Published in final edited form as:

Drug Alcohol Depend. 2020 July 01; 212: 107996. doi:10.1016/j.drugalcdep.2020.107996.

On the discounting of cannabis and money: Sensitivity to magnitude vs. delay

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Abstract

Background: While using most drugs of abuse is associated with higher than control rates of delay discounting, cannabis use may be the exception. As such, between-commodity differences in delay discounting (i.e., money vs. cannabis) have not been thoroughly examined. We examined these between-commodity differences using modern analytic techniques to disentangle effects of subjects' sensitivity to magnitude and delay as potential drivers of any obtained delay discounting rate differences.

Method: Fifty-eight college students (n = 33 cannabis users, n = 25 non-users) completed a monetary delay discounting task – with the cannabis users completing the cannabis problems questionnaire as well a delay discounting of cannabis task- in an on-campus laboratory.

Results: Responding between groups differed on the cannabis problems questionnaire, but not on delay discounting of monetary outcomes. Cannabis users, however, discounted cannabis at higher rates than money. Multilevel logistic regression revealed that these between-commodity delay discounting differences were due to subjects' differential sensitivity to the magnitude of these two commodities, rather than sensitivity to delay to receiving these commodities.

Conclusions: Although differences in delay discounting rate were not obtained between students that did and did not use cannabis, cannabis users did discount cannabis at higher rates than they did money - suggesting considerable generality of the between commodity differences in delay discounting obtained elsewhere. The current between-commodity delay discounting differences appear to be driven by differential sensitivity to the reinforcer magnitudes presented in each task – a finding that awaits replication across other comparisons before statements about generality can be made.

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Declaration of Competing Interest

The authors have no conflicts of interest to declare

Keywords

Cannabis; Delay discounting; College students

1. Introduction

Over the past several decades, research on delay discounting has robustly informed our understanding of substance use and misuse (Bickel et al., 2011a, 2014; Monterosso and Ainslie, 2007). Studies have found that individuals that smoke cigarettes (Bickel et al., 1999; Mitchell, 1999), drink to excess (Lemley et al., 2016; Vuchinich and Simpson, 1998), misuse opioids (Kirby et al., 1999; Madden et al., 1997), use cocaine (Coffey et al., 2003), methamphetamine (Monterosso et al., 2007) or nearly any other drug discount at higher rates than non-users – prompting researchers to posit that excessive delay discounting is a trans-disease process that undergirds a range of poor health behaviors (Bickel et al., 2012).

Unlike other substances of abuse, cross-sectional differences in delay discounting rates between those that do versus do not use cannabis have not been consistently demonstrated (Gonzalez et al., 2012) – slowing the development of a literature on relations between delay discounting and cannabis use disorder (CUD). Recent studies, however, suggest that higher rates of delay discounting are associated with more frequent cannabis use (Kim-Spoon et al., 2019; Oshri et al., 2018; Vanderbroek et al., 2016) and delay discounting for cannabis – but not money – is a significant predictor of cannabis use disorder symptoms (Strickland et al., 2017). Moreover, a pair of recent studies (Patel et al., in press; Strickland et al., 2019) suggest that individuals discount delayed cannabis at higher rates than money – a relation consistent with findings from users of heroin (Madden et al., 1997), alcohol (Petry, 2001), and cocaine (Bickel et al., 2011b).

While recent studies suggest that delay discounting rates for cannabis are higher than those for money, procedural details of those demonstrations limit their generality. For example, both studies used the 5-trial adjusting delay task – which preempts analysis of the data's orderliness. Additionally, both studies used crowdsourcing to assess discounting in specialized populations (e.g., non-medical users of prescription opioids). Moreover, the behavioral processes which drive these sorts of commodity-based differences in delay discounting rates remain unknown. Multilevel-modeling techniques which isolate the role of delay versus amount sensitivity on delay discounting rates have been developed (Wileyto et al., 2004; Young, 2018), yet these approaches are yet to be used to explore commodity-based differences in delay discounting rates. The current study used these multilevel modeling techniques to explore the behavioral processes driving differences in delay discounting rates for cannabis versus money in illicit cannabis users.

2. Method

2.1. Subjects

Participants were undergraduate students at a large midwestern university whom completed the current experiment in exchange for extra credit in one of their courses. A subset of these

students self-identified as cannabis users (i.e., $N = 33$). These students were predominantly white (60 %) women (85 %) with a mean age of 21.09 years old ($SD = 1.73$ years). These subjects, on average, had a score of 14.60 ($SD = 1.67$) on the cannabis problems questionnaire (Copeland et al., 2005). A second subset of participants were non-users ($N = 25$) whom were 76 % white, 68 % women, and on average 20.6 years old ($SD = 1.30$).

2.2. Procedure

Upon entering the laboratory subjects were seated in a private research cubicle (.91 m x 1.22 m) enclosed by a curtain and given an information statement to read. After reading the information statement, subjects completed a series of computerized tasks lasting approximately one hour – with the current report describing a subset of these data. Delay-discounting tasks were presented immediately after collecting demographic data, with the order counterbalanced across subjects. Both conditions used hypothetical amounts of money or hypothetical amounts of cannabis. Prior to starting the discounting procedure, participants were asked to estimate how many hits would be worth \$100 to them. The question was presented as follows: “How many hits of marijuana would be worth \$100 to you?”

2.2.1. Monetary delay discounting task—An adjusting amount procedure (Du et al., 2002) was used to assess delay discounting. Specifically, the subjects’ first choice was between \$100 after a delay and \$50 immediately. Choosing the immediate amount increased the immediate reward by 50 % of the difference, whereas choosing the delayed amount decreased the immediate amount by 50 % of the difference. This process was repeated six consecutive times at each of seven (1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years) ascending delays. The immediate reward value after the sixth choice for each delay was used as the estimated indifference point, or the value at which the participant would be indifferent between the immediate and delayed options.

2.2.2. Cannabis delay discounting task—The cannabis delay discounting task was identical to the monetary discounting task, with one exception. Specifically, subjects were asked to indicate how many hits of marijuana would be worth \$100. This amount was then used as the larger later amount and 50 % of that amount was used as the initial smaller sooner amount.

2.2.3. Cannabis problems questionnaire—Based on the Alcohol Problems Questionnaire (CPQ) (Williams and Drummond, 1994), this 27-item questionnaire asks subjects about problems they may encounter based on their cannabis use (e.g., “Have you given up any recreational activities you once enjoyed for smoking?”, “Have you felt more antisocial after smoking?”, “Have you driven while stoned?”). This instrument has demonstrated reliability and validity (Copeland et al., 2005).

2.3. Data analysis

Delay discounting data were analyzed in two ways. First, the indifference points were analyzed using Mazur’s hyperbolic discounting model ($Value = Amount / (1 + k * Delay)$) using multilevel modeling, as described by Young (2017). This provided estimates of delay discounting rate (k) that included all subjects yet minimized the impact of aberrant/

disorderly indifference points. As an additional diagnostic, the raw number of violations (providing a continuous measure) of the Johnson and Bickel (2008) orderliness criteria was compiled and compared (via Wilcoxon matched pairs signed rank test) across tasks. These delay discounting rates were log transformed to normalize the distribution and comparisons (i.e., discounting of money in cannabis users vs. controls; discounting of money vs. cannabis in cannabis users) were made via t-tests. A Pearson correlation was used to examine the relation between these discounting rates. Next, choice data from each trial were analyzed using multilevel logistic regression (Wileyto et al., 2004; Young, 2018) providing unique beta weights for cannabis users sensitivity to differences in magnitude and delays for both delay discounting of money and cannabis. These beta weights were then analyzed via a two-way repeated measures ANOVA.

3. Results

Choice on the delay discounting tasks was driven by both the delay to receiving each commodity and the commodity to be received. Specifically, a two-way repeated measures ANOVA of the indifference points found significant main effects of delay ($F[5,160] = 42.72, p < .0001$) and commodity ($F[1,32] = 7.39, p = .01$) as well as a significant delay x commodity interaction ($F[5,160] = 8.92, p < .0001$). The patterns of indifference points for cannabis (Median SE = 0.95, IQR = 0.90, 1.92) as well as money in cannabis users (Median SE = 0.46, IQR = 0.44, 0.46) and controls (Median SE = 0.46, IQR = 0.42, 0.47) were well described by the hyperbolic model. The top panel of Fig. 1 shows that individuals' who used cannabis (Mean $\ln[k] = -4.83, SD = 2.02$) and those that did not (Mean $\ln[k] = -5.31, SD = 1.95$) had similar delay discounting rates ($t[56] = 0.91, p = 0.37$). The bottom panel of Fig. 1 shows each individual's $\ln(k)$ values for cannabis and money. Discounting rates were higher ($t[32] = 3.54, p = 0.001$) for cannabis (Mean $\ln[k] = -3.15, SD = 3.20$) than money (Mean $\ln[k] = -4.83, SD = 2.02$). Responses on the CPQ did not significantly correlated with cannabis users discounting of money ($r = -0.10, p = 0.59$) or cannabis ($r = -.14, p = 0.45$).

Panel A of Fig. 2 shows the correlation between $\ln(k)$ values for cannabis (x-axis) and money (y-axis). The shaded region shows the 95 % confidence interval of the linear function. Discounting rates were significantly correlated ($r = 0.53, p = 0.001$) between commodities. Panel B of Fig. 2 shows the number of violations of the orderliness criterion outlined by Johnson and Bickel (2008) (i.e., no increases of greater than 20 % of the undiscounted amount from one indifference point to the next and the last indifference point must be at least 10 % lower than the first). To provide a more sensitive measure each rule violation is counted. Using a Wilcoxon matched pairs signed rank test we found that there were significantly more rule violations ($W = -141.0, p = .0002$) on the cannabis discounting task than on the monetary discounting task.

Panel C of Fig. 2 shows β scores representing individuals' sensitivity to magnitude and delay. Main effects of reward dimensions (i.e., magnitude vs delay) ($F[1,32] = 83.72, p < .0001$) and commodity (i.e., cannabis vs. money) ($F[1,32] = 43.21, p < .0001$) as well as a significant commodity by dimension interaction ($F[1,32] = 27.64, p < .0001$) were obtained. Follow-up analyses using Tukey's multiple comparisons test found a significant commodity

difference in sensitivity to magnitude ($p < .0001$) but not a significant commodity difference in sensitivity to delay.

4. Discussion

Consistent with most prior research on the topic, we were unable to obtain differences in delay discounting rates between cannabis users and controls (Johnson et al., 2010). Like prior studies examining discounting of commodities of abuse (Coffey et al., 2003; Madden et al., 1997; Petry, 2001) or other consumable commodities (Odum et al., 2006; Odum and Rainaud, 2003), however, the current study demonstrated that cannabis users' delay discounting rates for cannabis were higher than those for monetary rewards (Patel et al., in press; Strickland et al., 2019). There are four additional points we would like to make about these data.

Notably, the present findings provide insight to the behavioral processes driving between-commodity differences in delay discounting rates. Based on the current analysis (Young, 2018), differences in delay discounting between cannabis and money appear to be based on differences in sensitivity to the magnitude of those commodities, not differences in sensitivity to the delay to receiving those commodities. As described by Pitts and colleagues (Pitts and Febbo, 2004), this provides an enhanced understanding of the behavioral processes driving delay discounting differences. Stronger statements about this relation will be facilitated by replication of these findings across additional between commodity comparisons.

Second, the current findings add to a growing body of evidence suggesting that delay discounting may be relevant to understanding cannabis use disorder. Specifically, although the current findings replicated prior failures to find a relation between monetary delay discounting rate and cannabis use (Johnson et al., 2010), commodity-based differences were observed – consistent with what has been found with other substances of abuse (Bickel et al., 2011b; Lemley et al., 2017; Madden et al., 1997). These between-commodity differences are consistent with the domain specific-relation observed between delay discounting for cannabis and cannabis use disorder symptoms (Strickland et al., 2017). Given these relations, additional research on delay discounting in individual that use cannabis may be warranted – particularly given the changing legal landscape for recreational and medical cannabis.

Third, by using modern multi-level modeling techniques, the current analysis was able to retain the entire sample, rather than excluding subjects based on patterns of responding. This is possible because characteristics of this modeling technique minimize the effects of unsystematic data on the estimation of discounting rates at both the individual and group level (Young, 2017, 2018). As such, differential patterns of data orderliness remain an important datum. Notably, data from the cannabis discounting assessment violated the orderliness criterion described by Johnson and Bickel (2008) more than did the data from the discounting of monetary rewards. This may be due to the way that quantities of cannabis were presented (i.e., X hits now vs. X hits later) or a genuine difference in decision making between these two commodities. Unfortunately, the extent to which these

findings are consistent with those of Strickland et al. (2017), is unknown given that the five-trial discounting task (Koffarnus and Bickel, 2014) used in that analysis pre-empts any assessment of data orderliness. As such, this interesting relation awaits additional replication.

Lastly, limitations of the current study can be addressed by additional research. First, the sample size was modest. Although this may have limited our power to capture small effects, the robustness of the relations demonstrated suggest that the study was adequately powered. Second, the present study used hypothetical rewards. Although this procedural choice may limit the conclusions that can be made, numerous studies have found consistent findings across real and hypothetical rewards (Johnson and Bickel, 2002; Lawyer et al., 2011; Madden et al., 2004). Relatedly, by basing the discounting of cannabis on the number of hits equivalent to \$100, subjects may have made choices about numbers of hits of cannabis that are difficult to conceptualize – possibly impacting their sensitivity to the differing magnitudes. Future research with a lower equivalency value (e.g., \$10) could remedy this shortcoming. Third, a close look at the bottom panel of Fig. 1 will reveal that although there were differences between cannabis users discounting of cannabis versus money, the discounting of cannabis appeared to be broken into two subgroups, with one discounting delayed cannabis at a lower rate ($N = 9$) than the other ($N = 24$). Analysis of the demographic data from this subgroup revealed that the lower discounting group had a higher proportion of men ($X[1] = 8.26, p = 0.004$). While prior studies have demonstrated that gender modulates the relation between delay discounting and important variables (Jones et al., 2009; Yankelevitz et al., 2012), the reason for this difference remains unknown. Future research should investigate this interesting finding. Fourth, although the present study used improved modeling facilitated by multilevel modeling, the followup analyses still used the two stage (i.e., calculate discounting rates then compare them) analyses of which Young (2017, 2018) and others have been critical. It would have been possible to analyze group (cannabis users vs. controls) and commodity (cannabis vs. money) differences within the model, reducing the impact of extreme values. This analysis, however, would have entailed a considerable number of missing values (i.e., discounting of cannabis was only examined in cannabis users) and given the distribution of values (Fig. 1), this approach would have likely yielded the same results. Future research may choose to use a purer analytic approach. These limitations notwithstanding, the relations demonstrated in the present experiment were robust, suggesting that not only is cannabis discounted at higher rates than money, these discounting rate differences are likely due to differences in sensitivity to magnitude. These findings are interesting and will become more so as they are replicated with other commodities.

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Fig. 1.

The top graph shows delay discounting rates ($\ln(k)$) in cannabis users (left) and controls (right), with the horizontal bar showing mean discounting rates. The bottom graph shows cannabis users' delay discounting rates for money (left) and cannabis (right) with the horizontal bar showing mean discounting rates for each commodity.

Fig. 2.

The top left panel (A) shows the linear regression between cannabis users' discounting rates (ln[k]) for money (y-axis) and cannabis (x-axis), with the shaded area showing the 95 % confidence interval of the linear function. The top right panel (B) shows the number of Johnson and Bickel orderliness criteria violations per cannabis user when discounting cannabis (closed circles) or money (open squares). The bottom panel (C) shows the beta weights for the differences in reward magnitude (left) and reward delay (right) based on if subjects were discounting money (open squares) or cannabis (open circles). Horizontal lines show the mean and error bars show the standard deviation.