

# Cigarette smokers discount past and future rewards symmetrically and more than controls: Is discounting a measure of impulsivity?

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## Abstract

A considerable body of evidence indicates that consideration of the future and past are related. Future discounting studies indicate that cigarette smokers discount future outcomes more than non-smokers. The purpose of the present study was to determine if a similar profile of results could be obtained with a novel procedure evaluating the discounting of past outcomes, providing further support for future/past symmetry. Thirty cigarette smokers and 29 non-smokers participated in a computerized assessment of discounting of hypothetical future and past outcomes. Symmetry was supported, with a similar profile of results in future and past discounting procedures. These included: hyperbolic discounting, greater discounting of small-magnitude outcomes than large-magnitude outcomes, and greater discounting by cigarette smokers relative to non-smokers.

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## 1. Introduction

Considerable evidence supports the overlap of processes and brain regions associated with consideration of the past and anticipation of the future (see Buckner and Carroll, 2007, for a review). Recent observations of Hassabis and colleagues demonstrated that amnesic patients with bilateral damage to the hippocampus were impaired in their ability to imagine new personal experiences in addition to being unable to remember their past (Hassabis et al., 2007). Numerous other studies (e.g., Addis et al., 2007; Atance and O'Neill, 2001, 2005; Dretsch and Tipples, 2008; Okuda et al., 2003) of diverse populations and procedures support the hypothesis that behaviors associated with the past and future are closely related.

One research area that has extensively and exclusively focused on the future is temporal discounting (see Frederick et al., 2002; Green and Myerson, 2004, for reviews). Temporal discounting, often considered a measure of impulsivity, refers to the decrease in the subjective value of an outcome as delay to its availability increases (Green and Myerson, 2004). Studies

of temporal discounting indicate that future outcomes are discounted hyperbolically, that the degree of discounting decreases as the magnitude of the reward increases in humans (magnitude effect), and that losses tend to be discounted less than gains (sign effect).

Impulsivity is inferred from the perspective of temporal discounting when a smaller, more immediate reward is preferred to a later, larger one. Among the populations that exhibit greater discounting of future rewards relative to matched controls include: children with attention deficit and hyperactivity disorder (Schweitzer and Sulzer-Azaroff, 1995), cigarette smokers (Bickel et al., 1999), heroin addicts (Madden et al., 1997), cocaine-dependent individuals (Heil et al., 2006), and pathological gamblers (see Bickel and Marsch, 2001; Dixon et al., 2003; Reynolds, 2006, for reviews). The greater discounting (preference for the sooner smaller reward) exhibited by these populations has been considered *prima facie* evidence of impulsivity; that is, gratification was not deferred and/or preference for the immediate reward was not inhibited.

Recently, our group has extended this paradigm to the discounting of past outcomes (Yi et al., 2006). The results from that initial study demonstrated that past outcomes were discounted hyperbolically by undergraduate college students (e.g., they valued rewards in the near past more than rewards further back in

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the past), that small rewards were discounted more than large rewards (the magnitude effect), and rewards were discounted more than losses (sign effect). Moreover, the degree of past discounting was significantly correlated with future discounting. These results were not intuitive. From the standpoint of traditional economics, a preference might be expected for the largest amount in the distant past that would permit greater investment returns in the present. Another viewpoint is that the past is over, has led to the current condition, and therefore systematic valuing of the past is nonsensical. Instead, we found discounting of past and future outcomes were closely related, and past discounting tended to follow the functional relations observed in future discounting.

The present study is the first to compare temporal discounting of past and future outcomes among an addicted population, cigarette smokers, relative to controls. We will also examine whether the effects of magnitude and sign (gains and losses) observed in future discounting operate symmetrically in past discounting. Potentially, there are two outcomes: symmetry and asymmetry of past and future. First, if cigarette smokers discount future and past rewards more than controls, this finding will support the growing recognition of the close and possibly symmetric relationship between past and future. Moreover, this observation would also challenge the view that discounting is a measure of impulsivity since discounting of events in the past does not require the inhibition of responding or the delay of gratification. Second, we could find a lack of future and past discounting symmetry comparing smokers and non-smokers. If this result were observed, it would undermine or provide a limiting case about the relationship between the past and the future. A lack of symmetry would support the notion that future discounting is linked to impulsivity and that past discounting may be germane to other phenomena.

## 2. Methods

### 2.1. Participants

Sixty-nine participants were recruited using flyers and advertisements placed in local newspapers. All participants were compensated at a base rate of \$7.50 per hour plus an additional \$7.50 per hour if they completed the study. Participation was voluntary and all participants were consented according to an approved IRB protocol. Ten participants were disqualified from participation for cause (e.g., no shows).

**2.1.1. Smokers.** Thirty smokers (20 males and 10 females) between 18 and 55 (average 38.5) years of age participated. Smoking participants reported average monthly earnings of \$1374.30 per month and 13.83 previous years of education. All smokers reported smoking 20 or more cigarettes a day (average 25), met DSM-IV criteria for nicotine dependence, scored a six or higher on the Fagerström tolerance questionnaire (Fagerstrom, 1978) and had a carbon monoxide breath level of at least 12 ppm (EC 50 Micro-CO monitor, Bedford Scientific Ltd., Kent England). Data from one smoker in the past discounting of gains condition was lost; remaining data from this participant was included in all analyses.

**2.1.2. Non-smoking controls.** Twenty-nine non-smokers (13 males and 16 females) between 18 and 55 (average 31.86) years of age participated. Non-smoking participants reported averaging monthly earnings of \$1379.76 per month and 15.76 previous years of education. Comparison of relevant

Table 1  
Means (S.D.) of groups on demographic variables

	Smokers	Non-smokers	<i>p</i>
Gender	20 M/10 F	13 M/16 F	.09
Age	38.53 (11.72)	31.86 (11.78)	.03
Income (monthly)	\$1374.30 (1387.84)	\$1379.76 (1292.29)	.99
Education (years)	13.83 (2.83)	15.76 (2.80)	.01
FTQ	7.1		
CO	19.8		

demographics between smokers and non-smoking controls are reported in Table 1.

### 2.2. Apparatus

A laptop computer with a Microsoft XP home edition operating system, running a temporal discounting program written in Visual Basic 6.0, was used to obtain indifference points in the choice procedure. Responses were recorded when participants clicked on a mouse attached to the laptop or pressed buttons on the laptop keyboard. Participants sat in comfortable chairs at individual workstations in a quiet room under the supervision of a research assistant who was present throughout the experiment. In the event that participants had any problems making registered responses or using the mouse, the research assistants provided guidance.

### 2.3. Procedures

Smokers and non-smoking control participants completed future and past temporal discounting procedures for hypothetical money gains and losses in a single session. Future and past discounting procedures were completed in approximately 30 min.

**2.3.1. Future discounting.** The procedure employed here was described in Johnson and Bickel (2002). For each choice trial, participants chose between two hypothetical outcomes: an immediate outcome (“Receive \$[amount] right now”) and an outcome at some temporal distance in the future (“Wait [delay] and then receive \$ [amount]”). In each condition, the immediate outcome (called the adjusting outcome) was adjusted (i.e., increased or decreased) from trial to trial, while the future outcome (called the standard outcome) was held constant. Based on the program algorithm, the adjusting outcome approached the immediate value that the participant judged was subjectively equivalent to the future, standard outcome. The same procedure was employed with three standard magnitudes (\$10, \$100, and \$1000) at each of 7 delays to that option (1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years). In addition, whether the available options were gains (i.e., to gain the hypothetical money option) or losses was also varied (called the sign condition). A total of 42 indifference points (one for each combination of standard magnitude, delay, and gain or loss) were obtained from each participant.

**2.3.2. Past discounting.** A similar procedure was used to determine discounting of the past. However, the standard option was a hypothetical outcome at several timepoints in the more distant past and the adjusting option was a hypothetical outcome one hour ago. For each choice trial, participants chose between an outcome in the immediate past (“Having gained \$[amount] in hour ago”) and an outcome in the more distant past (“Having gained \$[amount] [delay] ago”). We selected the adjusting option available 1 h ago to insure that all choices concerned the past. The same magnitudes, signs (i.e., gains or losses) and delays as employed in the future discounting procedure were used in past discounting, with the delays reflecting time in the past rather than the future. The future discounting procedures preceded past discounting procedures; the order of the magnitude conditions were counterbalanced.

## 2.4. Statistical method

Data for the past discounting of gains condition was lost for one smoker; all remaining data for this participant was included in appropriate analyses.

Using Graphpad Prism 4.0, discounting parameters ( $k$ ) and goodness-of-fit measures ( $R^2$ ) were estimated according to the exponential:

$$v_d = Ve^{-kd} \quad (1)$$

and Mazur (1987) hyperbolic

$$v_d = \frac{V}{1 + kd} \quad (2)$$

models of discounting. In both equations, the discounted value of an outcome ( $v_d$ ) is equal to some function of the undiscounted value ( $V$ ), delay ( $d$ ), and the discount rate ( $k$ ). The discounting parameter provides a measure of the degree to which the value of a reward is discounted: a high discounting parameter indicates greater discounting and more impulsiveness. Statistical comparisons were conducted using Statistica for Macintosh. Comparison of goodness-of-fit ( $R^2$ ) measures was conducted with analysis of variance (ANOVA). The distribution of discounting parameters was skewed. Therefore, all analyses of discounting parameters are conducted following natural–logarithm transformations. Because of statistically significant differences between smokers and non-smokers on demographic variables thought to affect discounting (Table 1), comparison of discounting parameters were conducted with analysis of covariance (ANCOVA) with gender, age, monthly income, and years of education included as covariates.

## 3. Results

### 3.1. Overall comparison

Our first test of future and past symmetry was an overall comparison of the appropriate discounting model for future and past discounting. In both discounting conditions, indifference points decreased as temporal distance increased. Individual indifference points were fitted to both exponential (Eq. (1)) and hyperbolic (Eq. (2)) models of discounting and  $R^2$  were compared to determine the appropriate set of parameters for analysis of smoking status: future and past symmetry was supported. Wilcoxon matched-pairs tests were conducted on each relevant pair of hyperbolic/exponential  $R^2$  values (e.g., hyperbolic and exponential  $R^2$  values obtained from data in the \$100 future money gains condition), and the hyperbolic model provided a superior fit in all comparisons. Furthermore, the obtained mean  $p$ -value across all analyses was .0078, with only one analysis failing to reach  $p = .05$ . Furthermore, comparison of  $R^2$  measures from the hyperbolic model of discounting for each pair of relevant future and past discounting conditions (e.g., \$100 future and \$100 past money gains) via Wilcoxon matched-pairs tests indicated no significant differences in any comparison between the quality of fit to the two conditions; the obtained mean  $p$ -value across all analyses was .48, with no analysis reaching  $p = .10$ . Discounting parameters from the hyperbolic model (Eq. (2)) are therefore used from this point.

### 3.2. Smokers

In the analysis of smokers, the magnitude effect was observed (following Greenhouse–Geisser correction for non-sphericity) with discounting parameters across the time (future/past) and sign conditions ( $F(2, 56) = 5.64, p < .05$ ). Post hoc tests revealed

Table 2

Results of relevant comparisons of discounting rates obtained from smokers and non-smokers

Comparison	Smokers (significance)	Non-smokers (significance)
Overall magnitude	Yes	Yes
\$10 vs. \$100	No	No
\$10 vs. \$1000	Yes	Yes
\$100 vs. \$1000	No	No
Gains vs. losses	No	No
Future vs. past	No	No

statistically significant differences between \$10 ( $\bar{X} = -4.42$ ) and \$1000 ( $\bar{X} = -5.42, p < .05$ ), but not between \$10 and \$100 ( $\bar{X} = -4.99$ ) nor between \$100 and \$1000 ( $p > .05$ ) magnitude conditions. The sign effect was in the predicted direction, but this difference was not statistically significant ( $F(1, 28) = 2.92, p > .05$ ). Consistent with symmetry of past and future, the comparison of parameters from future ( $\bar{X} = -5.20$ ) and past ( $\bar{X} = -4.70$ ) conditions was not statistically significant ( $F(1, 28) = 2.52, p > .05$ ) in the analysis of smokers.

### 3.3. Non-smoking controls

Overall, a nearly identical profile of results was obtained in analysis of non-smokers. The magnitude effect (with no violation of sphericity) was observed ( $F(2, 56) = 4.53, p < .05$ ), with statistically significant differences between \$10 ( $\bar{X} = -5.97$ ) and \$1000 ( $\bar{X} = -6.75, p < .05$ ), but not between \$10 and \$100 ( $\bar{X} = -6.09$ ) nor between \$100 and \$1000 ( $p > .05$ ) magnitude conditions. A comparison of gains and losses was not statistically significant ( $F(1, 28) = 0.34, p > .05$ ). As with smokers, the comparison of parameters from future ( $\bar{X} = -6.67$ ) and past ( $\bar{X} = -5.86$ ) conditions was not statistically significant ( $F(1, 28) = 4.13, p > .05$ ) for non-smokers. The overall pattern of results in comparisons within smoking status (smokers and non-smokers) can be seen in Table 2.

### 3.4. Comparison of smokers and non-smokers

Another test of future and past symmetry is similar differentiation of smokers and non-smokers with future and past discounting assessments. As in previous research examining temporal discounting of drug-dependent populations, cigarette smokers discounted future gains ( $\bar{X} = -4.96$ ) significantly more than non-smokers ( $\bar{X} = -6.58; F(1, 53) = 7.18, p < .05$ ). Cigarette smokers also discounted past gains ( $\bar{X} = -4.26$ ) more than non-smokers ( $\bar{X} = -6.25; F(1, 52) = 7.53, p < .05$ ), further supporting future and past symmetry. Smokers discounted future losses ( $\bar{X} = -5.44$ ) and past losses ( $\bar{X} = -5.13$ ) more than non-smokers ( $\bar{X} = -6.77$  and  $\bar{X} = -5.47$ , respectively), though neither of these differences were statistically significant ( $F(1, 53) = 3.08, p > .05$  and  $F(1, 53) = 0.20, p > .05$ , respectively). A plot of median indifference points and best-fitting hyperbolic curves from smokers and non-smokers in the \$1000 future gains and losses conditions are the top two panels of Fig. 1. A plot of median indifference points and best-fitting hyperbolic

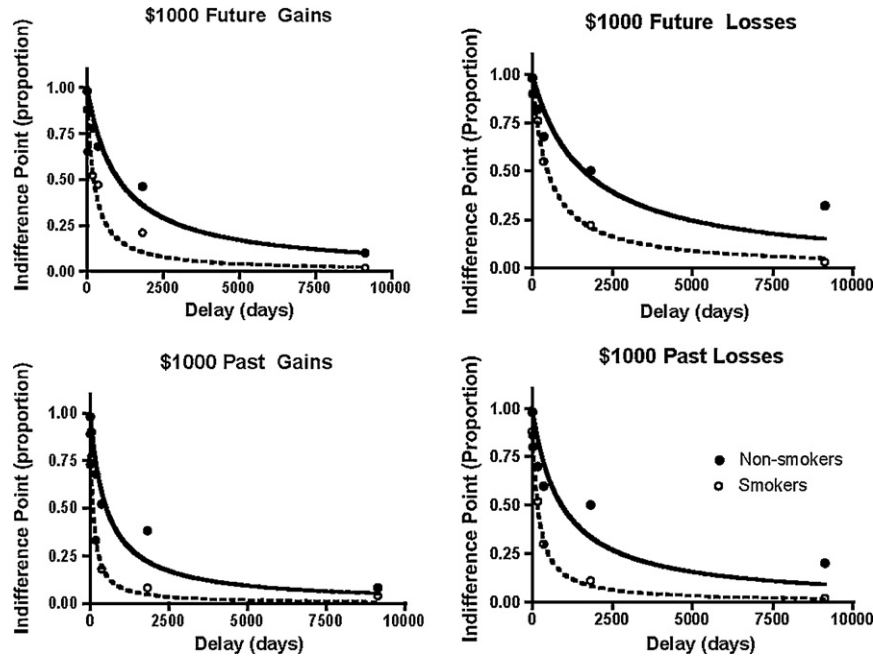


Fig. 1. Median indifference points (as present value proportions) and best-fitting hyperbolic curves obtained from smokers (open circles, dashed lines) and non-smokers (filled circles, solid lines) for \$1000 future gains (top left), \$1000 future losses (top right), \$1000 past gains (bottom left), and \$1000 past losses (bottom right). Goodness-of-fit measures ( $R^2$ ) range from .82 to .99 with median indifference points.

curves from the \$1000 past gains and losses conditions are the bottom two panels of Fig. 1.

### 3.5. Within-subject relationships

Our final test of future and past symmetry is the examination of a within-subject relationship of obtained discounting parameters. Pearson correlations were conducted, with results listed in a correlation matrix (Table 3). All correlations were positive, with most of them significant at  $p = .05$ . Noteworthy are the very high correlations between the discounting parameters for future gains and past gains (significant at  $p = .001$ , and following Bonferroni correction). This is illustrated in scatter plots of future and past discounting rates for \$1000 gains (top; Fig. 2) and \$1000 losses (bottom; Fig. 2). Non-significant correlations mostly involve the discounting of past losses conditions. As with parametric com-

parison of discounting parameters, correlations of discounting parameters support future and past symmetry.

## 4. Discussion

In this study, we examined the discounting of future and past gains and losses by cigarette smokers and controls. Overall, we found that the pattern of results for future and past outcomes was generally symmetrical for both smokers and controls, and cigarette smokers discounted both future and past hypothetical monetary gains significantly more than controls. These data demonstrate that the temporal construal of gains extends both into the past and the future. The lack of difference in discounting of past and future losses between smokers and controls, and the weaker correlations between past and future losses (relative to gains) may indicate potential differences between discounting gains and losses. Four points regarding the obtained results follow.

First, hyperbolic discounting, the magnitude effect, and population differences (smokers vs. controls) supports symmetry between future and past discounting of monetary gains. As in many previous studies of future discounting (e.g., Kirby, 1997) and in the one prior study of past discounting (Yi et al., 2006), the hyperbolic model of discounting proposed by Mazur (1987) proved a superior model of human discounting behavior. Furthermore, small-magnitude gains were discounted more than large-magnitude gains (the magnitude effect). This has been well demonstrated with money (hypothetical and real) and with hypothetical drug reinforcers (Baker et al., 2003; Giordano et al., 2002) among humans (drug dependent and human controls). The extension of the magnitude effect to the past and to cigarette

Table 3  
Pearson correlations between obtained discounting parameters

	FG10	FG100	FG1000	FL10	FL100	FL1000
PG\$10	.69**	.58**	.49**	.36*	.23	.28†
PG\$100	.66**	.65**	.63**	.38*	.25	.30†
PG\$1000	.59**	.62**	.72**	.35*	.23	.35*
PL\$10	.24	.28†	.29†	.22	.31†	.28†
PL\$100	.18	.22	.36*	.22	.40*	.33†
PL\$1000	.31†	.36*	.44**	.19	.20	.20

FG indicates future gains; FL indicates future losses; PG indicates past gains; PL indicates past losses.

†  $p < .05$ .

\*  $p < .01$ .

\*\*  $p < .001$ .

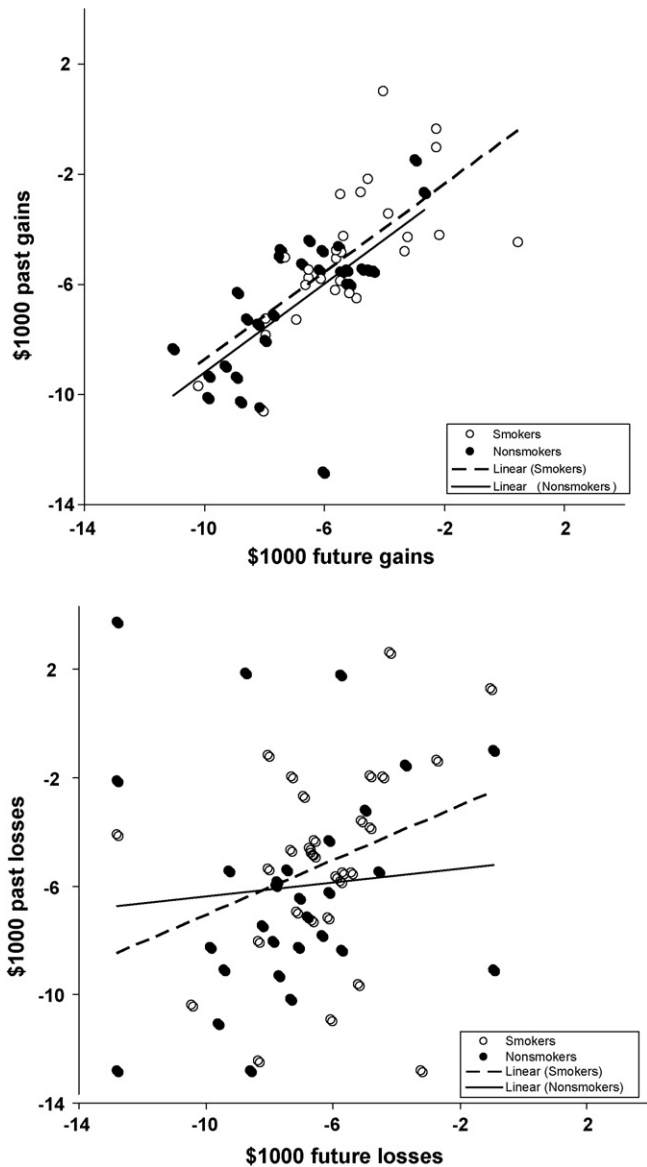


Fig. 2. Scatter plots with linear regression lines of future and past \$1000 gains (top) and losses (bottom). Smokers are represented by open circles and dashed lines. Non-smokers are represented by filled circles and solid lines.

smokers supports the notion that that processes and brain regions that value different magnitudes of reward may act similarly when considering both past and future rewards, affected comparably by the conditions associated with dependence on tobacco. The sign effect, where gains are discounted more than losses, was not replicated in the present experiment in either group, though non-significant differences were in the predicted direction. Future studies using these procedures in conjunction with neuroimaging techniques would be able to clarify the co-identity of brain regions associated with past and future discounting.

Second, greater preference for smaller, more immediate rewards over larger, more delayed rewards has been considered an indication of impulsivity; that is, the individual was unwilling or unable to defer gratification or inhibit responding. Although impulsivity can apply to a wide range of measures and observations (Evenden, 1999), the fact that cigarette smokers discount

past gains more than controls presents some challenges to the notion that discounting refers to inability to inhibit responding or delay gratification; there is nothing to inhibit in the past. Indeed, to insure that all choices were referential to the past is precisely why we selected an hour ago as the more immediate option in the past discounting condition of our study.

What is likely is that the same valuation and discounting processes are engaged when considering events in the future or in the past, and those who are dependent on substances are prone to be more focused on a temporally limited “now.” Consider that the experience of “now” likely includes events that happened in the immediate past and are anticipated to occur in the immediate future. Thus, the discounting of future and past rewards, rather than measuring the inability to inhibit responding, may define a temporal window that extends symmetrically from the present into both the future and the past. This smaller temporal window of high-discounting individuals suggests that cigarettes smokers may be more “stuck in time” (Roberts, 2002). The implications of this will have to be further examined, but may indicate a mechanism that explains why addicts seem to neither learn from prior experience nor anticipate the future. Moreover, these findings are also consistent with competing neurobehavioral systems hypotheses of addiction (Bechara, 2005; Bickel et al., 2007). These hypotheses suggest that addiction results from hyperactive impulsive systems exhibited by mid-brain systems related to reinforcement (e.g., limbic region) and hypoactive executive systems (e.g., prefrontal cortex). Given the principal function of the executive system and prefrontal cortex to cross-temporally organize behavior (Fuster, 1985; Fuster, 1997; Miller and Cohen, 2001), a diminished or hypoactive executive system and prefrontal cortex could result in the restricted temporal focus frequently observed among the addicted.

Third, the present study replicates the prior findings of greater discounting of future gains among cigarettes smokers (Bickel et al., 1999) and extends those results to discounting of past gains. We replicate a substantial number of studies that have demonstrated that adult cigarette smokers discount future gains more than controls (e.g., Baker et al., 2003; Heyman and Gibb, 2006; Mitchell, 1999; Ohmura et al., 2005; Reynolds et al., 2004). We also provide the first demonstration that nicotine-dependent individuals discount past gains more than controls. Consistent with the first published study of past discounting (Yi et al., 2006), this finding suggests that valuation is not only operative in considering future actions, but applies to the valuation of past events. What remains to be empirically determined, is whether other forms of dependence also demonstrate greater discounting of past outcomes, and if events that have been documented to alter discounting of the future (such as withdrawal; Giordano et al., 2002) also produce symmetrical changes in past discounting.

Fourth, observed results in the discounting of losses were somewhat equivocal. Though smokers discounted future and past losses more than non-smokers, this difference did not reach statistical significance. This is partially consistent with Baker et al. (2003), who found that cigarette smokers discount losses more than non-smokers, and Ohmura et al. (2005), who found no differences in the discounting of losses. Given the relatively limited between-condition variability observed in the discounting

of losses (Estle et al., 2006), this is not surprising. Importantly, the same profile of results was observed in both future and past discounting of losses, maintaining future/past symmetry.

Finally, this study was conducted using only hypothetical events, which may have influenced the findings. A growing body of literature has compared discounting of real and hypothetical future rewards as the focus of the study or as one condition of a larger study (Johnson and Bickel, 2002; Lagorio and Madden, 2005; Madden et al., 2003). These studies all demonstrate very similar findings when comparing identical magnitudes. Comparisons of real and hypothetical outcomes in the past, unlike the future, are procedurally challenging, if not impossible. As a consequence, direct comparison of real and hypothetical may not be possible. Fortunately, discounting is a phenomenon that has functional relations (e.g., hyperbolic in form, magnitude effect) that are well established and replicated. Thus, if the results of the hypothetical were spurious, it is difficult to imagine why the results would follow the contours of those functional relationships. Moreover, arguably there are multiple ways to interpret the past discounting procedures. The greater variability in past losses may indicate between-subject variability in the interpretation of the choice. Therefore, there may be value of debriefing participants and asking how the participants interpreted and framed the past discounting choices they were presented.

In conclusion, the present study extends the use of a novel discounting procedure to cigarette smokers. Cigarette smokers discount the future and past more than controls, providing compelling support of recent empirical findings and theoretical frameworks suggesting that the future and past may be causally linked. The ability to consider and value the future may be tied to the ability to value the past. With respect to addiction, this research opens up the possibility of new lines of inquiry examining whether variables that affect future discounting also affect past discounting. Similarly, there may be value in considering whether phenomena tied to the past such as memory could be used to change future discounting.

### Conflict of interest

Warren K. Bickel has been a partner in a small business, HealthSim, since 1997. He is also part owner of Laughing Moon Café since 2006. Dr. Bickel has been a member of the National Advisory Council for Drug Abuse since 2006.

All other authors declare that they have no conflicts of interest.

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Yi, statistical analysis; wrote results section; modified methods; Benjamin P. Kowal, wrote methods; conducted and collected data; Kirstin M. Gatchalian, conducted and collected data; All authors contributed to and have approved the final manuscript.

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