. This, in turn, would make the mean delay-discounting rate for the patients appear larger than that for the controls, even if they were identical. To explore the viability of this alternative explanation for the group difference in discount rates, we simulated the effects of various types of probability discounting as a function of delay on the estimated discount rates for the patients. It turns out that a different probability-discounting rate is needed for each of the three reward magnitudes to eliminate the difference in delay-discounting rates between the patients and controls, and the required rate is lower for the medium rewards than for the small and large rewards. Therefore, although it is plausible that patients may have had lower expected values of the delayed rewards than controls, we have no reason to think that this could completely account for the observed difference in delay-discounting rates. Such an alternative account would need to explain why medium rewards were seen as more probable than small or large rewards. In fact, previous studies have not found a magnitude effect for probability-discounting rates (see, e.g., Rachlin, Raineri, & Cross, 1991).

Probably the most tempting way to dismiss the observed difference in impulsiveness between patients and controls is to assume that patients chose the immediate rewards more often simply because they had a greater immediate need for the money. However, four observations argue against this account. First, although the patients had a lower average reported legal income, their monetary consumption rate is presumably much higher than the controls'. A typical heroin addict consumes roughly $36,000 worth of heroin each year. Most of this is paid for though sales of heroin to other users. In this context, the monetary rewards offered in this study were not so large that they would make a big difference in the addicts' consumption rates. Second, although the two groups differed in average income, the discount rates were not correlated with income, either across or within groups. If monetary need played a strong role in discount rates, one would expect income to mediate the observed estimates of k. Third, because these patients were receiving a drug that prevented withdrawal symptoms and that blocked the effects of other opioids, they did not have an immediate need for cash to purchase heroin to abate withdrawal or to produce euphoria (Bickel & Amass, 1995). Fourth, patients as a group did take both the sizes of the rewards and the delays to the rewards into account in making their choices. Only 2 of the 56 patients chose the immediate reward on every trial, and, as discussed above, the remainder did not simply choose the immediate reward when it was above some threshold amount. So even if the patients had a greater immediate monetary need than the controls, they still weighed that immediate need against the sizes of and the delays to the rewards. In sum, the data suggest that both patients and controls discounted monetary rewards as a decreasing function of delay, and patients did so more steeply than controls.

This is not the first study to show that substance abusers are more impulsive than non-drug users (e.g., Chalmers, Olenick, & Stein, 1993; Cookson, 1994; Rosenthal, Edwards, Ackerman, Knott, & Rosenthal, 1990; Sher & Trull, 1994). It is, however, the first to do so by measuring impulsiveness based on choices between potentially obtainable rewards. Another study (Madden et al., 1997) also found differences between controls and heroin addicts in discount rates, and much higher rates for heroin addicts than those reported here, but that study used entirely hypothetical rewards. The use of probabilistic rewards has an obvious motivational advantage over hypothetical rewards, and also may help avoid the self-presentation biases associated with self-report measures.

Although the data from this study suggest that opioid-dependent individuals tend to have higher delay-discounting rates than non-drug users, the present study could not address whether this difference preceded their addiction or resulted from years of substance abuse. It is noteworthy, however, that the number of days in treatment was not associated with the observed discount rate, suggesting that impulsiveness as measured here is relatively stable across time in treatment, which is associated with declining levels of drug use (Ball & Ross, 1991). Future studies may address whether higher discount rates precede or result from substance abuse, and whether higher discount rates are correlated with relapse, as has been shown with self-report measures of impulsiveness (e.g., Miller, 1991). Certainly a high discount rate is not a sufficient condition for substance abuse, because our control group contained people with very high rates who did not report any current or former history of drug use.

The discounting model of impulsiveness, like the behavioral choice theory in which it is embedded (see, e.g., Heyman, 1996; Kirby, 1996; Rachlin, 1995), assumes that addicts make choices, and that their choices are influenced by the magnitudes and delays of the outcomes involved. One of the implications of these results for treatment and prevention of addiction is that strategies that focus on the consequences of substance abuse for future outcomes, in terms of either dire consequences or forgone rewards, may have diminished impact because of the substantial reduction, due to delay discounting, in the values of those outcomes at the moment of choice (Petry et al., 1998). The threat of jail (which may not happen for years after getting caught using heroin), the potential of losing custody of one's children after months of custody hearings, the failure to obtain a degree or good job years down the road, or a premature death from AIDS are all consequences of substance abuse that are typically stressed in treatment and prevention programs. However, these consequences do not have immediate saliency. Their values may diminish with delay to ineffective levels, especially for individuals who discount at high rates, as did the substance abusers in this study. In contrast, programs that emphasize immediate rewards for abstinence may have a better chance of competing against drug use because these rewards are not as distant in time. Alcoholics Anonymous and Narcotics Anonymous capitalize on substance abusers' immediate time perspectives. Their slogans are "take one day at a time," and they provide social support for abstinence each day. Similarly, contingency management treatment programs provide tangible rewards, in the form of gift certificates, sporting equipment, movie passes, and so on, for submission of clean urine samples, and these treatments have been found to be very effective (Bickel, Amass, Higgins, Badger & Esch, in press; Higgins et al., 1994; Higgins et al., 1993; Silverman, Higgins, Brooner, & Montoya, 1996). A better understanding of how immediate and delayed benefits and adverse consequences affect decisions to use or not use drugs among individuals with high delay-discounting rates may further assist in designing and testing novel treatment and prevention approaches for substance abuse.

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