Published in final edited form as:
Exp Clin Psychopharmacol. 2010 February ; 18(1): 99–107. doi:10.1037/a0018333.

Delay Discounting in Current and Former Marijuana-Dependent Individuals

Matthew W. Johnson, Ph.D.,
Department of Psychiatry and Behavioral Sciences, Johnson Hopkins University School of Medicine, 5510 Nathan Shock Drive, Baltimore, MD 21224-6823, Tel: 410-550-0056, Fax: 410-550-0030

Warren K. Bickel, Ph.D.,
Department of Psychiatry and Behavioral Sciences, University of Arkansas for Medical Sciences

Forest Baker, Ph.D.,
Duke University

Brent A. Moore, Ph.D.,
Department of Psychiatry, Yale University School of Medicine

Gary J. Badger, M.S., and
Medical Biostatistics, University of Vermont

Alan J. Budney, Ph.D.
Department of Psychiatry and Behavioral Sciences, University of Arkansas for Medical Sciences

Matthew W. Johnson: mwj@jhu.edu

Abstract

Studies have found that a variety of drug dependent groups discount delayed rewards more than matched-controls. This study compared delay discounting for a hypothetical $1000 reward among dependent marijuana users, former dependent marijuana users, and matched-controls. Discounting of marijuana was also assessed in the currently marijuana-dependent group. No significant difference in discounting was detected among the groups, however currently dependent users showed a trend to discount money more than the other two groups. Within the dependent marijuana group, marijuana was discounted more than money, and discounting for money and marijuana were significantly and positively correlated. Regression analyses indicated that delay discounting was more closely associated with tobacco use than marijuana use. A variety of questionnaires were also administered, including impulsivity questionnaires. Dependent marijuana users scored as significantly more impulsive on the Impulsiveness subscale of the Eysenck Impulsiveness-Venturesomeness-Empathy questionnaire than controls. However, the three groups did not significantly differ on several other personality questionnaires including the Barratt Impulsivity Scale-11. The Stanford Time Perception Inventory Present-Fatalistic subscale was positively correlated with money and marijuana discounting, indicating that a greater sense of powerlessness over the future is related to greater delay discounting. Results suggest that current marijuana dependence may be associated with a trend

Correspondence to: Matthew W. Johnson, mwj@jhu.edu.

toward increased delay discounting, but this effect size appears to be smaller for marijuana than for previously examined drugs.

Keywords

marijuana; cannabis; delay discounting; temporal discounting; drug dependence

Delay discounting refers to the observation that a consequence's control over behavior decreases with increasing delay until the receipt of that consequence. At its core, delay discounting is an intuitive concept, in that when offered a choice between receiving $1,000 now, versus receiving $1,000 after a 1-year delay, most individuals would prefer the immediate $1,000. However, by systematically adjusting choices, as in psychophysical experiments, this intuitive concept becomes a powerful tool for understanding fundamental processes in decision-making. So, to continue with the example, when faced with the choice between receiving $900 now versus receiving $1,000 after a 1-year delay, some people may still prefer the immediate option, but others may prefer to wait for the larger delayed option. Likewise, when the immediate option becomes $800 now, an even larger proportion of individuals may prefer the delayed option. By assessing such choices in individuals across a variety of delays, delay discounting procedures are able to specifically quantify the devaluation of rewards across delays, which in turn allows for an a index of overall discounting rate. Because the degree to which an individual discounts by delay is quantified using choice procedures, delay discounting is considered a behavioral index of impulsivity.

Several studies have shown that drug-dependent individuals discount delayed money rewards significantly more than matched-control non-dependent individuals. Delay discounting seems to model a cardinal feature of drug dependence: chronically choosing a smaller immediate reward (the drug) over larger but delayed rewards (improved health, employment, family life, etc.). Populations shown to discount significantly more than controls include heroin-dependent individuals (e.g., Kirby, Petry & Bickel, 1999; Madden, Petry, Badger & Bickel, 1997), dependent tobacco cigarette smokers (e.g., Baker, Johnson & Bickel, 2003; Bickel, Odum & Madden, 1999; Johnson, Bickel & Baker, 2007; Mitchell, 1999; Reynolds, 2006), alcoholics (e.g., Petry, 2001; Vuchinich and Simpson, 1998), and cocaine dependent individuals (.e.g., Coffey, Gudleski, Saladin, Brady, 2003; Heil, Johnson, Higgins & Bickel, 2006). In addition to finding that drug dependent individuals discount money more than controls, several studies have found that drug dependent individuals discount delayed drugs more than delayed money (Baker et al., 2003; Bickel et al., 1999; Coffey et al., 2003; Madden et al., 1997; Petry, 2001). These findings suggest that delay discounting may be fundamentally involved in the process of drug dependence (Bickel and Johnson, 2003).

The purpose of the present study was to extend the investigation of delay discounting to dependent marijuana users. The study was conceptualized from a theoretical perspective assuming that as a drug of dependence, marijuana is similar to other drugs of dependence across multiple key domains, including having a specific neuropharmacological substrate with ties to brain reward systems, a characteristic withdrawal syndrome, and the occurrence of frequent relapse among those in treatment (Budney & Moore, 2002). It was hypothesized, therefore, that marijuana dependent individuals would show greater delay discounting than matched non-marijuana dependent participants, similar to findings with other drugs of dependence. Although group differences for delay discounting between dependent marijuana users and controls have not been examined, two studies have examined marijuana or delta-9-tetrahydrocannabinol (THC; the principle active constituent of marijuana) in the context of delay discounting. McDonald, Schleifer, Richards, and de Wit (2003) found that acute THC administration to non-dependent marijuana users resulted in no significant changes in delay discounting

performance. However, the acute effects of a drug on discounting may not necessarily be related to population differences between dependent users and controls. Kollins (2003) found that age of first marijuana use was significantly correlated with discounting (earlier use associated with increased discounting). Again, it is unclear whether these results would suggest group differences between dependent users and controls.

In addition to a currently dependent marijuana-using group and matched-control nonuser group, we also examined a matched group of former (dependent) marijuana users. This provided the opportunity to extend previous results with other drugs showing that former dependent users discount less than currently dependent users (Bickel et al., 1999; Petry, 2001). The hypothesis in the present study was that if the currently marijuana dependent group discounted more than non-user controls, then the former marijuana dependent group would discount less than the currently marijuana dependent group. Participants in all three groups performed a delay discounting procedure for a $1000 hypothetical monetary reward. Previous studies have supported the validity of hypothetical-choice methods in delay discounting (Johnson & Bickel, 2002; Lagorio & Madden, 2005; Madden et al., 2003, 2004). In an attempt to extend findings with other drugs showing that dependent users discount the drug more than money (Baker et al., 2003; Bickel et al., 1999; Coffey et al., 2003; Madden et al., 1997; Petry, 2001), discounting for hypothetical marijuana was assessed in the currently marijuana-dependent group. Our expectation, as with other drugs of dependence (and also other primary reinforcers; Estle, Green, Myerson & Holt, 2007; Odum & Baumann, 2008; Odum, Baumann & Rimmington, 2006; Odum & Rainaud, 2003), was that discounting of marijuana would be significantly greater than discounting of money. Tobacco users made up a roughly equal percentage of each group. Because tobacco use has been widely associated with increased delay discounting across several studies, regression analyses explored the relative contribution of tobacco and marijuana use on delay discounting in the present study. This analysis of tobacco use, which is known to relate to delay discounting, served to provide a positive control by which to judge results obtained regarding marijuana use and delay discounting.

Participants also completed a variety of questionnaires and tasks assessing impulsivity and other domains that may relate to impulsivity, in order to assess their relationship with delay discounting and/or marijuana dependence. These included two widely used questionnaire measures of impulsivity, the Eysenck Impulsiveness-Venturesomeness-Empathy questionnaire (IVE or I7; Eysenck & Eysenck, 1978; Eysenck, Easting & Allsopp, 1985), and the Barratt Impulsivity Scale-11 (BIS-11; Barratt, 1985; Patton et al., 1995). Beyond questionnaire measures assessing impulsivity *per se*, participants completed three tasks assessing one's degree of psychological orientation toward the future or future consequences - the Future Time Perspective (FTP; Wallace, 1956), the Stanford Time Perception Inventory (STPI; Zimbardo, 1992), and the Consideration of Future Consequences Scale (CFCS; Strathman, Gleicher, Boninger, & Edwards et al., 1994) - based on the hypothesis that these measures may assess a similar construct as delay discounting. Based on the hypothesis that childhood experiences of environmental instability and unpredictability may provide little experience with delayed reinforcement, and therefore may contribute to increased rates of delay discounting and drug dependence in adulthood, the Retrospective Family Unpredictability Scale was also included as a measure (R-FUS; Ross & Hill, 2000; Ross & McDuff, 2008).

Method

Participants

All participants were recruited through local newspaper advertisements and fliers. Criteria for all three groups were determined before participant recruitment and data collection. The current and former marijuana-dependent groups were recruited specifically for this study. The non-using control participants were selected from among volunteers participating in a concurrently

running study administering the same measures (Baker et al., 2003). Selection of these control subjects was based on demographic variables in Table 1 in order to match the other groups. Outcome measures were completely disregarded in control group selection. Exclusion criteria for all groups were: age less than 18 years, evidence of a psychiatric disorder within the last year, having received psychiatric care or taken psychiatric medications within the last year, self-reported diagnosis of a psychiatric disorder within the lifetime (with the exception of drug abuse/dependence), evidence of anxiety disorder since age 16 years, suicidal attempts or ideation in the past year, and currently meeting DSM-IV criteria for drug abuse or dependence other than for marijuana, tobacco, and caffeine. DSM-IV criteria were determined using checklists originally developed by Hudziak et al. (1993) and updated from DSM-III-R criteria to DSM-IV criteria. The 30 currently marijuana-dependent participants had to have reported using marijuana on at least 25 days per month for the last six consecutive months, satisfy three or more of the DSM-IV criteria for marijuana dependence, not be currently seeking treatment for their marijuana use, and not be using marijuana to treat a medical condition. The 30 ex-dependent marijuana users had to satisfy these same criteria via retrospective self-report for at least six consecutive months of past use, but have reported no marijuana use within the last year. The 22 control participants had to have reported using marijuana less than 40 times in the lifetime and not within the last six months. The criteria of 40 uses, which allowed for the inclusion of individuals who could be considered light experimental users, was determined before the study began, and was used for the control group because of the high prevalence of marijuana use relative to other drugs of abuse would make recruitment challenging. Further, using a control group that consisted of 100% never-users of marijuana might call into question the normative nature of the control group. We attempted to match the three groups on demographic and drug use characteristics (Table 1). The only statistical difference detected in the final sample was that the currently marijuana-dependent individuals had a higher Quick Test (Ammons & Ammons, 1962) intelligence score than the control group and the ex-dependent group.

Procedure

A research assistant initially interviewed potential participants over the telephone. This interview collected demographic information and screened out substance abuse or psychiatric disorders. Qualified individuals were invited to participate in the study, which required attending one 2 – 3 hour session. Participants gave written informed consent for the study, which was approved by the University of Vermont Institutional Review Board. Participants were studied individually and received $15 per hour compensation.

Research sessions were conducted individually with each participant. All participants signed an informed consent form. The currently marijuana-dependent individuals were asked to specify an amount of marijuana that would be equivalent to receiving $1000.

> I want you to imagine that you have a choice between receiving some money and receiving some marijuana. For the following statement, please fill in the number of ounces of marijuana that would make the two choices equally attractive to you. Receiving $1000 right now would be just as attractive as receiving _____ ounces of marijuana.

After answering the equivalence question, participants were administered the Quick Test (Ammons & Ammons, 1962) to obtain a measure of intelligence. The participants then performed the Future Time Perspective tasks I, II, and III (Wallace, 1956). The FTP has previously found that opioid-dependent individuals have a shorter future time perspective than match control individuals (Petry, Bickel, Arnett, 1998). The FTP generally assesses the how far into the future one tends to project when answering open-ended questions, and results in five dependent measures as described by Petry and colleagues. Next, the participants completed

the IVE questionnaire (Eysenck and Eysenck (1978). This questionnaire results in three subscales: Impulsiveness (the degree to which one behaves without thought of risks or consequences), Venturesomeness (the propensity to behave despite having the knowledge of possible risks), and Empathy. After this, the participants performed the delay discounting assessment computer program for money and marijuana (only in the current marijuana group). All participants also completed a health delay discounting measure similar to the money and marijuana discounting measures; however, the health procedure failed to yield systematic data in this study and its data are not shown. The order in which these commodities were examined was counterbalanced. Participants then completed the BIS-11 questionnaire (Barratt, 1985; Patton et al., 1995), which results in three factors: non-planning, motor impulsivity, and cognitive impulsivity. Next, participants completed the STPI questionnaire (Zimbardo, 1992), which provides scores for five different categories of time perspective and their psychological consequences: future-oriented (planning, focus on the future), past-oriented (focus on the past), present-hedonic (present focus based on enjoyment), present-fatalistic (present focus based on a sense of powerlessness over the future), and time press (importance of time as a resource). Participants then completed the CFCS questionnaire (Strathman et al., 1994), which results in a single score reflecting the extent to which future consequences are considered. After this, participants completed the R-FUS (Ross & Hill, 2000; Ross & McDuff, 2008), from which a total unpredictability score was calculated reflecting the extent of unpredictability in one's childhood family environment.

Delay Discounting Assessment

Delay discounting was assessed with an interactive computer program written in Visual Basic © presented on a laptop computer (Johnson & Bickel, 2002). On each trial the participant chose between two hypothetical options: a smaller immediate reward presented in a rectangle on the left of the screen, and a larger delayed reward presented in a rectangle on the right of the screen. For example, one possible set of options was "Receive $500 right away" and "Receive $1000 after waiting 1 month." Above and centered between the two rectangles was a circle, which remained green while awaiting the participant's response. The participant was instructed to click on the rectangle showing the option he or she would prefer. Upon selection of one of the two rewards, the circle turned red for 1-second while new choices were presented in the rectangles. While the circle was red, responses could not be registered. Once the circle was green again, the participant was free to respond to the next trial.

In order to obtain indifference points, the magnitude of the smaller immediate reward was adjusted according to a double limit algorithm (Richards, Zhang, Mitchell & de Wit, 1999). This algorithm adjusted the smaller immediate reward magnitude in $20 blocks across trials in order to converge on a point of indifference with the delayed $1000 reward. One advantage of this algorithm is that it functions to confirm previous responses, and therefore safeguards against any single erroneously registered choice from determining an indifference point. Indifference points for seven delays until the larger delayed reward were determined in succession. Delays used were: 1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years. A randomly determined half of participants received these delays in ascending order, and the other half received these delays in descending order. See Johnson and Bickel (2002) for a more detailed description of the delay discounting computer procedure.

Finally, only for the currently dependent marijuana using group, the delay discounting of marijuana rewards was assessed with an analogous procedure using amounts of hypothetical marijuana as the smaller immediate and larger later rewards. The amount of marijuana subjectively equivalent to $1000 obtained from the participant earlier in the session served as the larger later reward, and a smaller amount of immediately available marijuana served as the smaller immediate reward. Marijuana amounts were expressed in ounces, quarter ounces, and

eighth ounces. For example, one possible set of options was “Receive now: 2 ounces, plus two quarter ounces, plus one eighth ounce” and “Wait 1 month and then receive: 4 ounces.” The magnitude of the immediately available marijuana was adjusted by the algorithm across trials using eighth ounce blocks.

For each discounting assessment of each commodity, the seven indifference points were used to estimate the *k* parameter value in the hyperbolic decay model (specified in Equation 1; Mazur, 1987),

$$\text{Indifference point} = \frac{\text{Larger later amount}}{1 + k \times \text{Delay}} \quad (1)$$

where *k* is a free parameter representing the extent to which the reward is discounted. Estimates of the *k* parameter were obtained with least squares nonlinear regression. The time unit of days was used as for the D variable in all regression analyses; therefore, all *k* estimates carry the reciprocal of days (i.e., days^{-1}) as units. A logarithm (base 10) transformation was applied to the *k* parameter estimates before parametric statistics were applied, because discounting parameters are typically positively skewed (Myerson & Green, 1995; Rachlin, Raineri & Cross, 1991; Richards et al., 1999). In addition, for each set of indifference points, an area under the curve measure was calculated using the method described in Myerson, Green & Warusawitharana (2001). This method makes no assumption about the mathematical form of the discounting function.

Results

An algorithm (Johnson and Bickel, 2008) was applied to the discounting data of each commodity for each participant in order to identify nonsystematic discounting data (i.e., instances in which the participant may have been inattentive or otherwise insensitive to the task). This algorithm was intended to identify instances in which indifference points were not generally monotonically decreasing with delay, or in which no evidence of discounting was apparent even at the 25-year delay. Specifically, data were identified as nonsystematic if either of the two following criteria were met: 1) if any indifference point (starting with the 1-week delay) was greater than the preceding indifference point by a magnitude greater than 20% of the larger later reward (e.g., $200 in the money condition); 2) if the 25-year indifference point was not less than the 1-day indifference point by at least a magnitude equal to 10% of the larger later reward (e.g., $100 in the money condition). Meeting the first criteria calls into question the systematic nature of the data because it indicated that the value of a reward increases with delay, which violates the most basic expectation of delay discounting data and suggests idiosyncratic rule-governed behavior or inattention. Meeting the second criteria indicates that the independent variable (delay) shows no relationship with the dependent variable (reward value), suggesting insensitivity to the task. When applied to money, the algorithm found 2, 1, and 2 nonsystematic discounting functions in the current, ex, and control groups, respectively, resulting in 77 participants with systematic money discounting data. When applied to marijuana discounting in the currently marijuana-dependent group, the algorithm found 4 nonsystematic discounting functions, resulting in 26 participants with systematic marijuana discounting data. In all subsequent analyses involving discounting data, these nonsystematic data were omitted. If a participant had nonsystematic data for a commodity, only data for that commodity were eliminated; systematic data for other commodities for that participant were included in analyses. Residual analyses of the remaining discounting curves supported the fit of Equation 1.

Group and Commodity Delay Discounting Comparisons

Figure 1 shows individual k values and group means for all three groups, and for both money and marijuana. The figure indicates that groups did not reliably differ in discounting. For statistical comparison of delay discounting across the groups for money discounting, Quick Test intelligence score was included as a covariate. Similar analyses without the covariate did not change the results. For statistical tests involving delay discounting (across groups and between money and marijuana as commodities) but not involving questionnaire results, alpha was set at .05 for significance testing. A one-way ANOVA examining money discounting (transformed k) compared the three marijuana-use groups for the 77 participants with systematic money discounting data. The group effect was not significant [$F(2,73)=1.05$, $p=.35$].

In order to compare both commodities (money and marijuana), a repeated measures ANOVA within the currently marijuana-dependent group compared the discounting of money and marijuana in the 24 individuals with systematic data for both commodities. The commodity effect was significant [$F(1,23)=15.38$, $p<.001$], showing that marijuana was discounted significantly more than money. To explore the nature of this difference, a similar repeated measures ANOVA was conducted while controlling for reported marijuana use rate (bouts per day). The difference between money and marijuana discounting was no longer significant after controlling for marijuana use rate [$F(1,22)=1.83$, $p=.19$]. All discounting analyses were replicated using the area under the curve measure (AUC; Myerson, et al., 2001) instead of the transformed *k* measure. Performing analyses with AUC rather than transformed k did not change whether any results reached significance.

Relative Association of Marijuana and Tobacco Use with Delay Discounting

In order to further explore the association of marijuana and tobacco use with discounting, a multiple regression analysis was performed on money discounting (transformed k) using the following variables as predictors loaded in a single step: marijuana use bouts per day, tobacco cigarettes smoked per day, and intelligence score (because intelligence score differed across groups). Results are presented in Table 2. Beta values (standardized partial regression coefficients) represent the relative contribution of each variable for predicting money discounting in the context of the other predictor variables. The only significant predictor of discounting was tobacco cigarettes smoked per day.

Evaluating Delay Discounting Results Relative to Previous Findings with Other Drugs of Dependence

Because analyses showed a non-significant trend for the currently marijuana dependent group to discount money more than the other groups, an analysis of effect size was conducted to evaluate the marijuana results relative to data from previously published drug dependent groups. Cohen's d (using the pooled standard deviation) was calculated for the transformed k money data between the currently marijuana-dependent and control groups, and was found to be 0.20, indicating a small effect. For comparison, Cohen's d was also determined for three previously published studies conducted in the same laboratory comparing drug-dependent and control groups in money discounting. Cohen's d was found to be 0.78 for a study comparing opioid dependent and control participants (Madden et al., 1997), and was found to be 0.80 (Bickel et al., 1999) and 0.81 (Baker et al., 2003) for two studies comparing heavy tobacco smokers and control participants. Using the standard deviations and number of participants with systematic data from the currently-dependent and control groups, it was determined that this study had power equal to .76 to find a significant difference of effect size 0.80 (approximate effect size in the previous studies mentioned above) at alpha=.05.

Correlation between Discounting Measures

The correlation between money and marijuana discounting within the currently marijuana-dependent group was significant and positive (r=.723, n=24, p<.001).

Group Comparisons of Questionnaires

Due to the number of statistical comparisons involving the questionnaire scales, alpha was set at .01 for significance testing of group comparisons of questionnaire measures, and correlations between delay discounting and questionnaire measures. The scales from the various questionnaires are presented in Table 3. These scales were compared across the three groups using ANOVA with intelligence as a covariate, with the exception that FTP measures were compared using Kruskal-Wallis tests due to skewed data. The only significant differences between the groups were on the Eysenck Impulsiveness subscale [F(2,79)=11.47, p<.001] and the STPI Present-hedonic subscale [F(2,79)=5.50, p<.01]. Tukey HSD post hoc tests revealed that the currently marijuana-dependent group scored significantly higher than the control group on the IVE Impulsivity subscale (p<.001). Other post hoc comparisons for the IVE Impulsivity subscale and all comparisons for the STPI Present-Hedonic subscale were not significant, although the trend was for the control group to score lower than the ex and currently dependent groups.

Correlations between Discounting Measures and Questionnaire Measures

Correlations were performed comparing money discounting to all questionnaire scales (Pearson's correlations with the exception of FTP scales in which Spearman's correlations were used). These correlations only included the participant who provided systematic data (i.e., 77 out of 82 from all groups for money discounting, and 26 out of 30 in the currently dependent marijuana group for marijuana discounting). Across all groups, money discounting was significantly and positively correlated with the STPI present-fatalistic subscales (r=.293, n=77, p=.01). Spearman correlations were also performed within the currently marijuana-dependent group between marijuana discounting and the various questionnaire scales. Marijuana discounting was significantly and positively correlated with the STPI present-fatalistic scale (r=.583, n=26, p<.01). No other tested correlations were significant.

Discussion

Contrary to the study hypothesis and in contrast with previous studies showing drug-dependent groups discount more than control groups, marijuana dependent individuals were not found to discount significantly more than the non-user control group. This lack of effect does not appear to be due to a lack of sufficient power to detect effect sizes found in previous studies with other drug dependent populations. The present study employed a similar number of participants as several published studies showing significant differences between drug dependent individuals and control individuals (e.g., Bickel et al., 1999; Coffey et al., 2003; Heyman & Gibb, 2006; Mitchell et al., 2005; Petry & Casarella, 1999; Reynolds, 2006; Vuchinich & Simpson, 1998). One possible interpretation is that marijuana dependence, unlike other forms of drug dependence, is not associated with increased discounting. However, this seems unlikely given that there was a trend for currently marijuana-dependent individuals to discount money more than controls. The effect size of this trend indicated a smaller effect than that found in other drug-dependent and control comparisons collected with similar methods in the same laboratory. Consistent with this interpretation, regression results suggest that within the present study, delay discounting was more closely associated with tobacco use than marijuana use. It remains unclear whether a substantially larger study might detect a significant difference between currently marijuana-dependent individuals and matched controls. Figure 1 suggests the possibility that the currently marijuana-dependent group may consist of a flatter distribution (and perhaps a trend toward a bimodal distribution) in money discounting, suggesting that

marijuana dependence may be more strongly associated with delay discounting for a subgroup of dependent users. A tentative conclusion at the present time is that marijuana dependence may be associated with delay discounting, but less so than forms of drug dependence previously investigated (e.g., tobacco, cocaine, opioids, alcohol). If this conclusion is correct, then the present data also suggest that, as with tobacco and alcohol (Bickel et al., 1999; Petry, 2001), former dependent marijuana users discount less than currently dependent users.

Marijuana dependence shares several commonalities with other forms of drug dependence, including having a neuropharmacological substrate with ties to brain reward systems, a characteristic withdrawal syndrome, and frequent relapse among those in treatment (Budney & Moore, 2002). Why, then, would it differ from other drugs in the strength of its association with delay discounting? Perhaps an important framework for understanding drug dependence is that different drugs can be rank ordered along multiple dimensions related to their dependence potential. For example, while psychomotor stimulants such as cocaine typically rank high on several measures of laboratory drug reinforcement (e.g., Griffiths, Brady & Bradford, 1979), they are associated with only relatively mild (i.e., not medically severe) withdrawal symptoms among dependent users (Lago & Kosten, 1994). In other words, while drug withdrawal is an important clinical phenomenon in drug dependence, it plays a less prominent role for stimulant dependence relative to sedatives and opioid dependence. Similarly, while delay discounting may be an important clinical phenomenon in drug dependence generally, the present results suggest it may play a relatively small role in marijuana dependence relative to other drugs such as tobacco. Indeed, drug dependence may result from multiple underlying processes, and delay discounting may be only one of those processes (Bickel and Johnson, 2003).

One possible explanation for a weaker association between delay discounting and marijuana dependence relative to other drugs previously studied may be that marijuana is associated in the public view with less salient future health consequences. Perhaps low discounters may be dissuaded from trying drugs such as tobacco, resulting in a disproportionate number of high discounters initiating these drugs (with some proportion going on to become dependent). To the extent that the public may view marijuana as less associated with future negative consequences, a broader array of individuals along the distribution of discounting in the population may initiate marijuana use, with some proportion of those initiates becoming dependent. Consistent with this hypothesis, data from the National Comorbidity Study indicate a larger proportion of the population has used marijuana compared to other illicit drugs (Anthony, Warner & Kessler, 1994). Although only a proportion of these become dependent (at a roughly similar rate to other drugs of abuse), the resulting sizeable marijuana-dependent population may include a relatively large distribution of individuals across the delay-discounting continuum. This may seem inconsistent with the strong association between delay discounting and tobacco use, which is even more prevalent than marijuana use. However, it is possible that the very well-known and salient future health consequences of tobacco use make it a special case, that is, a drug especially prone to self-selection of high discounters, as mentioned above. It should be noted that this suggested hypothesis assumes that increased delay discounting causes drug dependence, whereas it may also be possible that drug use increases delay discounting. However, the two possibilities are not mutually exclusive, and it seems likely that both may be true.

Of the 18 personality questionnaire subscales examined in this study, only the Eysenck IVE Impulsivity subscale, which measures the degree to which one behaves without thought of risks or consequences, statistically differentiated the marijuana-dependent group from the control group. There is no clear explanation as to why scores on this specific scale but not others, including the BIS-11, showed differences across groups.

The currently marijuana-dependent group discounted marijuana significantly more than money. The observation that marijuana dependent individuals discount future marijuana more than an equivalent amount of money is consistent with studies demonstrating that tobacco, heroin, and crack/cocaine dependent individuals discount their drug of dependence more so than money (Baker et al., 2003; Bickel et al., 1999; Coffey et al., 2003; Madden et al., 1997; Petry, 2001). However, because the discounting of other non-monetary, consumable commodities was not assessed in these studies, one cannot determine if rapid discounting of the drug is indicative of a drug of dependence, or is a more general feature of consumable commodities or primary reinforcers. That is, a number of studies have shown that non-drug consumable reinforcers such as food are discounted more than money (Estle et al., 2007; Odum & Baumann, 2008; Odum & Rainaud, 2003; Odum, et al., 2006). The present results showing that the difference between money and marijuana discounting was no longer significant after controlling for marijuana consumption rate is consistent with the interpretation that marijuana was discounted more than money because it is a consumable, primary reinforcer.

Both discounting measures were positively and significantly correlated with each other. The STPI Present-Fatalistic subscale was positively correlated with money and marijuana discounting, indicating that a greater sense of powerlessness over the future is related to greater delay discounting. However, no significant correlations were found between delay discounting and other questionnaire scales. These results are consistent with the variability observed across studies in previous research examining the correlations between discounting and personality questionnaires (e.g., Coffey et al., 2003; Madden et al., 1997; Mitchell, 1999; Richards et al., 1999). In the present study, the correlation between money and marijuana discounting was higher than correlations between discounting and personality questionnaires, suggesting that although commodities can be discounted at different rates, individuals nonetheless have some trait-like disposition toward delay discounting that is relatively distinct from what is captured by questionnaire measures.

If future studies yield similar results, they may confirm that the association between discounting and drug dependence may be weaker for marijuana than for previously studied drugs (e.g., tobacco, cocaine, opioids, alcohol). Future research examining discounting in a wider variety of populations (i.e. different drugs of abuse) may help to further examine the contribution of delay discounting to the phenomenon of drug dependence.

Acknowledgments

The research was supported by National Institute on Drug Abuse Grants R01 DA11692 and T32 DA07242. We thank Amy E. H. Prue for her assistance in collecting and organizing the data.

References

Ammons RB, Ammons CH. The Quick Test (QT): Provisional manual. Psychological Reports 1962;11:111–161.

Anthony JC, Warner LA, Kessler RC. Comparative epidemiology of dependence on tobacco, alcohol, controlled substances, and inhalants: Basic findings from the national comorbidity survey. Experimental and Clinical Psychopharmacology 1994;2:244–268.

Baker F, Johnson MW, Bickel WK. Delay discounting in current and never-before cigarette smokers: Similarities and differences across commodity, sign, and magnitude. Journal of Abnormal Psychology 2003;112:382–392. [PubMed: 12943017]

Barratt, ES. Impulsiveness subtraits: Arousal and information processing. In: Spence, JT.; Izard, CE., editors. Movtivation, Emotion, and Personality. North Holland: Elsevier Science Publishers; 1985. p. 137-146.

Bickel W, Odum A, Madden GJ. Impulsivity and cigarette smoking: delay discounting in current, never, and ex-smokers. Psychopharmacology 1999;146:447–454. [PubMed: 10550495]

Bickel, W.; Johnson, MW. Delay Discounting: A fundamental Behavioral Process of Drug Dependence. In: Lowenstein, G.; Read, D.; Baumeister, R., editors. Time and Decision: Economic and Psychological Perspective on Intertemporal Choice. New York: Russell Sage Foundation; 2003. p. 419-440.

Budney AJ, Moore BA. Development and consequences of cannabis dependence. Journal of Clinical Pharmacology 2002;42(11 Suppl):28S–33S. [PubMed: 12412833]

Coffey SF, Gudleski GD, Saladin ME, Brady KT. Impulsivity and rapid discounting of delayed hypothetical rewards in cocaine-dependent individuals. Experimental and Clinical Psychopharmacology 2003;11:18–25. [PubMed: 12622340]

Epstein LH, Richards JB, Saad FG, Paluch RA, Roemmich JN, Lerman C. Comparison between two measures of delay discounting in smokers. Experimental and Clinical Psychopharmacology 2003;11:131–138. [PubMed: 12755457]

Estle SJ, Green L, Myerson J, Holt DD. Discounting of monetary and directly consumable rewards. Psychol Sci 2007;18:58–63. [PubMed: 17362379]

Eysenck SB, Eysenck HJ. Impulsiveness and venturesomeness: Their position in a dimensional system of personality description. Psychological Reports 1978;43:1247–1255. [PubMed: 746091]

Eysenck SB, Pearson PR, Easting G, Allsopp JF. Age norms for impulsiveness, ventruesomeness and empathy in adults. Person Individ Diff 1985;6:613–619.

Griffiths, RR.; Brady, JV.; Bradford, LD. Predicting the abuse liability of drugs with animal drug self-administration procedures: Psychomotor stimulants and hallucinogens. In: Thompson, T.; Dews, PB., editors. Advances in behavioral pharmacology. Vol. 2. New York: Academic Press; 1979. p. 163-208.

Heil SH, Johnson MW, Higgins ST, Bickel WK. Delay discounting in currently using and currently abstinent cocaine-dependent outpatients and non-drug-using matched controls. Addictive Behaviors 2006;31:1290–1294. [PubMed: 16236455]

Heyman GM, Gibb SP. Delay discounting in college cigarette chippers. Behav Pharmacol 2006;17:669–679. [PubMed: 17110793]

Hudziak J, Helzer JE, Wetzel MW, Kessel KB, McBee B, Janca A, et al. The use of the DSM-III-R Checklist for initial diagnostic assessments. Comprehensive Psychiatry 1993;34:375–383. [PubMed: 8131381]

Johnson MW, Bickel WK. Within-subject comparison of real and hypothetical money rewards in delay discounting. Journal of Experimental Analysis of Behavior 2002;77:129–146.

Johnson MW, Bickel WK. An algorithm for identifying nonsystematic delay-discounting data. Experimental and Clinical Psychopharmacology 2008;16:264–274. [PubMed: 18540786]

Johnson MW, Bickel WK, Baker F. Moderate drug use and delay discounting: a comparison of heavy, light, and never smokers. Experimental and Clinical Psychopharmacology 2007;15:187–194. [PubMed: 17469942]

Kirby KN, Petry NM, Bickel WK. Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. Journal of Experimental Psychology: General 1999;128:78–87. [PubMed: 10100392]

Kollins. Delay discounting is associated with substance use in college students. Addict Behav 2003;28:1167–1173. [PubMed: 12834659]

Lago JA, Kosten TR. Stimulant withdrawal. Addiction 1994;89:1477–1481. [PubMed: 7841859]

Lagorio CH, Madden GJ. Delay discounting of real and hypothetical rewards III: steady-state assessments, forced-choice trials, and all real rewards. Behav Processes 2005;69:173–187. [PubMed: 15845306]

Madden GJ, Begotka AM, Raiff BR, Kastern LL. Delay discounting of real and hypothetical rewards. Experimental and Clinical Psychopharmacology 2003;11:139–145. [PubMed: 12755458]

Madden GJ, Petry NM, Badger GJ, Bickel WK. Impulsive and self-control choices in opioid-dependent patients and non-drug-using control patients: Drug and monetary rewards. Experimental & Clinical Psychopharmacology 1997;5:256–262. [PubMed: 9260073]

Madden GJ, Raiff BR, Lagorio CH, Begotka AM, Mueller AM, Hehli DJ, Wegener AA. Delay discounting of potentially real and hypothetical rewards: II. Between- and within-subject comparisons. Experimental and Clinical Psychopharmacology 2004;12:251–61. [PubMed: 15571442]

Mazur, JE. An adjusting procedure for studying delayed reinforcement. In: Commons, ML.; Mazur, JE.; Nevin, JA.; Rachlin, H., editors. Quantitative Analysis of Behavior: Vol. 5. The Effect of Delay and of Intervening Events on Reinforcement Value. Hillsdale, NJ: Erlbaum; 1987. p. 55-73.

McDonald J, Schleifer L, Richards JB, de Wit H. Effects of THC on behavioral measures of impulsivity in humans. Neuropsychopharmacology 2003;28:1356–1365. [PubMed: 12784123]

Mitchell JM, Fields HL, D'Esposito M, Boettiger CA. Impulsive responding in alcoholics. Alcohol Clin Exp Res 2005;29:2158–2169. [PubMed: 16385186]

Mitchell SH. Measures of impulsivity in cigarette smokers and nonsmokers. Psychopharmacology 1999;146:455–464. [PubMed: 10550496]

Myerson J, Green L. Discounting of delayed rewards: Models of individual choice. Journal of the Experimental Analysis of Behavior 1995;64:263–276. [PubMed: 16812772]

Myerson J, Green L, Warusawitharana M. Area under the curve as a measure of discounting. Journal of the Experimental Analysis of Behavior 2001;76:235–243. [PubMed: 11599641]

Odum AL, Baumann AA. Cigarette smokers show steeper discounting of both food and cigarettes than money. Drug Alcohol Depend 2007;91:293–296. [PubMed: 17720334]

Odum AL, Baumann AA, Rimington DD. Discounting of delayed hypothetical money and food: effects of amount. Behav Process 2006;73:278–284.

Odum AL, Rainaud CP. Discounting of delayed hypothetical money, alcohol, and food. Behav Process 2003;64:305–313.

Ohmura Y, Takahashi T, Kitamura N. Discounting delayed and probabilistic monetary gains and losses by smokers of cigarettes. Psychopharmacology 2005;182:508–515. [PubMed: 16167142]

Patton JH, Stanford MS, Barratt ES. Factor structure of the Barratt impulsiveness scale. J Clin Psychol 1995;51:768–774. [PubMed: 8778124]

Petry NM, Bickel WK, Arnett M. Shortened time horizons and insensitivity to future consequences in heroin addicts. Addiction 1998;93:729–38. [PubMed: 9692271]

Petry NM, Casarella T. Excessive discounting of delayed rewards in substance abusers with gambling problems. Drug and Alcohol Dependence 1999;56:25–32. [PubMed: 10462089]

Petry NM. Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. Psychopharmacology 2001;154:243–250. [PubMed: 11351931]

Rachlin H, Raineri A, Cross D. Subjective probability and delay. Journal of the Experimental Analysis of Behavior 1991;55:233–244. [PubMed: 2037827]

Reynolds B. Do high rates of cigarette consumption increase delay discounting? A cross-sectional comparison of adolescent smokers and young-adult smokers and nonsmokers. Behavioural Processes 2004;67:545–549. [PubMed: 15519004]

Reynolds B. The Experiential Discounting Task is sensitive to cigarette-smoking status and correlates with a measure of delay discounting. Behavioural Pharmacology 2006;17:133–42. [PubMed: 16495721]

Richards JB, Zhang L, Mitchell SH, de Wit H. Delay or probability discounting in a model of impulsive behavior: Effect of alcohol. Journal of the Experimental Analysis of Behavior 1999;71:121–143. [PubMed: 10220927]

Ross LT, Hill EM. The Family Unpredictability Scale: Reliability and validity. Journal of Marriage and the Family 2000;62:549–562.

Ross LT, McDuff JA. The Retrospective Family Unpredictability Scale: Reliability and Validity. J Child Fam Stud 2008;17:13–27.

Strathman A, Gleicher F, Boninger DS, Edwards CS. The consideration of future consequences: Weighing immediate and distant outcomes of behavior. Journal of Personality and Social Psychology 1994;66:742–752.

Vuchinich RE, Simpson CA. Hyperbolic temporal discounting in social drinkers and problem drinkers. Experimental and Clinical Psychopharmacology 1998;6:292–305. [PubMed: 9725113]

Wallace M. Future time perspective in schizophrenia. Journal of Abnormal and Social Psychology 1956;52:240–245.

Zimbardo, PG. Stanford Time Perception Inventory Manual. Stanford, CA: Stanford University, Department of Psychology; 1992.

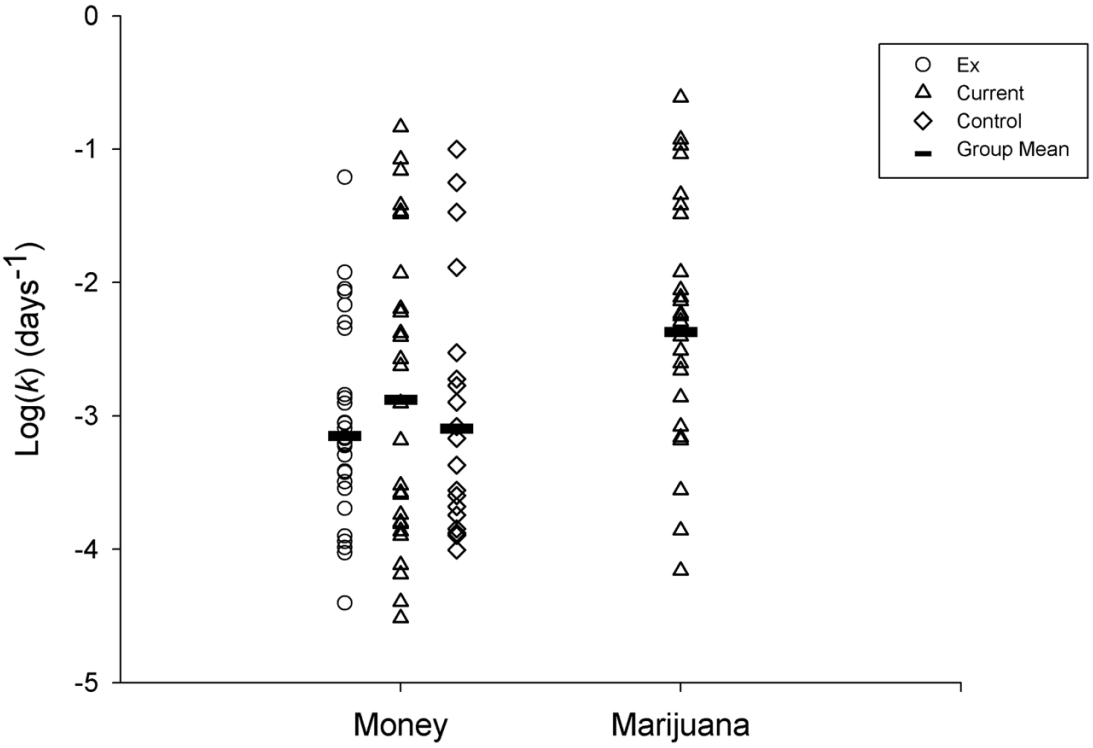

Figure 1.
Individual log-transformed k values and group means for all groups and both commodities studied. A higher transformed k value indicates increased delay discounting or more impulsivity.

Table 1

Participant characteristics.

	Group		
Characteristic	**Ex**	**Current**	**Control**
N	30	30	22
Age (years)	28.9 ± 10.8	27.4 ± 9.9	25.9 ± 8.6
Gender (% Female)	43	43	59
Education (years)	14.0 ± 2.1	13.2 ± 2.1	14.3 ± 1.9
Monthly income ($US)	945 ± 1488	736 ± 1505	508 ± 755
Quick Test intelligence*	41.7 ± 3.3	41.9 ± 2.6	38.6 ± 3.6
Percent daily tobacco users	40%	50%	41%
Tobacco use (cigs/day)	3.7 ± 6.2	5.5 ± 9.3	5.6 ± 10.3
Current marijuana use (bouts/day)**	0 ± 0	2.6 ± 1.4	0 ± 0

Note. Values represent mean ± SD. Significance evaluations based on two sample t-tests, with the exception of gender and percent daily tobacco users, which were based on chi square tests. Significant differences are noted by asterisks.

* Ex vs. controls $p < .01$. Current vs. controls $p < .001$. Ex vs. current ns.

** Current vs. either other group $p<.001$. Ex vs. control ns.

Table 2

Multiple regression results for money discounting.

Predictor variable	Beta	t	p
Intercept		−1.92	.06
Cigarette use (cigarettes/day)	.326	2.79	.007
Current marijuana use (bouts/day)	.072	.625	.53
IQ	−.059	−.505	.62

Overall model: R=.364, F(3,73)=3.72, p=.02

Table 3

Questionnaire scores by group. Means and SD are reported for all measures with the exception of all FTP scores, for which medians and ranges are reported due to skewed distributions of scores.

	Group		
Questionnaire scale	**Ex**	**Current**	**Control**
FTP Extension (years)	19.5 (3.0 – 75.0)	24.0 (1.0 – 100.0)	19.5 (4.0 – 52.0)
FTP Mean predicted (years)	7.2 (1.1 – 20.2)	5.8 (0.8 – 22.8)	5.4 (1.2 – 20.4)
FTP Coherence (rho)	0.98 (0.86 – 1.00)	0.97 (0.70 – 1.00)	0.93 (0.13 – 1.00)
FTP Story 1 (years)	2.9×10^{-5} (1.9×10^{-6} – 99)	1.9×10^{-5} (3.8×10^{-8} – 2.0×10^{3})	7.1×10^{-5} (9.5×10^{-7} – 2.0)
FTP Story 2 (years)	4.9 (1.9×10^{-6} – 69)	1.5 (1.9×10^{-6} – 79)	1.1×10^{-4} (6.3×10^{-7} – 84)
BIS-11 Non-planning	24.6 (4.1)	25.8 (5.1)	23.5 (4.6)
BIS-11 Motor	16.6 (4.0)	16.9 (3.4)	15.3 (3.9)
BIS-11 Cognitive	23.2 (4.4)	25.2 (5.6)	22.4 (4.0)
IVE Impulsiveness*	11.3 (4.9)	13.1 (4.5)	7.4 (5.4)
IVE Venturesomeness	11.1 (2.6)	11.2 (3.1)	10.9 (4.4)
IVE Empathy	13.5 (2.8)	13.3 (2.8)	12.2 (3.6)
STPU Future-oriented	51.0 (7.8)	49.3 (8.3)	52.5 (7.0)
STPI Past-oriented	25.7 (4.7)	26.1 (4.4)	26.2 (4.7)
STPI Present-hedonistic**	26.4 (4.6)	26.8 (3.9)	24.0 (5.0)
STPI Present-fatalistic	22.1 (4.1)	24.0 (5.4)	20.8 (4.4)
STPI Time-press	7.4 (1.7)	7.2 (2.0)	7.3 (1.6)
CFCS	3.3 (0.7)	3.1 (0.7)	3.4 (0.7)
R-FUS	2.5 (0.6)	2.6 (0.6)	2.3 (0.5)

Note. Groups were compared using ANOVA with intelligence as a covariate, with the exception that FTP measures were compared using Kruskal-Wallis tests due to skewed distributions of scores.

* ANOVA $p<.001$; Tukey HSD showed current > control ($p<.001$), others comparisons NS

** ANOVA $p<.01$; all Tukey HSD comparisons NS