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A Comparison of Delay Discounting in Adolescents and Adults in Treatment for Cannabis Use Disorders

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Abstract

Delay discounting is associated with problematic substance use and poorer treatment outcomes in adolescents and adults with substance use disorders. Although some research has addressed delay discounting among individuals with cannabis use disorders (CUD), results have been equivocal and no study has examined whether discounting rates differ between adolescent and adult cannabis users. The aim of this study was to compare discounting rates between adolescents and adults in treatment for CUD in order to determine whether discounting at intake or changes in discounting across treatment differed between age groups. Participants were 165 adolescents and 104 adults enrolled in treatment for CUD. Participants completed a delay discounting task at intake and end of treatment for two commodities (money and cannabis) at two different magnitudes ($100 and $1000). Repeated measures mixed models examined differences in discounting rates by commodity and magnitude across age groups at intake, and changes in discounting across treatment. At intake, adolescents discounted money more than adults, while adults showed greater discounting at $100 magnitude than $1000. In addition, adults had greater decreases in discounting of cannabis over the course of treatment. Overall, adolescents appeared less sensitive to changes in magnitude of rewards, discounted money at higher rates, and showed less improvement in discounting over the course of treatment compared to adults. Comparing delay discounting in adolescents and adults with CUD can contribute to a better understanding of how development influences the impact of discounting on substance use in order to better inform treatment for substance use disorders.

Keywords

Delay Discounting; Cannabis Use Disorders; Treatment; Adults; Adolescents

Delay discounting is a dimension of impulsive decision-making that is broadly defined as a decrease in reward value with an increasing delay to receipt (Bickel & Marsch, 2001; Bickel, Yi, Landes, Hill & Baxter, 2011). Delay discounting can be measured by providing individuals with a series of choices between smaller rewards available sooner, or more immediately in the future versus larger, more delayed rewards. Individuals who prefer smaller, more immediate rewards over larger, delayed rewards have higher rates of discounting and are considered to have greater levels of impulsive decision-making. High

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discounting is associated with a variety of problematic health-related behaviors (i.e. obesity, risky sexual activity, problematic gambling, and substance abuse/dependence; Alessi & Petry, 2003; Chesson et al., 2006; Epstein, Salvy, Carr, Dearing, & Bickel, 2010; MacKillop et al., 2011; Reynolds, 2006; Weller, Cook, Avsar, & Cox, 2008), and is thought to be a trans-disease process with common neurobiological underpinnings (Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012).

Delay discounting changes across adolescence and young adulthood, with evidence that discounting rates are highest during adolescence, then decrease until reaching stability in adulthood (Green, Fry, & Myerson, 1994; Steinberg et al., 2009). Developmental differences between adolescents and adults have been observed in brain regions that are associated with discounting; limbic structures that are associated with reward sensitivity develop earlier in adolescence, whereas structures in the frontal and prefrontal cortices linked to executive functioning develop later into adulthood (Blakemore & Choudhury, 2006; Giedd et al., 1999; Gogtay et al., 2004). Differential activation in areas implicated in reward sensitivity and decision-making provide a neurobiological framework for increased impulsive decision-making and engagement in risky behaviors during adolescence. Consistent with this framework, one study found that higher discounting rates in adolescent substance users were associated with less activation in the frontal and prefrontal cortices, and less deactivation of reward sensitive neural structures than observed in those with lower discounting rates (Stanger et al., 2013).

Both adolescents and adults with high discounting rates may be especially susceptible to the development of substance use disorders due to the reinforcing effects of drugs that occur in close proximity to administration, which may outweigh more distant future rewards from choosing not to use such as improved health or better employment opportunities. Indeed, compared to healthy controls, adolescent and adult substance users have higher discounting rates across both licit and illicit drugs, including alcohol, tobacco, opioids and stimulants (Reynolds, 2006), and discounting rates are higher among those who meet criteria for a substance use disorder (MacKillop et al., 2011). In clinical studies, discounting rates appear to decrease over the course of substance abuse treatment, (Black & Rosen, 2011; Landes, Christensen, & Bickel, 2012; Yi et al., 2008) suggesting that impulsive decision-making may improve with decreased substance use. However, this finding is not unequivocal and some evidence suggests that discounting rates remain stable across time regardless of treatment status (e.g. Yoon et al., 2007).

While substance users generally have greater discounting rates compared to healthy controls, few studies have examined the role of discounting in individuals with cannabis use disorders (CUD). Higher delay discounting is associated with signs of heavy cannabis use and dependence (e.g. compulsive craving, younger age of onset and regular use, and treatment-seeking; Heinz, Peters, Boden, & Bonn-Miller, 2013), although this relationship might vary based upon severity of CUD symptoms (i.e. Stea, Hodgins, & Lambert, 2011). The only study that directly compared discounting in cannabis users compared to healthy controls found no significant differences in discounting between groups (Johnson et al., 2010). In addition, the only study that examined change in discounting rates during treatment for CUD found that, among adults, discounting either remained stable, or

increased depending on treatment condition (Peters, Petry, LaPaglia, Reynolds, & Carroll, 2013). To date, no study has examined change in discounting in treated adolescents.

Given the dearth of research examining delay discounting in cannabis users, more research is needed to determine if there is a systematic relationship between cannabis use and discounting, if that relationship varies with age of the user, and to better understand how discounting changes across the course of treatment in individuals with CUD. The objective of the current study is to compare discounting rates between adolescent and adult cannabis users enrolled in treatment for CUD in order to determine if a) intake discounting rates differ between age groups, and b) the magnitude of pre- to post- treatment changes differ between age groups. To our knowledge, this is the first study to directly compare discounting rates in adults and adolescents in treatment for substance use disorders.

Method

Participants

Participants were 165 adolescents and 104 adults enrolled in two pilot studies and two randomized controlled trials examining behavioral treatments for cannabis use disorders. Across these studies, inclusion criteria were: 1) current cannabis use (adolescents: use during the prior 30 days or a cannabis positive urine test at intake; adults: cannabis use on at least 50 of the previous 90 days), and 2) met criteria for Diagnostic and Statistical Manual of Mental Disorders IV Cannabis Abuse or Dependence as determined by a structured diagnostic interview (Hudziak, Copeland, Stanger, & Wadsworth, 2004). Exclusion criteria were: 1) dependence on alcohol or other drugs except nicotine, 2) psychological or medical distress in need of immediate treatment, 3) legal status that might result in imminent incarceration, 4) plans to move out of the area in the next 12 months, or 5) not being fluent in English. Participants were recruited from advertisements in local newspapers, radio stations, notices mailed to local health and social service professionals (and local schools for adolescent studies), and posters located throughout the local community. Advertisements were worded to target current cannabis users seeking treatment for CUD (or parents of adolescents with CUD).

Adolescents included in the study were between the ages of 12 to 18 (M = 15.8, SD = 1.3), 88% male and 59% African American. Adults were age 18 or older (M = 34.0, SD = 10.2), 55% male and 49% African American. Additional participant characteristics are presented in Table 1. The Institutional Review Board of the University of Arkansas for Medical Science approved all studies.

Procedure

Assessments and treatment sessions were completed at a University-based outpatient clinic in Little Rock, Arkansas. All participants provided written consent/assent (parent consent if <18) prior to enrollment in the study. Participants then completed a comprehensive intake assessment that included the delay discounting procedure. Eligible participants were enrolled into the adolescent or adult studies and randomized to a treatment condition. Across age groups, eligible participants were randomly assigned to treatment conditions in the

randomized control trials, but were not randomized to treatment conditions in the pilot studies. Treatment conditions were the same in pilot and randomized trials. Treatments were generally similar across age groups and included several behavioral treatment conditions [i.e. cognitive-behavioral therapy (CBT), motivational enhancement therapy (MET)], and abstinence-based incentives (i.e. contingency management; CM) alone or in combination. If participants were assigned CM, the schedule and magnitude was similar across age groups, and all participants receiving CM also received MET/CBT. The major differences between treatments were a) the duration of treatment in adults and adolescents was 12 and 14 weeks, respectively, b) the adult studies had a minimal treatment control condition (i.e. 2 sessions of MET) whereas adolescent studies had a full MET/CBT control condition, c) the adult studies were evaluating a computer-delivered behavioral treatment for CUD so a portion of participants received a computerized version of the treatment (thought this did not affect treatment outcomes relative to therapist-delivered intervention), d) a portion of adolescents received comprehensive parent training, and e) all adolescents that received CM also received home-based CM delivered by parents. Following the final treatment session, participants completed an end of treatment (ETX) assessment, which included the delay discounting procedure. Additional procedural details for adolescent and adult studies can be found in Budney et al., (2011); and Stanger et al., (2012).

Measures

Delay Discounting Procedure—A delay discounting task (previously described in Stanger et al., 2012) was administered using a computerized choice program, whereby participants were asked to make choices between smaller, immediate rewards and larger, delayed rewards (Baker, Johnson, & Bickel, 2003; Johnson & Bickel, 2002). During each trial, participants were presented with two choice buttons: a smaller immediate reward button on the left of the computer screen, and a larger delayed reward button to the right of the computer screen. The larger delayed reward remained constant, while the smaller immediate reward was determined using an adjusting amount algorithm (Du, Green, & Myerson, 2002). Delay periods were 1 day, 1 week, 1 month, and 6 months, and delays were always presented in increasing order. At each delay, six trials were administered. The starting value of the smaller, sooner (adjusting) reward was always 50% of the larger, delayed reward. On subsequent trials, the smaller sooner reward adjusted up or down by 50% depending on the subject's choice (smaller, sooner choices resulted in decreases; larger, delayed choices resulted in increases).

This procedure was used to calculate an indifference point at each commodity and magnitude in each session for all participants. An indifference point is the value of the immediate reward that is considered as attractive as the alternative delayed reward. Indifference points were calculated for four commodity/magnitude conditions in each session, twice for hypothetical monetary rewards with magnitudes of $100 and $1,000; and twice for amounts of cannabis that were subjectively rated as equivalent to $100 and $1,000. For cannabis discounting, participants rated amounts of cannabis in grams or ounces that were equivalent to $100 and $1,000 during the intake session, and these equivalencies were used in subsequent choice titration procedures (see Stanger et al., (2012) for a more detailed description of the procedure for determining equivalencies). During each session,

presentations of commodities for adolescents were held constant (i.e. adolescents always began with money and completed cannabis last), but commodities were counterbalanced in adults. Magnitude was counterbalanced across participants in both age groups.

Data Analysis

Delay discounting data were assessed for orderliness using a previously published algorithm (Johnson and Bickel, 2008). Specifically, individuals with any indifference point that was larger than the previous point by more than 20% of the large outcome (with the exception of the first point) were identified as having nonsystematic data. Using an approach similar to a previous study examining discounting across multiple tasks (i.e. Green and Lawyer, 2014), participants identified as having nonsystematic data on two or more tasks were excluded from the sample. Twenty adolescents and 7 adults with nonsystematic discounting data on two or more tasks were excluded using this approach. Mazur's (1987) hyperbolic equation: $V_d = V/(1 + kD)$, was fit to each participant's indifference points using nonlinear regression (SAS, PROC NLIN). In Mazur's (1987) equation, *Vd* is the discounted value of the delayed reward, *D* is the delay, *V* is the undiscounted delayed reward, and *k* is the estimated index of discounting. High values of *k* indicate greater discounting. All *k* estimates were transformed using a natural logarithm, ln*k*, to reduce positive skew, which is typical among DD data.

Table 2 presents means, SD and data available by age group, commodity and magnitude at intake and ETX time-points. At ETX, discounting data was available for approximately 67% of adolescents and 51% of adults. An analysis of variance examined whether intake discounting rates differed between individuals that attended intake and ETX compared to those who did not attend ETX. Among adolescents, participants that attended ETX had a mean ln*k* of −4.1 (*SD* 3.1) at intake versus a mean of −4.0 (*SD* 3.7) at intake for those who did not attend ETX. Adults that attended ETX had a mean ln*k* of −4.3 (*SD* 3.0) at intake vs a mean of −4.3 (*SD* 3.3) at intake for those that did not attend ETX. There were no significant main effects or interactions of ETX attendance and age group on intake discounting rates (ps > 0.8).

Differences in discounting at intake and change in discounting from intake to ETX as a function of commodity, magnitude and age group was assessed with repeated measures mixed models analyses using a compound symmetry covariance structure and a between-within procedure to approximate degrees of freedom for the error term (PROC MIXED; SAS version 9.3). Given the amount of missing data, we selected mixed effects models as they are robust to data that is missing at random (i.e. data that are dependent on observed but not unobserved values), or data that are missing completely at random (i.e. not dependent on observed or unobserved values; Fitzmaurice, Laird & Ware, 2004). The mixed effects model includes all available observations including those at intake for which there is no ETX observation. This method provides the best estimate of delay discounting at each time-point and accurate estimates of differences within person, and is superior to a complete case analysis which may produce biased estimates of effect and invalid inferences when the data is missing at random (Fitzmaurice, Laird & Ware, 2004; Rubin and Little, 2002). Since tobacco use has been associated with increased discounting in previous studies (e.g. Audrain-McGovern et al., 2004; Bickel, Odum, & Madden, 1999) frequency of tobacco use

(past 30 days) was included as a covariate in all analyses to control for potential confounding effects of tobacco use on discounting rates, but no significant effects of tobacco were found. Significant differences in gender and rate of marijuana use (days used in the past 30) were also included as covariates in all analyses, with no significant effects found for either variable. Follow-up testing for significant interactions was conducted by examining simple effects using least-squared means statements, and main effects were assessed using Tukey-Kramer adjusted differences of least-squared means.

Results

Discounting Rates Prior to Treatment

Median indifference points and hyperbolic discounting curves for adolescents and adults at intake (prior to the onset of treatment) are presented in Figure 1, and mean discounting rates (ln*k*) are presented in Table 2. Mixed models analyses examined whether intake discounting rates (ln*k*) differed as a function of age group across commodity type and reward magnitude. Regardless of age group, significant main effects of commodity [$F(1,233) = 29.19$, $p<.001$] and magnitude [$F(1,235) = 25.80$, $p<.001$] were observed, with follow-up tests indicating that cannabis was discounted more than money [$t(233) = 4.84$, $p<.001$], and $100 was discounted more than $1000 [$t(235) = 4.68$, $p<.001$]. A significant two-way interaction was found between age group and commodity [$F(1,233) = 11.66$, $p<.001$], with simple effects tests revealing that adolescents showed higher discounting of money than adults [$F(1,233) = 32.61$, $p<.001$; Figure 3]. In addition, a significant age group by magnitude interaction was found [$F(1,235) = 6.59$, $p<.05$], with simple effects tests revealing that adults showed higher discounting of $100 than $1000 ($F(1,235) = 24.53$, $p<.001$; Figure 4). There were no differences in discounting by magnitude among adolescents. No significant three- or four-way interactions were observed.

Pre- to Post- Treatment Changes in Discounting

Median indifference points and hyperbolic discounting curves for adolescents and adults at ETX are presented in Figure 2, and mean discounting rates (ln*k*) are presented in Table 2. Repeated measures mixed models analyses examined whether changes in discounting (ln*k*) from intake to ETX differed as a function of age group by each commodity type and reward magnitude. A main effect of time-point [$F(1,143) = 32.71$, $p<.001$] indicated that discounting decreased from intake to ETX [$t(143) = 5.57$, $p<.001$]. A two-way interaction between age group and time-point was also significant [$F(1,143) = 4.36$, $p<.05$]. Simple effects tests revealed that adults had greater decreases in discounting rates from intake to ETX [$F(1,136) = 22.95$, $p<.001$], compared to adolescents [$F(1,136) = 9.81$, $p<.01$]. Across age groups, a two-way interaction indicated that discounting rates differed by commodity and time-point [$F(1,140) = 4.93$, $p<.05$], with follow-up testing revealing that discounting rates for cannabis decreased from intake to ETX at a greater rate compared to discounting for money [$F(1,136) = 31.30$, $p<.001$). Figure 5 presents changes in discounting from intake to ETX, by age group and commodity. No significant three- or four-way interactions were found.

Discussion

This was the first study to provide a direct comparison of delay discounting between adolescents and adults enrolled in similar evidence-based treatments for similar types of substance use problems. As expected, relative to adults, adolescents discounted money at higher rates, which confirms previous research indicating that adolescents discount delayed rewards to a greater extent than adults (e.g. Green et al., 1994; Steinberg et al., 2009). In addition, adolescents were less sensitive to differences in magnitude of rewards across commodities (i.e. discounting rates were similar for adolescents at the $100 and $1000 magnitudes). This finding has potential implications for treatment using contingency management interventions that provide incentives contingent upon abstinence from a particular substance, which is objectively verified using urinalysis. For substances such as cannabis, it can take approximately two weeks to one month for elimination of THC urine metabolites before abstinence can be verified using standard rapid urine screens, reflecting a significant delay between initiation of abstinence and receipt of rewards. Thus, adolescents with high discounting rates may find the effects of immediate cannabis more reinforcing than the delayed rewards provided in contingency management interventions, and may require larger magnitude delayed CM reinforcers than adults to initiate and sustain abstinence.

A comparison of changes in discounting over the course of treatment between age groups revealed a trend toward significance. Follow-up tests revealed that adults had greater decreases in discounting over the course of treatment relative to adolescents, which is consistent with prior research demonstrating decreases in discounting in adults participating in treatment for substance use disorders (Black & Rosen, 2011; Landes et al., 2012). However, this finding is inconsistent with the one previous study examining changes in discounting across treatment for CUD, in which discounting remained stable or increased during treatment depending on treatment condition (Peters et al., 2013). Methodological differences may partially explain these discrepant findings. Peters et al (2013) used an experiential discounting task, where participants made a series of choices between a small, certain amount (i.e. $0.15) and larger, uncertain rewards (i.e. $0.30 with a 35% probability of being delivered) with delays ranging from 0–28 seconds. The observation from this study that adolescents' discounting rates remained fairly stable over the course of treatment, along with previous findings demonstrating that higher delay discounting predicts negative treatment outcomes in adolescents with CUD (Stanger et al., 2012), suggests that adolescents may benefit from neurocognitive treatments that target impulsive decision-making in order to reduce discounting rates during treatment for CUD. Some preliminary evidence suggests that working-memory training may be one such intervention (Bickel et al., 2011).

Several findings related to discounting emerged that were similar across age groups. At intake, participants discounted cannabis more than money, and discounted $100 in money and cannabis more than $1000. The finding that discounting decreased as reward magnitude increased (regardless of commodity) is consistent with a wide body of studies that have reported a similar decrease in discounting with increasing reward magnitudes (e.g. Green, Myerson & McFadden, 1997; Green et al., 1994; Green, Myerson, Oliviera, & Chang, 2013;

Johnson & Bickel, 2002; Kirby, 1997). In addition, changes in discounting across treatment differed by commodity. Greater changes in discounting of cannabis were observed from pre- to post- treatment compared to discounting for money, which is not surprising considering that participants were in treatment for cannabis and more likely to be abstinent at the end of the study. Given the variability in discounting for different commodities, these findings suggest that including multiple commodities in future studies examining changes in discounting during treatment would be advantageous for assessing characteristics of discounting that differentially relate to treatment outcome.

Several limitations of the current study warrant mention. First, findings might be specific to those in treatment for CUD, and may not generalize to those in treatment for other substances or non-treatment-seeking substance users. Second, socioeconomic status was not collected for all participants in the current study, and since SES is related to discounting this could not be eliminated as a potential explanation for differences between age groups. Third, treatment heterogeneity, and differences in subject characteristics and referral sources for the studies may have altered the results of the current analysis. The purpose of this study was to compare two distinct samples of cannabis users at different developmental levels, which introduces other subject characteristics that may not have been measured. In addition to controlling for tobacco use, significant differences in gender and rate of marijuana use were accounted for by entering each as a covariate in the statistical model. However, there are likely other differences between groups that cannot be ruled out as potential explanation for group differences. Fourth, a substantial amount of participants did not complete the delay discounting assessment at ETX. It is important to note that a) pre-treatment discounting rates were similar between those who completed the intake assessment only and those who completed both intake and ETX assessments, and b) the mixed models approach used to analyze the data makes the best use of all available data and provides the best estimate of effects given the method's robustness. Nevertheless, the missing data at ETX presents a limitation to the study and warrants caution when interpreting change in discounting across treatment. Despite these limitations, this study provides direct evidence of age differences in discounting at intake and differential changes in discounting during treatment for CUD. Comparing delay discounting in adolescents and adults with CUD is important to better understand how development influences the impact of impulsive decision-making on substance use, and to better inform treatment for substance use disorders.

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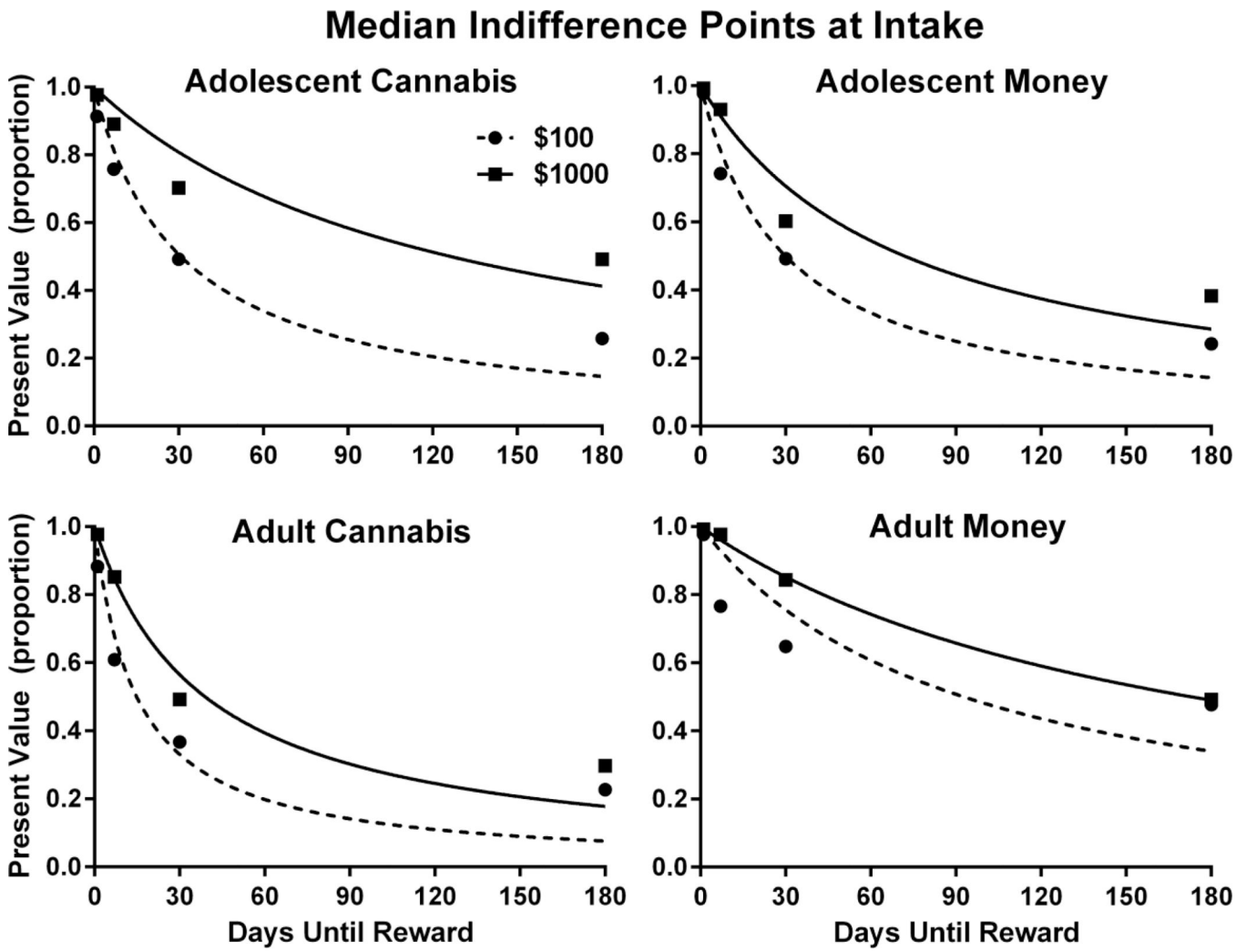

Figure 1.

Median indifference points and estimated hyperbolic discounting curves for adolescents and adults at intake. Median indifference points for the $100 (circles/dashed line) and $1000 (squares/solid line) are displayed at delays of 1, 7, 30, and 180 days.

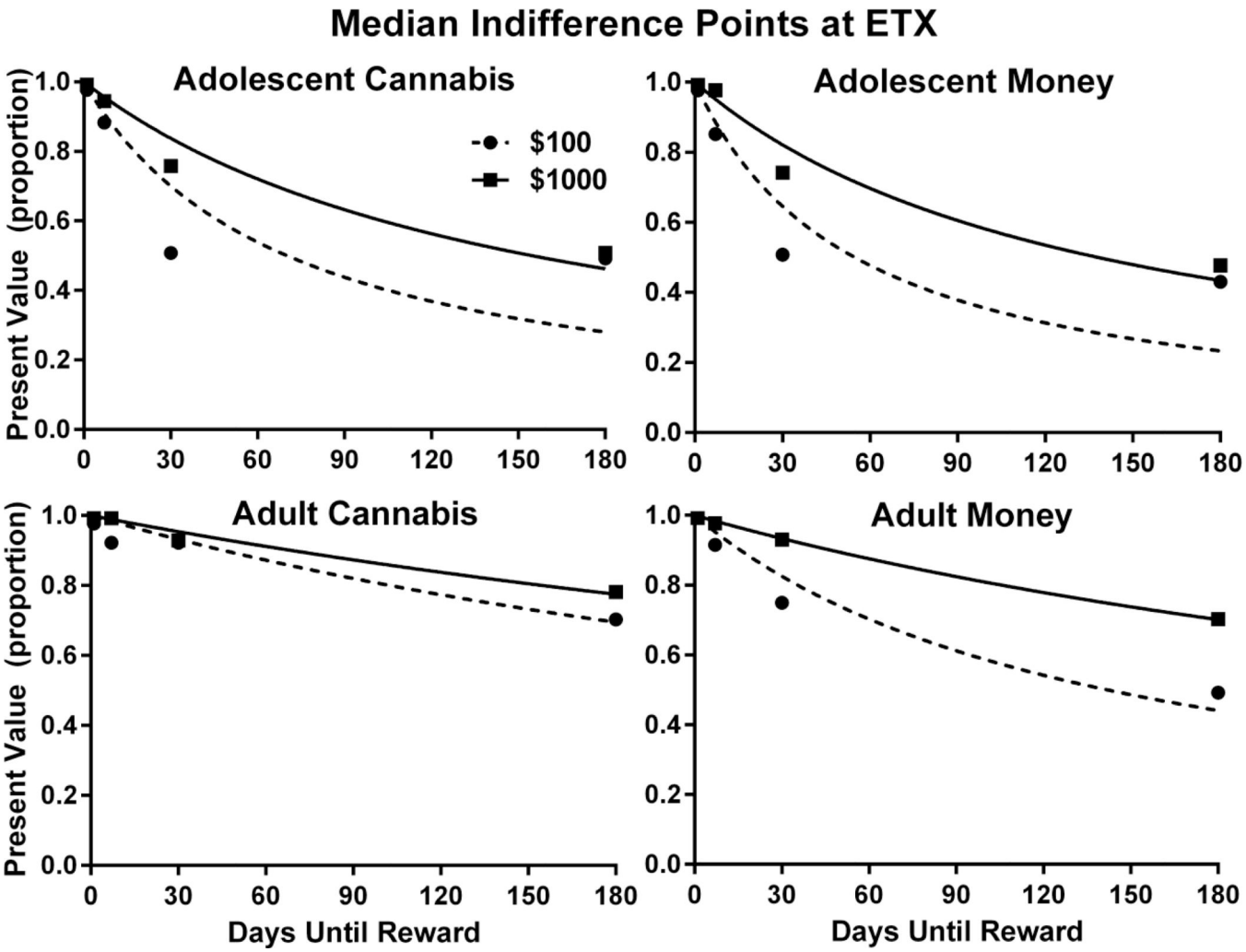

Figure 2.

Median indifference points and estimated hyperbolic discounting curves for adolescents and adults at end of treatment (ETX). Median indifference points for the $100 (circles/dashed line) and $1000 (squares/solid line) are displayed at delays of 1, 7, 30, and 180 days.

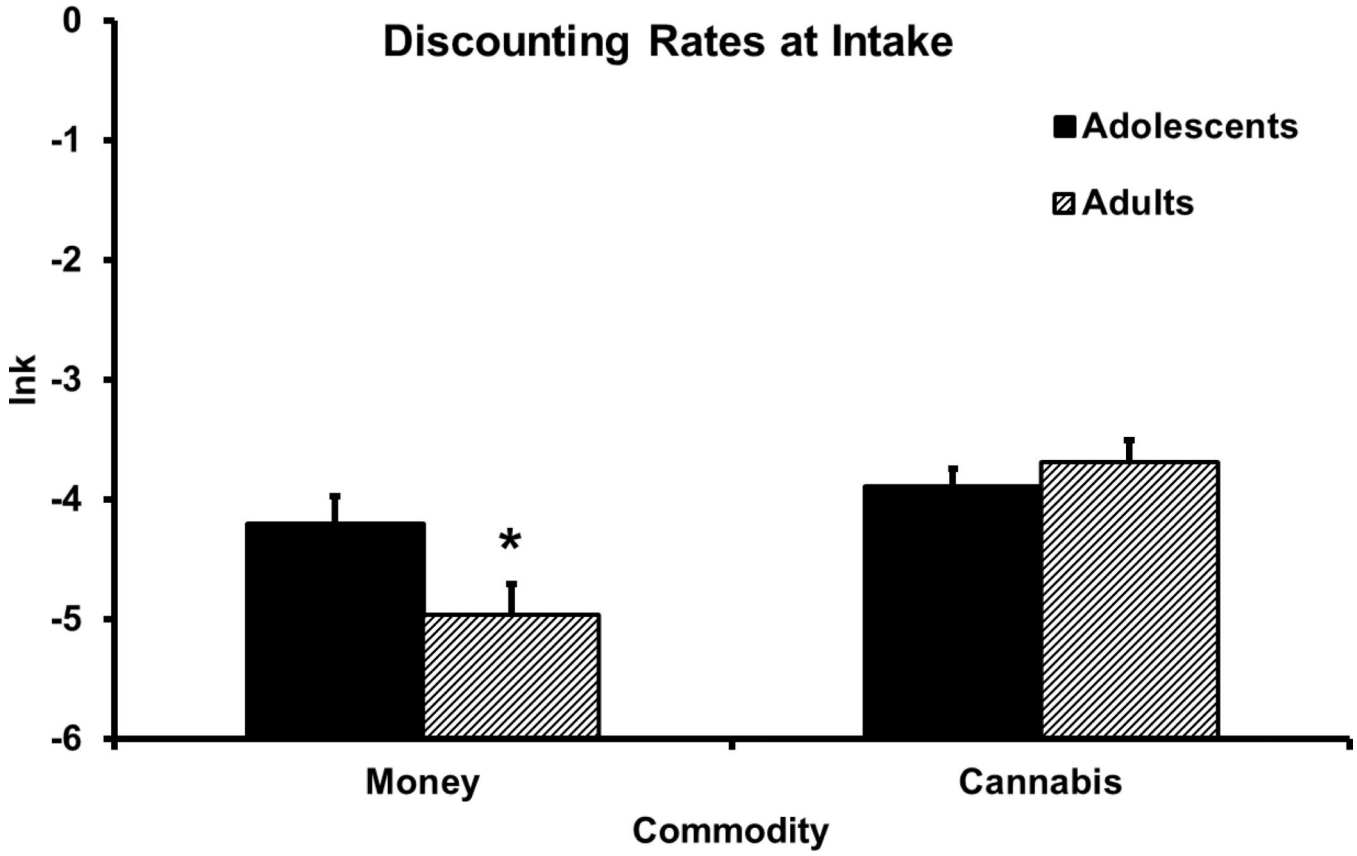

Figure 3.

Delay discounting rates at each commodity by age group (collapsed across magnitude). Error bars represent ±1 standard error of the mean. A significant age by commodity interaction was present; adults discounted money at a lower rate compared to adolescents. There were no differences at the cannabis commodity. *p<.05.

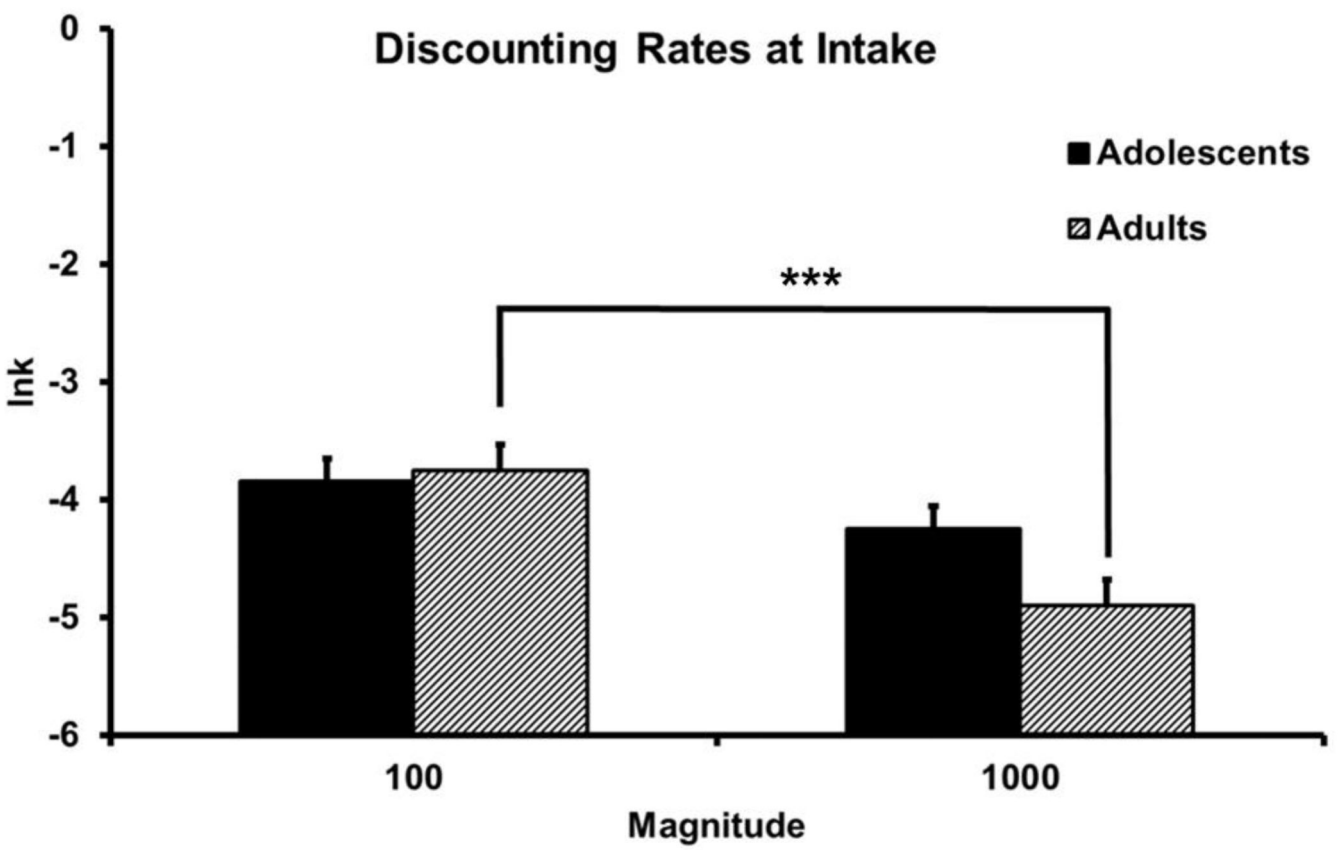

Figure 4.

Delay discounting rates at each magnitude by age group (collapsed across commodity). Error bars represent ±1 standard error of the mean. A significant age by magnitude interaction was present; adults discounted $1000 at a lower rate compared to $100. There were no differences in discounting at each magnitude among adolescents. ***p<.001.

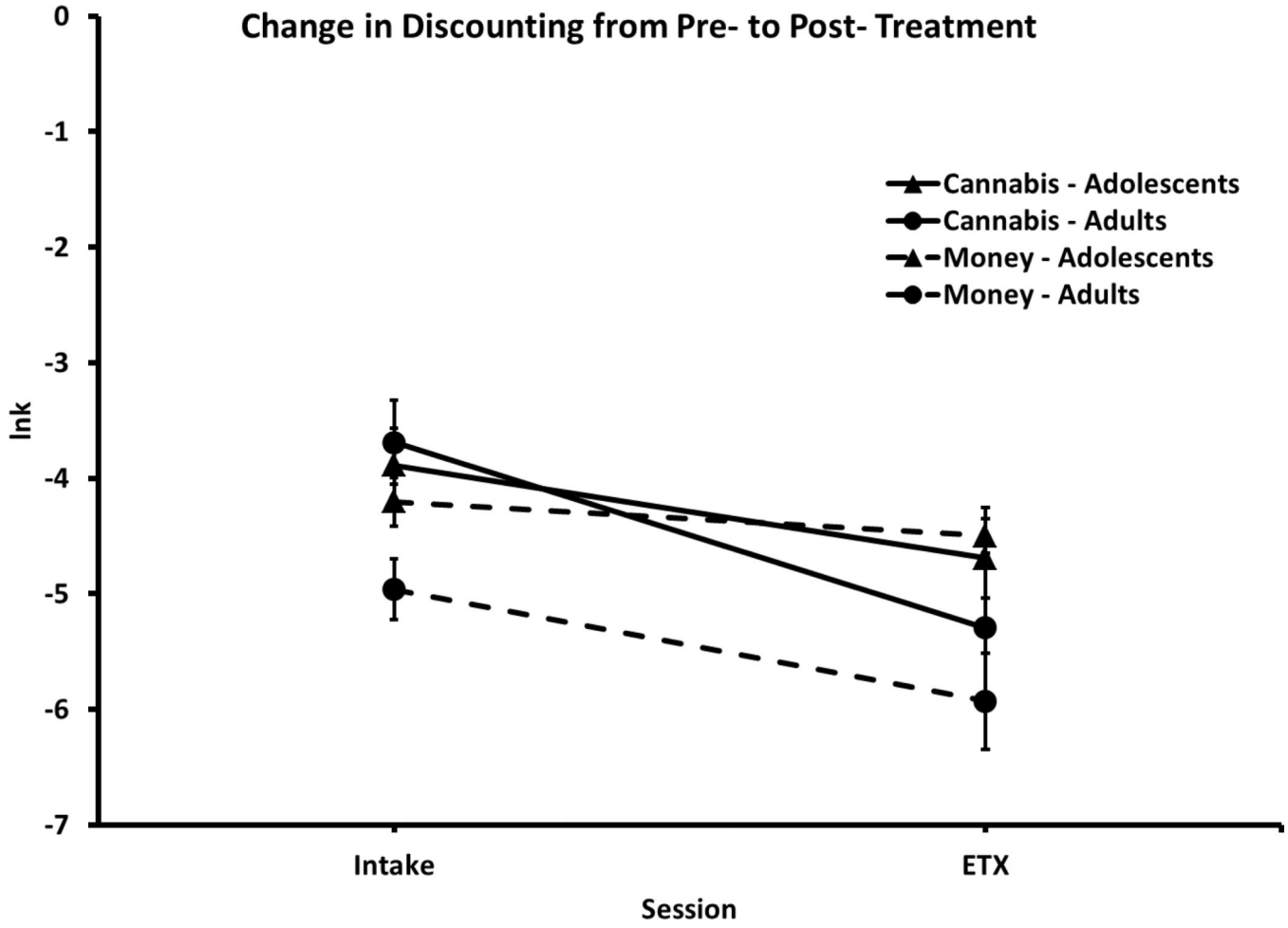

Figure 5.

Change in delay discounting (lnk) from intake to end of treatment (ETX) by age group (collapsed across magnitude). Error bars represent ±1 standard error of the mean. A significant age by time-point interaction ($p<.05$) indicated that discounting rates decreased at a greater rate in adults compared to adolescents. A significant commodity by time-point interaction ($p<.05$) indicated that cannabis discounting rates decreased at a greater rate compared to money. There were no three- or four-way interactions.

Table 1

Participant Characteristics and Substance Use at Intake

Characteristic	Adolescents	Adults	p-value[a]
	***M (SD)* or % (*N*)**	***M (SD)* or % (*N*)**	
N	165	104	
Age	15.8 (1.3)	34.0 (10.2)	<.001
Gender (Male)	88%	55%	<.001
Ethnicity[b]			.251
Caucasian	38%	48%	
African-American	59%	49%	
Other	3%	3%	
Drug Use			
Age of Frist Use (Cannabis)[c]	13.5 (1.9)	15.1 (3.0)	<.001
Cannabis (Past 30 Days)	10.7 (9.6)	22.2 (8.8)	<.001
Tobacco (% of Sample)	51%	42%	.105
Tobacco (Past 30 Days)[d]	17.6 (11.7)	27.2 (6.5)	.678

Note:

[a] t-tests, chi square, and fisher exact tests were used to assess group differences.

[b] N = 89 for adult ethnicity.

[c] N = 103 for adults.

[d] N = 160 for adolescent tobacco use (past 30 days) and N = 103 for adults.

Table 2

Delay Discounting and Data Available by Time-Point across Commodity, Magnitude, and Age

	Cannabis				Money			
	$100		$1000		$100		$1000	
	M (SD)	Data (N)	*M* (SD)	Data (N)	*M* (SD)	Data (N)	*M* (SD)	Data (N)
Adolescents								
Intake	−3.8 (3.7)	143	−4.0 (4.0)	143	−3.9 (2.6)	145	−4.5 (2.4)	145
ETX	−4.3 (3.4)	95	−5.1 (3.3)	96	−4.3 (2.4)	97	−4.7 (2.3)	97
Adults								
Intake	−3.1 (3.4)	94	−4.3 (3.6)	96	−4.4 (2.7)	97	−5.5 (2.4)	97
ETX	−5.0 (4.5)	48	−5.6 (4.5)	48	−5.5 (2.9)	48	−6.3 (2.8)	48

Note: Data columns reflect the number of participants that completed discounting tasks at each time-point. ETX = End of Treatment