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Delay discounting, impulsiveness, and addiction severity in opioid-dependent patients

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Abstract

Individuals who abuse drugs show higher delay discounting (DD) rate and impulsiveness scores compared with controls; however, it is unclear if DD rate covaries with severity of the addiction or if an individual's discounting rate can be changed by effective substance abuse treatment. This study compared methadone maintenance treatment (MMT) patients (n = 30) who had not used illegal drugs for 2 years with drug-using MMT patients (n = 30) and controls (n = 25) in terms of addiction severity, DD rate, and impulsiveness. Methadone patients abstinent from illegal drugs scored significantly lower on a number of addiction severity measures than the drug-using methadone patients. In addition, both groups of MMT patients showed significantly higher rates of DD and impulsiveness than the control group; however, no differences in DD rate or impulsiveness were found between the groups of patients. Results suggest that DD rate and impulsiveness may not covary with indicators of addiction severity in MMT patients. Published by Elsevier Inc.

Keywords: Delay discounting; Impulsiveness; Addiction severity; Opioids; Methadone maintenance

1. Introduction

Individuals with substance abuse disorders often seem to behave impulsively, choosing small immediate rewards associated with drug use over ostensibly larger but delayed rewards such as good health, freedom from incarceration, and good family relations. *Delay discounting* (DD) refers to the loss of subjective value of a reward as a function of delay to the reward. In general, studies on DD have shown that given an objectively defined reward (such as money), as delay to the reward increases, the *subjective* value of the reward decreases (Rachlin & Green, 1972). This appears to be true for the general population, and in addition, a growing number of studies have revealed that substance-abusing individuals consistently exhibit higher DD rates than nonabusing controls (e.g., Bickel, Kowal, & Gatchalian, 2006; Kirby, Petry, & Bickel, 1999; Madden, Petry, Badger, & Bickel, 1997; Odum & Bauman, 2010; Petry & Cassarella, 1999; Reynolds, Richards, Horn, & Karraker, 2004; Richards, Zhang, Mitchell, & De Witt, 1999; Vuchinich and Simpson, 1998). In light of these findings, it has been suggested that a better understanding of DD rate may have important implications for the prevention and treatment of substance abuse.

Studies on discounting by delay originated in the field of operant intertemporal choice (Ainslie, 1974, 1975; Mazur, 1987; Rachlin & Green, 1972). Mazur (1987) found that when pigeons are given a choice between smaller amounts of food delivered immediately and a larger amount of food delivered after some delay, their choices are best described by the following hyperbolic model:

$$v_d = V/(1 + kd) \quad (1)$$

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where v_d is the current subjective value of a delayed reward (the indifference point), V is the nominal value of the delayed reward, d is the delay duration, and k is an empirically derived constant proportional to the degree of DD. Thus, the higher the value of k, the more rapidly the subjective value of a reward decays as a function of time to its delivery.

In 1991, Rachlin, Rainieri, and Cross demonstrated hyperbolic discounting of hypothetical cash rewards in humans. In that study, volunteers were asked to choose between a constant amount of cash ($1,000) to be delivered after some delay (e.g., 1 month) and cash amounts ($1 to $1,000) to be delivered immediately (Rachlin, Rainieri, & Cross, 1991). The subjective value of the delayed amount was defined as the indifference point (v_d), or the point at which an individual switches from choosing a smaller immediate amount to a larger delayed amount. By repeating the choice procedure over a range of delay intervals, Rachlin obtained discounting functions that are best described by hyperbolic models (Killeen, 2009; Mazur, 1987; McKerchar et al., 2008). Importantly, similar discounting functions have been obtained when real or hypothetical rewards are used (Johnson & Bickel, 2002; Madden, Begotka, Raiff, & Kastern, 2003). The estimation of DD rate has now been extended to various populations of substance users, and, to date, there is overwhelming evidence that users of tobacco, alcohol, opioids, cocaine, and methamphetamine discount by delay significantly more than matched nonusing controls (for comprehensive reviews, see Bickel et al., 2006; Green & Myerson, 2004; Reynolds, 2006; and Yi, Mitchell, & Bickel, 2010).

1.1. DD and severity of the drug problem

In addition to the observed differences in DD rate between drug users and nonusers, a number of studies have found that the *magnitude* of discounting as a function of delay covaries with severity of the substance abuse problem. For example, in two studies, Vuchinich and Simpson (1998) compared light social drinkers with problem drinkers, and with heavy social drinkers, and found higher rates of DD in heavy social drinkers and problem drinkers than in light social drinkers. Bretteville-Jensen (1999) compared active injecting amphetamine and/or heroin abusers with past abusers of amphetamine and/or heroin and nonusing controls and found that both, active and past abusers, discounted the value of delayed monetary rewards more than the controls; in addition, their group of active abusers discounted delayed rewards more than past abusers. Petry (2001) compared active alcoholics with abstinent alcoholics and with control subjects without a history of alcohol dependence on their rate of discounting of money ($1,000 and $100) and alcohol (150 and 15 bottles of an alcoholic beverage) as a function of delay. Petry's study showed that the two groups of alcoholics discounted money at higher rates than the control group. In addition, with exception of the $1,000 condition, active alcoholics discounted at a higher rate than the alcohol-abstinent group. In other words, in three of four comparisons, the most rapid discounting was observed in active alcoholics, followed by abstinent alcoholics, and followed by controls. Then, in a study comparing DD rate between controls and samples of drug users, Kirby and Petry (2004) found that DD rates were increasingly higher for controls, abstinent heroin users, and active heroin users. Bickel, Odum, and Madden (1999) compared DD of hypothetical monetary outcomes by current, never, and ex-smokers of cigarettes. They found that current smokers discounted the value of delayed money more than did both comparison groups and that never and ex-smokers did not differ in their discounting of money. Taken together, these cross-sectional studies suggest that DD rate and drug use may be related in one of three ways. DD rate may either (a) change as a function of severity of the substance use, increasing when the drug abuse problems are more severe and decreasing as a consequence of abstinence; (b) be a preexisting condition predicting the likelihood of drug use and/or recovery from drug use; or (c) result from an interaction of both processes. In addition, it is possible that both substance use and DD might be predicted by a third variable such as IQ (Black & Rosen, 2011; de Wit, 2009; Perry & Carroll, 2008; Robles, 2010).

In support of the second proposition (b), some prospective studies have shown that preexisting differences in DD rate may play a defining role in recovery from substance use. For example, Tucker et al. (Tucker, Vuchinich, & Rippens, 2002; Tucker, Vuchinich, Black, & Rippens, 2006; Tucker, Roth, Vignolo, & Westfall, 2009) using the Alcohol-Savings Discretionary Expenditure (ASDE) index, found that allocation of monetary expenditures to either alcoholic beverages or savings—which presumably reflects relative preference for immediate versus delayed rewards—predicted abstinence from alcohol in nontreated problem drinkers at the 2-year follow-up. In addition, data pooled from three studies using the ASDE index revealed that the index incrementally predicted future rates of abstinence from alcohol in recently resolved treated and nontreated problem drinkers (Tucker et al., 2009). Regarding smokers, a number of studies show that preexisting DD rate can predict abstinence following cessation treatment. Krishnan-Sarin et al. (2007) found that scores on the experiential DD test (Reynolds & Schiffbauer, 2004) predicted abstinence from smoking in adolescents who participated in a cessation program, although scores on Kirby's DD measure (Kirby et al., 1999) did not. Recently, MacKillop and Kahler (2009) found that, among treatment-seeking smokers (who were also heavy drinkers), DD rate predicted the number of days to first relapse to cigarette smoking after cessation treatment independently of degree of nicotine dependence. Similarly, Yoon et al. (2007) found that the individual rate of DD predicted postpartum relapse to cigarette smoking among women who had discontinued smoking during pregnancy. Importantly, the study also showed that DD

rate did not change over time regardless of their smoking status at 24 weeks postpartum. Finally, a prospective longitudinal study was recently published on the relationship between baseline DD rate and the probability of taking up smoking among a large cohort of volunteers followed from 15 to 21 years of age. In that study, Audrain-McGovern et al. (2009) found that the degree of DD was relatively stable when measured repeatedly over 3 years, that higher DD rate at baseline predicted a heightened probability to take up smoking, and that having taken up smoking did not affect DD rate. To our knowledge, theirs is the first prospective study clearly showing DD rate acting as a stable preexisting variable predicting initiation of substance use rather than changing as a consequence of it.

On the other hand, some studies have found no differences in DD rate associated with abstinence. For example, a recent study that measured discounting rate for marijuana and hypothetical cash in self-reported current marijuana-dependent individuals, former marijuana-dependent individuals, and controls found no significant differences in DD rate among the groups (Johnson et al., 2010). In addition, Kirby and Petry (2004) compared groups of self-reported 14-day abstinent and current users and found lower DD rate among abstinent opiate abusers compared with active users but did not find differences between abstinent alcohol-dependent individuals and abstinent cocaine users compared with active alcohol and cocaine users. Then, Heil, Johnson, Higgins, and Bickel (2006) compared the DD rate among cocaine-dependent patients who were either currently using or had maintained abstinence from cocaine for 30 consecutive days and a group of nonusing community controls. Their study showed no differences in discounting rate between cocaine-using and cocaine-abstinent subjects although, consistent with previous studies, both groups showed higher rates of DD than the group of community controls. Taken together, these studies (Kirby & Petry, 2004; Heil et al., 2006) show, as Heil points out, that abstinence of up to 30 days from cocaine may not have a sufficient effect on DD rate to be detectable or that abstinence from cocaine or alcohol for up to 30 days may not be stable enough to be predicted by a higher preexisting DD rate.

1.2. Effects of cognitive skills on DD

Impulsiveness can be defined as the tendency to act without proper regard for the long-term consequences of those acts. Properly pondering the long-range consequences of our behavior, however, requires adequate cognitive skills and an environment suitable to such decision making. It seems fair to assume, therefore, that the lack of cognitive skills and a favorable environment might lead to errors and impulsive choices. Supporting this view, some studies have found that IQ scores correlate negatively with DD rate (de Wit, Flory, Acheson, McCloskey, & Manuck, 2007; Reynolds, Leraas, Collins, & Melanko, 2009; Shamosh & Gray, 2008). A meta-analysis of 24 studies on the relation between IQ score and DD rate found a significant negative relation among these variables, independently of the tests used to measure IQ and DD (Shamosh & Gray, 2008). Moreover, a study by de Wit et al. (2007) with a large sample of healthy adults showed that both, DD rate and nonplanning impulsiveness, correlated negatively with IQ scores *independently* of the subjects' socioeconomic status and educational attainment. In addition, it has been reported that deficits in working memory (Bechara & Martin, 2004) and concentration during assessment of DD (Hinson, Jameson, & Whitney, 2003; Upton, Brackett, Crone-Todd, & Lambert, 2010) increase estimates of DD rate. Although IQ is a relatively stable measure, to the extent that lower DD rate might depend on a person's ability to properly ponder future events, it may be possible for some individuals to acquire the skills to choose in less impulsive ways. Recent studies have shown that interventions to enhance memory skills (Bickel, Yi, Landes, Hill, & Baxter, 2011) and to improve money management skills (Black & Rosen, 2011) can decrease estimates of DD rate in stimulant-abusing persons; in addition, Black and Rosen found the changes in DD to be associated with a greater likelihood of drug abstinence. Taken together, these studies suggest that cognitive skills, particularly those involved in planning and decision making, may be important predictors of both DD rate and drug use.

1.3. Purpose of the study

This study was conducted to assess the effects of prolonged and confirmed abstinence from illegal drugs on impulsiveness and DD rate. The study compared rate of DD between methadone maintenance treatment (MMT) patients who had submitted urine samples free from illicit drugs during 24 or more consecutive months, MMT patients who continued to use illicit drugs, and a sample of non-drug-using community controls matched on age, gender, and race.

2. Materials and methods

2.1. Participants

Sixty MMT patients attending a university-affiliated substance abuse treatment clinic participated in the study. Half of the patients (n = 30) had continued to use illicit opioids and other drugs after at least 4 weeks of treatment. The remaining 30 MMT patients qualified for the study because according to the clinic's random urine testing program, they had remained abstinent from drugs of abuse (opiates, cocaine, amphetamines, benzodiazepines, PCP, propoxyphene, barbiturates, and THC) continuously for the previous 24 months. Regular drug testing at the clinic was conducted through a computerized random selection of patients at least once per month. All urinalyses were conducted by a certified commercial laboratory. For all

clinical and research purposes, missing urine samples were considered drug-positive. In addition to the patients, 26 non-drug-using volunteers were recruited and assigned to the control group. Qualifying candidates were men and women between 18 and 65 years old and without current diagnosis for mental illness (e.g., schizophrenia) that might affect their ability to respond to the assessments. Control subjects were recruited through advertisements posted at various locations in the community. Initial qualification for participation in the study was determined through a brief telephone interview and, in the case of consenting MMT patients, through evaluation of their urinalysis records. All participating volunteers signed a consent form approved by the institution's review board. Study participants were compensated with $50 for completion of the assessments.

Demographic information for the study sample is presented in Table 1. The groups were similar in age, gender, and racial composition. In the table, significant differences between the groups are identified in the last column by letters (a, b, and c) corresponding to drug-using patients, drug-abstinent patients, and controls. On average, control participants completed more years of education (15.3) than drug-using (12) and drug-abstinent (11) MMT patients. More control participants were employed full-time (95%) than participants in both groups of patients (33.3%). There were no unemployed control participants, whereas 60% and 67% of the drug-using and drug-abstinent patients, respectively, were unemployed at the time of the study. Monthly income differed significantly between the drug-using patients and the control participants only, with controls reporting a higher income. Significantly more patients in both MMT groups than control participants smoked cigarettes. Significantly more drug-using patients were on probation (17%) than abstinent patients (6%) or control participants (none). Both groups of MMT patients reported a higher number of life DWI arrests than control participants, and a significantly higher number of arrests (all kinds) during the previous year were reported by the drug-using patients than by either the abstinent patients or controls.

2.2. Assessments

In addition to a questionnaire designed to collect demographic information and history of drug use, assessments included a computerized DD task (Robles, 2001; Robles and Vargas 2007), Eysenck's I7 Impulsiveness Inventory (Eysenck, 1993; Eysenck, Pearson, Easting, & Allsopp, 1985), the Shipley Living Scale (Zachary, 1991) intelligence test, and, among methadone patients only, a self-administered computer-aided form of the Addiction Severity Index (ASI; McLellan et al., 1985). Also, on the day the assessments were performed, all participants provided a urine sample collected at the study site that was tested for opiates, cocaine, benzodiazepines, amphetamines, and THC. These samples underwent qualitative analysis by a certified commercial laboratory. Data collection for each subject was conducted during a single session lasting approximately 2 hours for patients and 1 hour for participants in the control group. The session duration differed due to the extra time required to complete the ASI.

2.2.1. Eysenck's I7 Impulsiveness Inventory

The Eysenck's I7 Impulsiveness Inventory is a 54-item (true/false) questionnaire composed of the impulsiveness, venturesomeness, and empathy subscales, with reliability of $\alpha = .77$ (Eysenck & Eysenck, 1968; Eysenck, 1993; Eysenck, Pearson, Easting, & Allsopp, 1985).

2.2.2. The Shipley Institute of Living Scale

The Shipley Institute of Living Scale is a brief self-administered instrument that yields IQ estimates strongly correlated with the revised Wechsler Adult Intelligence Scale (WAIS-R) (Zachary, 1991; Zachary, Crumpton, & Spiegel, 1985). The test is composed of two scales: vocabulary and abstraction.

Table 1
Characteristics of the study sample

Study sample	Drug-using patients[a]	Drug-abstinent patients[b]	Controls[c]	$P \leq .05$ *
n	30	30	26	
Age (*SE*)	43.32 (1.43)	46.63 (0.91)	40.90 (1.65)	N/S
Male (%)	53.33	56.67	40.00	N/S
White (%)	93.10	77.40	75.00	N/S
Years of education (SD)	12.16 (0.31)	11.2 (0.35)	15.35 (0.51)	ac, bc
Full-time employed (%)	33.33	33.33	95.00	ac, bc
Unemployed (%)	60.00	66.67	0.00	ac, bc
Median monthly income (IQR)	$750 (150–1,410)	$1,550 (711–2,425)	2,000 (1400–2,500)	ac
On parole (%)	3.33	0.00	0.00	N/S
On probation (%)	16.67	6.67	0.00	ab, ac
Life DWI arrests (*SD*)	1.43 (0.52)	0.83 (0.19)	0.05 (0.05)	ab, ac
All past-year arrests (*SD*)	0.66 (0.18)	0.03 (0.03)	0.00	ab, ac
Cigarettes per day (*SD*)	18.93 (2.17)	16.5 (2.37)	1.4 (1.01)	ac, bc
Current recreational drug use (%)	53.33	0	0.00	ab, ac
Past alcohol problems (%)	56.67	50.00	0.00	ac, bc

* Differences between groups are indicated by the letters a, b, and c in the last column, corresponding to group columns.

2.2.3. The ASI

The ASI (McLellan et al., 1985) is an instrument that assesses the degree of severity of an individual's substance abuse problem during the past month in seven relevant areas: medical, psychiatric, legal, and employment status, as well as drug use, alcohol use, and family/social relationships. Composite scores are derived from responses to items within each of these areas and range from 0.00 to 1.00, with higher scores indicating more severe problems. A computer-assisted self-administered form of the ASI was used (Butler et al., 2001). The composite scores obtained with the self-administered form of the ASI correlate moderately to strongly with those obtained with the interview (0.47–0.87), and both forms have similar reliability (Rosen, Henson, Finney, & Moos, 2000).

2.2.4. Delay discounting

A computerized abbreviated task (Robles, 2001; Robles & Vargas, 2007) was used to estimate individual rates of DD. The program showed a series of computer screens depicting two index cards, one for the immediate and one for the delayed reward. Placement of the cards on the screen was counterbalanced (left–right) across delay values. Participants chose between the two cards by clicking on the "Select" button within each card. Once a choice was made, a full screen marked the 2-second intertrial interval (ITI) and prevented multiple responses. After the ITI, the next choice was presented, and the cycle continued until the end of the assessment. All choices were between hypothetical cash amounts. The magnitude of the delayed reward was $1,000, and the delay intervals tested were 6 hours, 1 day, 1 week, 2 months, 6 months, 1 year, 5 years, and 25 years (after Madden et al., 1997). The values of immediate rewards (all U.S. dollars) tested were 1,000, 999, 995, 990, 960, 940, 920, 850, 800, 750, 700, 650, 600, 550, 500, 450, 400, 350, 300, 250, 200, 150, 100, 80, 60, 40, 20, 10, 5, and 1. In this task, the immediate rewards were presented in descending order, and once a subject showed indifference (i.e., switched from choosing the immediate to the delayed amount), the rest of the trials in the delay series were omitted. The complete DD procedure took approximately 20 minutes. Before the assessment, the experimenter showed each participant how to use the computer mouse; all but one were already familiar with it. Then, participants were given the following instructions:

> This program will show you a series of screens where you will be asked to choose between an amount of money available now, and $1,000 available after some delay. The amount of money available now and the delay between now and the time when you could receive the $ 1,000 will vary from screen to screen. Although the money described in this program is hypothetical, "pretend money," I need you to make the decisions as if you were really going to get the amounts you choose, and honestly select the alternative you prefer. I don't expect you to choose one or the other; please don't choose what you think I might want you to choose, but click on the alternative you really prefer. The program will automatically go on to the next screen, and it will tell you when you are done.

2.3. Data analysis

The data are summarized by either the mean and standard error or the median and interquartile range (IQR). Group comparisons of categorical data were made with the chi-square test. Because of nonnormality of the data, comparison of other demographic characteristics, IQ scores, and urine test results were made with Kruskal–Wallis one-way analysis of variance (ANOVA) with a Bonferroni's adjustment for post hoc comparisons. Comparisons of ASI scores were made with Mann–Whitney rank sum tests. Individual indifference points were obtained, and DD rates (k) were estimated by nonlinear regression using Mazur's hyperbolic model (see Equation 1). Because of nonnormality of k, log-transformed k values were used in the analyses. Trait impulsiveness between the groups was compared with ANOVA and Tukey's honestly significant difference post hoc test. Multiple logistic regression was used to identify predictors of smoking status.

3. Results

3.1. DD rate

Congruent with previous reports, Mazur's hyperbolic model described the data well, accounting for 96%, 98%, and 96% of the variance for MMT nonusers, MMT drug users, and the general population group, respectively (see Fig. 1).

Using IQ, years of education, and income as covariates, significant differences in DD rate (k) by group were detected, $F(2, 83) = 20.63$, $p < .02$. Post hoc comparisons (Tukey's) revealed that the two groups of methadone maintenance patients, mean $\ln(k) = -4.97$ and -5.13, discounted delayed money at significantly higher rates ($p = .001$) than the control group, mean $\ln(k) = -7.07$, whereas no differences in rate of DD were found between the two groups of MMT patients.

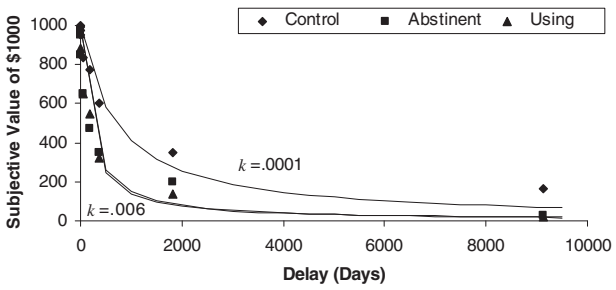

Fig. 1. Rates of delay discounting (k) for drug abstinent patients, drug-using patients, and the control group, respectively. Symbols represent estimated group median rates. Lines depict functions predicted by the hyperbolic model using the empirically derived k values.

3.2. Trait impulsiveness

A one-way ANOVA of scores on Eysenck's I7 Impulsiveness Inventory detected differences among the three groups, $F(2, 83) = 10.4$, $p < .001$. Post hoc analysis (Tukey's) showed that both, the drug-abstinent ($M = 4.4$) and drug-using ($M = 5.36$) groups of MMT patients, scored higher on trait impulsiveness than the control group ($M = 2.9$; both comparisons $p < .05$) and that the two groups of patients did not differ on impulsiveness scores.

Based on a potential relationship revealed by the graphic distribution of scores, the relationship between impulsiveness and years of education was assessed. A Pearson's product–moment test showed a significant negative correlation ($r = -.24$, $p < .03$) between subjects' impulsiveness scores and years of education.

3.3. Intelligence

ANOVA on ranks of IQ scores obtained on the Shipley Living Scale revealed significant differences among the groups ($H = 12.98$, $df = 2$, $p = .002$). Post hoc comparisons showed significantly higher IQ scores among control participants, median IQ = 110 (104–115), compared with drug-using patients, median IQ = 103 (89–111), and abstinent, median IQ = 96 (89–106), $p < .001$, MMT patients; IQ scores for drug-abstinent MMT patients were not significantly different from drug-using patients ($p > .84$).

3.4. Addiction Severity Index

Composite scores for both groups of patients are shown in Table 2. In all domains, the drug-using patients attained equal or higher severity scores than the abstinent patients. Statistically significant differences between the two groups of MMT patients were observed in the legal ($p = .03$), psychiatric ($p \leq .02$), drug use ($p = .02$), and alcohol use ($p = .01$) domains.

3.5. Smoking

A multiple logistic regression analysis was performed with current smoking status (yes/no) as the outcome and DD rate [ln(k)], impulsiveness score, IQ, years of education, and income as predictors among all study participants. Only DD rate (odds ratio = 1.364, 95% confidence interval [CI] = 1.038–1.791) and years of education (odds ratio = 0.741, 95% CI = 0.571–0.961) significantly ($p < .05$) contributed to the resulting model.

Table 2
Median (IQR) ASI composite scores for MMT patients

	Mann–Whitney comparison		
Domain	Drug-abstinent	Drug-using	p
Medical status	.528 (.178–.833)	.531 (.188–.808)	.70
Employment status	.500 (.163–.500)	.500 (.243–.748)	.38
Alcohol use	.192 (.000–.280)	.238 (.168–.405)	.01
Drug use	.169 (.124–.322)	.278 (.192–.367)	.02
Legal status	.000 (.000–.113)	.150 (.000–.210)	.03
Family status	.261 (.200–.384)	.326 (.206–.484)	.10
Psychiatric status	.114 (.450–.347)	.379 (.131–.521)	.02

3.6. Urinalysis

All study participants submitted a urine sample immediately before completing the study assessments. As expected, all urinalysis tests for the control group were negative for all drugs, and all tests for patients in the drug-abstinent group were negative for illegal drugs. On the other hand, urine tests for drug-using MMT patients were positive for cocaine (23%), THC (23%), nonprescribed opiates (10%), benzodiazepines (16%), and amphetamines (3%). None of the participants appeared intoxicated at the time of the assessments.

4. Discussion

Results from this study show that controlling for IQ, years of education, and income, MMT patients who had been continuously abstinent from illicit drugs for at least 2 years did not differ in degree of DD from a group of MMT patients who continued to use illicit drugs. In addition, consistent with previous reports, rates of DD for the control group were lower than the rates observed among both groups of MMT patients. Parallel results were observed on impulsiveness scores; the two groups of MMT patients scored significantly higher than the control participants on trait impulsiveness, whereas no differences were observed between the two groups of MMT patients. These findings are important, considering that the two groups of methadone patients clearly differed in addiction severity as indicated by their ASI scores, the consistency of their urinalysis results and adherence to MMT procedures over 2 years, and the urinalysis results obtained during the study. In other words, significant drug abstinence and increased personal stability were not associated with lower impulsiveness scores or DD rates in our sample of MMT patients. Finally, consistent with previous reports, this study showed significant differences in IQ between the groups, with MMT patients scoring lower than controls.

Our findings differ from several reports showing covariation between DD rate and addiction severity in relation to smoking, alcohol, and cocaine (e.g., Bickel et al., 1999; Bretteville-Jensen, 1999; Kirby & Petry, 2004; Petry, 2001; Tucker et al., 2009). However, the present findings are consistent with studies showing no relationship between DD rate and addiction severity among alcohol, tobacco, marijuana, and cocaine users (e.g., Bickel et al., 1999; Heil et al., 2006; Johnson et al., 2010; Kirby & Petry, 2004; Reynolds & Schiffbauer, 2004); with studies showing that elevated rates of DD may precede drug use (e.g., Audrain-

McGovern et al., 2009; Krishnan-Sarin et al., 2007; Tucker et al., 2002, 2006, 2009; Yoon et al., 2007); with studies showing that DD may be unaffected by drug use and abstinence (e.g., Audrain-McGovern et al., 2009; Heil et al., 2006); and with studies showing differences in DD rate between drug users and nonusing controls (e.g., Bickel et al., 2006; Kirby et al,. 1999; Madden et al., 1997; Odum & Bauman, 2010; Petry & Cassarella, 1999; Reynolds et al., 2004; Richards et al., 1999; Vuchinich & Simpson, 1998).

One viable hypothesis of how DD rate and drug use are functionally related proposes that DD rate changes as a consequence of drug use, increasing with more drug use and decreasing with drug abstinence. Our finding that addiction severity but not DD rate or impulsiveness differed between the groups of patients does not support that hypothesis, at least in MMT patients. Rather, it appears that neither discounting rate nor impulsiveness scores were modified by *efficacious* MMT in this study. An alternative hypothesis states that DD rate may be a preexisting condition acting as a risk factor for drug use and/or or predicting the likelihood of recovery from drugs. Because we found no differences in DD rate between groups of patients that clearly differed in addiction severity, our data suggest that among MMT patients, the rate of DD (as a preexisting condition) may be a risk factor for drug use, but it is not always a reliable predictor of recovery from drug use. It is also possible that DD rates among our sample of patients might have changed over the course of treatment; however, because no baseline measurement of DD rate was obtained in this study, that possibility cannot be directly assessed.

Compared with other populations in which degree of DD has been studied, such as current and ex-users of tobacco and alcohol, there are potentially critical differences with MMT patients that could explain the discrepancy in results regarding addiction severity and DD rate. For example, in contrast with abstinent smokers and drinkers who are not exposed to nicotine and alcohol, MMT patients remain chronically exposed to opioids. To date, it is not known if chronic exposure to opioids might have an increasing effect on DD rate.

In addition, compared with ex-smokers and abstinent drinkers, MMT patients may not require the same level of relapse prevention skills to remain abstinent. On the one hand, tobacco and alcohol are legally and readily available, and on the other, methadone dramatically reduces opioid craving and reward. In other words, it is possible that patients receiving efficacious drug treatment that does not involve prolonged substitution therapy may be forced to develop better self-control skills than patients receiving substitution therapy to remain abstinent; in turn, having better self-control skills should result in lower estimates of DD rate.

Finally, it seems reasonable to think of higher IQ as a proxy for better cognitive functioning (e.g., memory, concentration) and skills (e.g., general quantitative ability, financial planning ability), both of which have been shown to affect DD rate. It is possible, then, that the differences in DD and impulsiveness observed between patients and controls in this study may reflect the differences observed in IQ scores.

Previous research has shown that smokers discount at higher rates than nonsmokers. In addition, the literature suggests that a higher rate of DD is a risk factor for smoking and that taking up smoking or relapsing do not affect DD rate. Because in our sample both groups of MMT patients smoked more than the control group, we conducted a multiple logistic regression analysis to determine the extent to which DD rate, impulsiveness, IQ, years of education, and income might predict smoking status in our samples of patients and controls. Supporting previous findings, our analysis revealed that only two variables were significant predictors of smoking: DD rate (a risk factor) and number of years of education (a protecting factor).

In our sample as a whole, income was not correlated with IQ, years of education, DD rate, or impulsiveness scores. However, control participants reported higher income, more years of education, and lower rate of unemployment than both groups of patients. Our results leave open the possibility that a number of factors including lower IQ, lower educational attainment, low socioeconomic status, and unemployment (all of which tend to covary), along with chronic exposure to opioids and other drug use, may account for the differences in DD rate observed between the MMT patients and control volunteers.

Although this and other cross-sectional studies shed light on our understanding of DD rate and its potential role in preventing and treating substance abuse problems, prospective studies and randomized controlled trials are still needed to unequivocally establish the nature of the relationships between DD rate, addiction severity, cognitive skills, and effective substance abuse treatment.

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