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Delay Discounting in Current and Never-Before Cigarette Smokers: Similarities and Differences Across Commodity, Sign, and Magnitude

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Research has found that nicotine-dependent individuals delay discount monetary gains at a higher rate than matched controls. Delay discount rates, however, have also been found to vary across within-subject variables such as the magnitude of the outcome (e.g., $10 or $1,000), whether the outcome constitutes a gain or a loss, and the commodity being evaluated (e.g., money or health). The present study comprehensively investigated the differences in delay discounting between current and never-before cigarette smokers and across these within-subject variables. Both groups exhibited a magnitude, sign, and commodity effect. Current smokers' delay discount rates for monetary outcomes, however, were higher than never-before smokers across all magnitudes and both signs. This trend was also found for delayed health outcomes, but failed to reach significance.

The notion that drug-dependent individuals are more impulsive than non–drug-dependent individuals is not new. In the past, studies have generally relied on questionnaire-based personality assessments to uncover differences in impulsiveness between drug- and non–drug-dependent individuals. For example, heavy drug users (Golding & Cornish, 1987), hospitalized and inpatient substance abusers (King, Jones, Scheuer, Curtis, & Zarcone, 1990; Rosenthal, Edwards, Ackerman, Knott, & Rosenthal, 1990), opioid-dependent patients (Madden, Petry, Badger, & Bickel, 1997), and cigarette smokers (Bickel, Odum, & Madden, 1999) have scored significantly higher on the Eysenck Impulsivity Questionnaire (Eysenck & Eysenck, 1978) than control groups. Differences in impulsivity between drug- and non–drug-dependent individuals have also been found with other questionnaire-based measures such as the Barratt Impulsiveness Scale (Barrat, 1985; Kirby, Petry, & Bickel, 1999; Mitchell, 1999), the Stanford Time Perception Inventory (Petry, Bickel, & Arnett, 1988; Zimbardo, 1992), and the Future Time-Perspective scale (Alvos, Gregson, & Ross, 1993; Manganiello, 1978; Murphy & DeWolfe, 1986; Wallace, 1956).

A more recent trend in research on drug abuse and impulsivity is the use of delay discounting as an index of impulsivity. Delay discounting refers to the fact that the subjective value of an outcome (e.g., receiving $100) depreciates when it is delayed. Another way of stating this is that delayed outcomes have less impact on behavior than immediate outcomes. The rate at which the value of a delayed outcome depreciates as it is delayed can vary. For example, a person who feels that $100 paid in 2 months is equivalent in value to receiving $50 now is delay discounting the outcome at a higher rate than a person who feels that the $100 in 2 months is equivalent in value to receiving $80 now. Impulsivity may reflect a high rate of delay discounting. Figure 1 shows two hypothetical discount functions for some outcome. The value of the outcome is highest when there is no delay and decreases as delay increases. Function A represents a more "impulsive" delay discount function than Function B because the value of the outcome is delay discounted at a higher rate in Function A than in Function B.

The rate at which an individual delay discounts an outcome can be determined using a psychophysical procedure. In the psychophysical procedure, a participant is presented with a standard delayed outcome option and an immediate outcome option that is adjusted until the participant considers the two options equivalent in value (Stevens, 1975). For example, a participant may be presented with a choice between $100 paid after 1 month and a smaller amount of money paid immediately (e.g., $25). The magnitude of the immediate outcome is adjusted from $25 until the participant is indifferent between the delayed and immediate outcomes (e.g., indifferent between $100 in 1 month and $70 now). The participant then evaluates the value of $100 paid after other delays as well (e.g., 6 months, 1 year, or 5 years). The rate at which the value of the $100 is delay discounted is estimated by fitting a function to the indifference points obtained for each of the delays.

Studies have shown that delay discounting by both humans (Rachlin, Raineri, & Cross, 1991) and nonhumans (Rodriguez & Logue, 1988) is well described by Mazur's (1987) hyperbolic equation:

$$Vp = \frac{V}{(1 + kD)} \quad (1)$$

where Vp is the present (discounted) value of a reward with an objective (undiscounted) value of amount V. The k parameter represents sensitivity to delay, D. More specifically, when $k = 0$, delaying a reward does not cause it to lose any value (the function of value by delay would be a flat line); higher values of k result in a function that declines steeply. Thus, the k value is directly related

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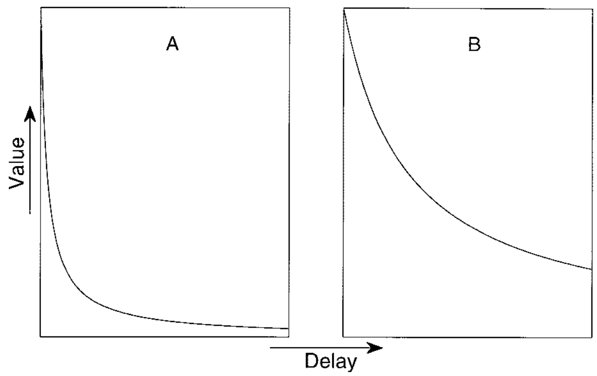

Figure 1. Hypothetical delay discount functions. Both functions show the present value of a reward as it is delayed. Function A represents a delay discount function that is more "impulsive" than the one represented by Function B, because in Function A, the present value of the reward is much more sensitive to delay.

to delay discount rate and, therefore, may be used as an index of impulsivity. In fact, both delay discounting functions in Figure 1 are based on Equation 1, but the *k* value in Function A is 10 times greater than the *k* value in Function B.

Drug-dependent individuals have been found to delay discount hypothetical monetary gains at a higher rate than matched controls (for a review, see Bickel & Marsch, 2001). Delay discount rates, however, have also been found to vary depending on factors associated with the outcome. These factors include the commodity being evaluated (i.e., domain effect), whether the outcome constitutes a gain or a loss (i.e., sign effect), and the magnitude of the outcome (i.e., magnitude effect). The effects of domain, sign, and magnitude on delay discount rates have not been compared between nicotine- and non–nicotine-dependent individuals. Thus, a central question in the current investigation is whether nicotine-dependent individuals are similar to non–nicotine-dependent individuals in that their delay discount rate for an outcome is affected by its domain, sign, and magnitude. Another question of interest is whether nicotine-dependent individuals delay discount outcomes at a higher rate than non–nicotine-dependent individuals regardless of the domain, sign, and magnitude. Answering these questions would lead to a better understanding of how pervasive the difference in impulsivity is between drug- and non–drug-dependent individuals. Research on the effects of domain, sign, and magnitude on delay discount rate is reviewed next.

Domain Effect

The domain effect refers to the finding that the rate at which outcomes are delay discounted depends on the commodity being considered. Chapman and Elstein (1995) compared delay discount rates for hypothetical money gains, vacations, and health gains and found that health gains were delay discounted at a higher rate than monetary gains and vacations (which did not differ in delay discount rate). However, Cairns (1992) found that delay discount rates were higher for hypothetical money losses than for hypothetical health losses. In an attempt to resolve this inconsistency, Chapman (1996) conducted another series of experiments looking at the effect of domain and sign on discount rate when health and money were matched on value. Although there was evidence of higher delay discount rates for health than money when considering gains and higher delay discount rates for money than health when considering losses, not all of the analyses supported this interaction. Raineri and Rachlin (1993) compared, post hoc, delay discounting rates between receiving $50/day for 1 year, a 1-year vacation, and the use of a rental car for 1 year. They found that on average delay discount rates were highest for the rental car, followed by the vacation, and then the money. The authors suggested that the domain effect was due to the rate at which these commodities could be consumed. Lastly, several studies have compared delay discount rates between hypothetical money and hypothetical drug of dependence in drug-dependent individuals. Opioid-dependent individuals were found to delay discount heroin at higher rates than money (Madden, Bickel, & Jacobs, 1999; Madden et al., 1997; Odum, Madden, Badger, & Bickel, 2000), and cigarette smokers were found to delay discount cigarettes at higher rates than money (Bickel et al., 1999).

In summary, drug-dependent individuals clearly delay discount hypothetical drug gains at a higher rate than hypothetical monetary gains. It is unclear whether non–drug-dependent individuals delay discount health and money at different rates. Delay discount rates for health and money may, however, interact with the sign of the outcome (gain or loss). Most important, delay discount rates for health outcomes have not been tested in drug-dependent individuals, nor have delay discount rates for health outcomes been compared between drug- and non–drug-dependent individuals.

Sign Effect

The sign effect refers to the finding in which outcomes that constitute a gain are delay discounted at a higher rate than outcomes that constitute a loss. Several studies have found that people (whose history of drug use was not determined) delay discount hypothetical money gains at a higher rate than hypothetical money losses (Benzion, Rapoport, & Yagil, 1989; Loewenstein, 1988; Shelley, 1993; Thaler, 1981). The sign effect has also been found in the delay discounting of hypothetical health outcomes (Chapman, 1996; MacKeigan, Larson, Draugalis, Bootman, & Burns, 1993). The sign effect, however, has never been investigated in delay discounting by drug-dependent individuals nor has it been compared between drug- and non–drug-dependent individuals.

Magnitude Effect

The magnitude effect refers to the finding that outcomes of larger magnitudes (e.g., $1 million) are delay discounted at lower rates than outcomes of smaller magnitudes (e.g., $100). The magnitude effect is well documented in the evaluation of hypothetical money gains (Benzion et al., 1989; Green, Fristoe, & Myerson, 1994; Green, Myerson, & McFadden, 1997; Kirby & Maraković, 1995; Myerson & Green, 1995; Raineri & Rachlin, 1993; Thaler, 1981; but for probabilistic rewards, see Green, Myerson, & Ostaszewski, 1999a). Raineri and Rachlin also found magnitude effects in the delay discounting of vacations and the use of a rental car. Delay discount rates of hypothetical health outcomes are also susceptible to the magnitude effect (Chapman, 1996; Chapman & Elstein, 1995). The magnitude effect has never been investigated in delay discounting by drug-dependent individuals nor has it been compared between drug- and non–drug dependent individuals.

Validity and Reliability of Delay Discount Rates

Studies that have measured delay discount rates in humans have primarily asked participants to evaluate hypothetical outcomes. This raises the question of whether the findings based on these studies generalize to the delay discounting of real outcomes. A few studies have measured delay discount rates for real rewards. In these studies, participants (whose history of drug use was not determined) actually received the outcome they preferred on one randomly selected trial (Johnson & Bickel, 2002; Kirby, 1997; Kirby & Maraković, 1995, 1996). Furthermore, delay discounting of a real $10 reward was measured in psychiatric outpatients (Crean, de Wit, & Richards, 2000) and in current and never-before cigarette smokers (Mitchell, 1999). Kirby et al. (1999) gave heroin addicts and matched controls a one in six chance of receiving one of the choices they made during a delay discounting assessment of a delayed $85 reward. The results of all of these studies are congruent with the results of studies based on hypothetical outcomes in that delay discount rates for real outcomes are well described by Equation 1, and drug-dependent individuals delay discount real rewards at a higher rate than matched controls. Kirby, however, noted that across studies, hypothetical monetary gains seem to be delay discounted at a lower rate than real monetary gains. Johnson and Bickel (2002) conducted a within-subject comparison between delay discount rates for real and hypothetical monetary rewards and found no systematic differences. More important, no study has ever done a within-subject comparison of drug-dependent individual's delay discount rates between real and hypothetical monetary gains. Thus, it remains to be seen whether drug-dependent individuals delay discount hypothetical and real outcomes at the same rate.

Another issue concerning the measurement of delay discount rates is whether the obtained delay discount rates are reliable; only one study has assessed this. Simpson and Vuchinich (2000) measured delay discount rates for hypothetical monetary gains twice in two different sessions, 1 week apart from each other, and found that the test–retest reliability was quite high. No study, however, has tested the test–retest reliability of delay discount rates in drug-dependent individuals.

To gain a better understanding of the similarities and differences in delay discounting between drug- and non–drug-dependent individuals, the current study comprehensively investigated delay discount rates for various outcomes in both current cigarette smokers and never-before cigarette smokers. Current and never-before cigarette smokers evaluated various hypothetical delayed outcomes that consisted of receiving or losing different commodities (money, health, and cigarettes) of various magnitudes (e.g., $10, $100, and $1,000). To assess the external validity of the delay discount rates for the hypothetical outcomes, participants also evaluated real delayed monetary gains ($10 and $100). To assess the test–retest reliability of the delay discount rates, participants returned to the laboratory 1 week later and evaluated all of the delayed outcomes a second time.

Method

Participants

Participants were 30 current smokers and 30 never-before smokers who were recruited through newspaper advertisements and fliers posted in prominent public places in Burlington, Vermont. People who replied to the ads were screened, and those who reported substance abuse or psychiatric disorders were eliminated (the exception being nicotine dependence for current cigarette smokers). Current smokers were people who reported smoking at least 20 cigarettes per day, had a Fagerstroem Test for Nicotine Dependence (Heatherton, Kozlowski, Frecker, & Fagerstroem, 1991) score of at least 6, and answered "yes" to at least three questions on the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM–IV*; American Psychiatric Association, 1994) drug checklist for cigarettes. Never-before smokers were people who reported that they had never smoked cigarettes. We tried to select never-before smokers whose demographics (shown in Table 1) matched those of the current smoker group. Participants gave written informed consent for the study, which was approved by the University of Vermont Institutional Review Board. Participants were tested individually and received $15 compensation per hour of participation (paid after each session), plus the monetary rewards that they earned during the "real money gain" conditions (described next).

Procedure

Prior to coming to the lab, a research assistant interviewed people on the phone who expressed interest in participating in the study. The brief phone interview consisted of gathering demographic information and screening for any substance abuse and psychiatric disorders; those who qualified were invited to participate in the study. The study consisted of three sessions, each taking 2–3 hr to complete. The only constraint on when the sessions were conducted was that the third session had to occur 1 week after the second session.[1] Current smokers were instructed to smoke as usual before they arrived for testing; several breaks were scheduled throughout the sessions for all participants (during which current smokers were allowed to smoke). During each session, a research assistant administered the study to participants at a table in a small quiet room.

In the first session, all participants signed an informed consent form, provided a carbon monoxide reading (an indicator of smoking), and were administered the Quick Test (Ammons & Ammons, 1962) to assess their IQ. Furthermore, all participants were asked to estimate a duration of improved health that would be equivalent to receiving $1,000 and a duration of worse health that would be equivalent to losing $1,000. For example, to obtain a health gain that was equivalent to receiving $1,000, participants read the following:

> I want you to think about your health over the past month. Now I want you to imagine that you have a choice between receiving some money and temporarily feeling 10% better. That means you would feel more alert, have more energy, be physically stronger, have less body fat, and be less likely to become sick. However, this 10% increase in your health would only be temporary and then you would return to your current state of health. For the following statement, please fill in the duration of improved health that would make the two choices equally attractive to you:

[1] Not all participants were able to return to the laboratory exactly 1 week later for Session 3. Three participants returned earlier than 1 week (2 returned 5 days later and 1 returned 6 days later). Six participants returned more than 1 week later (2 participants returned 8 days later, and 4 participants each returned 9 days, 11 days, 12 days, and 16 days later, respectively).

Table 1
Demographics for Current and Never-Before Smokers

Variable	Current smokers		Never-before smokers	
	M	*SD*	*M*	*SD*
Carbon monoxide reading	27	13.2	2	1.5
Sex (% men)	57		57	
Age (years)	30.9	9.7	33.0	10.9
Education (years)	12.9	2.0	14.8	2.3
Monthly income ($)[a]	1,200	525–1,375	1,450	825–2,245
Quick Test IQ score	37.2	4.2	40.3	4.1

[a] Median (interquartile range).

> *Receiving $1,000 right now would be just as attractive as experiencing _______ (years, months, weeks, days) of 10% better health.*

The health loss equivalence exercise was presented in the same manner except that it was in terms of feeling 10% worse for some duration of time versus losing $1,000. Current smokers were also asked to estimate the number of packs of cigarettes given to them that would be equivalent to receiving a certain amount of money ($10, $100, and $1,000). Current smokers also estimated the number of packs of cigarettes lost that would be equivalent to losing a certain amount of money ($10, $100, and $1,000). For example, to obtain a cigarette gain that was equivalent to receiving $1,000, participants read the following:

> I want you to imagine that you have a choice between receiving some money and receiving packs of cigarettes. For the following statement, please fill in the number of packs that would make the two choices equally attractive to you:
>
> *Receiving $1,000 right now would be just as attractive as receiving _______ packs of cigarettes.*

All participants also filled out an additional set of questionnaires that are not analyzed here.

During the second session, participants worked through computer programs (described in detail later) that measured delay discount rates for various outcomes. In these programs, participants were asked to make a series of choices between a standard larger later (LL) option and an adjusting smaller sooner (SS) option. The magnitude of the SS option was adjusted across trials until an indifference point was determined (described in detail later). Once an indifference point was determined, the LL option was delayed further and the titration procedure was repeated. For all commodities (across all magnitudes and both signs), the present value of the LL option was assessed at seven different delays (1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years).

During the second session, both groups first evaluated delayed hypothetical monetary gains. Three different magnitudes were presented ($10, $100, and $1,000), which were counterbalanced for ascending and descending order of presentation. Second, both groups evaluated delayed hypothetical health gains. Participants were presented with the duration of improved health that they stated was equivalent to receiving $1,000 in Session 1. Third, current smokers evaluated delayed hypothetical cigarette gains. Participants were presented with three magnitudes of cigarettes, which were the number of packs that they stated was equivalent to receiving $10, $100, and $1,000 in Session 1, in the same order as presented for money gains. The second half of the session consisted of repeating the same delay discounting assessment computer programs in the first half (in the same order), but in terms of losses. After evaluating hypothetical money and health (and cigarettes for current smokers) at all of the magnitudes and in terms of losses, participants then evaluated real delayed money gains of two magnitudes: $10 and $100. Participants were instructed that two choice trials (one for each magnitude) would be chosen at random and they would receive the option that they had chosen during the trial. Participants had the option of having the money mailed to them or they could return to the laboratory and pick it up after the appropriate date. If an immediate outcome had been selected, the money was paid at the end of the session.

Participants returned to the laboratory 1 week later for the third session, which was identical to the second session except that participants were debriefed at the end of the session.[2] During Sessions 2 and 3, participants also completed a few other brief choice exercises on the computer that are not reported here.

Delay Discounting Measure Computer Programs

Delay discount rates were assessed with computer programs presented on a laptop computer using Visual Basic software. On each trial, the screen presented a choice between two outcomes: one SS option and one LL option. The SS and LL options were displayed in rectangular command buttons on the left and right side of the screen, respectively. Above and centered between the two response buttons was a green circle that signaled participants to choose between the two options. Participants chose one of the two options by clicking the mouse on the appropriate command button. After participants chose an option, the circle turned from green to red, and the SS amount was either increased or decreased. Participants were unable to choose an option when the circle was red. After a 1-s delay, the circle turned back to green and participants could again choose between the options. There was no limit to the time a participant could wait before making his or her choice.

The computer varied the SS option amount according to a double limit procedure adapted from the one reported by Richards, Zhang, Mitchell, and de Wit (1999). Briefly, the computer randomly selected an amount (or a duration for health) for the SS option (in adjustment increments described next) from within a range set by two outer limits. These limits adjusted so that the SS option converged upon an indifference point; that is, the point at which a participant was indifferent between the SS option and the LL option (for more details, see Richards et al., 1999). An important aspect of the double limit procedure is that any single erroneous response will not result in the determination of an indifference point. That is, if a current response is inconsistent with previous responses, the appropriate limits are reset. For example, if a participant had chosen $12 right away over $100 in a year, but then chose $100 in a year over $14 right away, the lower limit of the range from which the SS amount was selected would be reset to $0 and the program would continue. When the difference between the upper and lower limits was equal to the adjustment interval (see next paragraph), the current SS amount was recorded as the indifference point.

The computer determined indifference points for both gains and losses for money, health, and cigarettes. As an example of the presentation phrases for money gains, the SS choice might have stated, "Receive $10 right away," while the LL choice might have stated, "Receive $100 after waiting 1 year." For losses, the word "Receive" was replaced by "Lose." Choices for cigarettes and health used an amount previously determined to be subjectively equivalent by the participant to a money amount ($10, $100, or $1,000 for cigarettes and $1,000 for health). The money was adjusted by intervals of 2% (i.e., $0.20, $2, and $20 for $10, $100, and $1,000 magnitudes, respectively). Cigarettes were adjusted by individual cigarettes for the $10 equivalence, packs of cigarettes for the $100 equivalence, and 2% of the larger later outcome expressed in packs for the $1,000 equivalence. Health was expressed in years, months, weeks, and days, and was adjusted by individual days.

[2] One participant in the current smoker group did not complete the cigarette discounting conditions in Session 3.

Analyses

Equation 1 was fit to the seven indifference points for each outcome for each participant. For example, the rate at which a participant delay discounted the $100 gain outcome across the seven delays was indexed by the *k* parameter in Equation 1. Thus, a *k* parameter was derived for each of the outcomes, resulting in 40 *k* parameters for each never-before cigarette smoker (20 from Session 2 and 20 from Session 3) and 52 *k* parameters for each current cigarette smoker (26 from Session 2 and 26 from Session 3). The *k* parameter in Equation 1 has a skewed distribution. Therefore, all parametric statistical tests were performed on the natural log transformation of the data, which normalized the distributions. A series of six planned analyses of variance (ANOVAs) tested the effects of domain, sign, magnitude, and cigarette smoking status on the delay discount rates obtained during Session 2. To assess the test–retest reliability of the delay discount rates, correlations were computed between the delay discount rates obtained during Session 2 and those obtained 1 week later during Session 3. To reduce the familywise Type I error rate, the alpha level for all statistical tests was set at .025.

Results

Figure 2 shows the (untransformed) median *k* values for each group for each of the outcomes presented during Session 2. Figure 3 shows the (untransformed) median *k* values for each group for each of the outcomes when participants evaluated the outcomes a second time, 1 week later, during Session 3. For both Figures 2 and 3, taller bars indicate a higher rate of delay discounting (i.e., a higher level of impulsivity).

Table 1 displays the demographics of the two groups. Independent *t* tests assessed whether the current and never-before smoker groups systematically differed in terms of their age, years of education, monthly income, and IQ. The two groups did not significantly differ in age, $t(58) = 0.76$, $p = .45$, but there was a significant difference in years of education, monthly income, and IQ: $t(58) = 3.36$, $p < .01$; $t(58) = 2.66$, $p = .01$; and $t(58) = 2.88$, $p < .01$, respectively.

Table 2 shows the correlations between smoking status and age, years of education, monthly income, and IQ as well as the correlations between smoking status and the obtained natural log *k* values for various delayed outcomes. Current smokers were scored as “0” and never-before smokers as “1.” Thus, the significant positive correlations between smoking status and the demographics reflect the fact that the never-before smoker group had higher education, income, and IQ scores than the current smoker group. Negative correlations between the obtained natural log *k* values and the demographics reflect higher demographic scores being associated with lower delay discount rates (i.e., lower levels of impulsivity).

The first ANOVA tested for differences in delay discount rates for hypothetical money gains and losses between current and

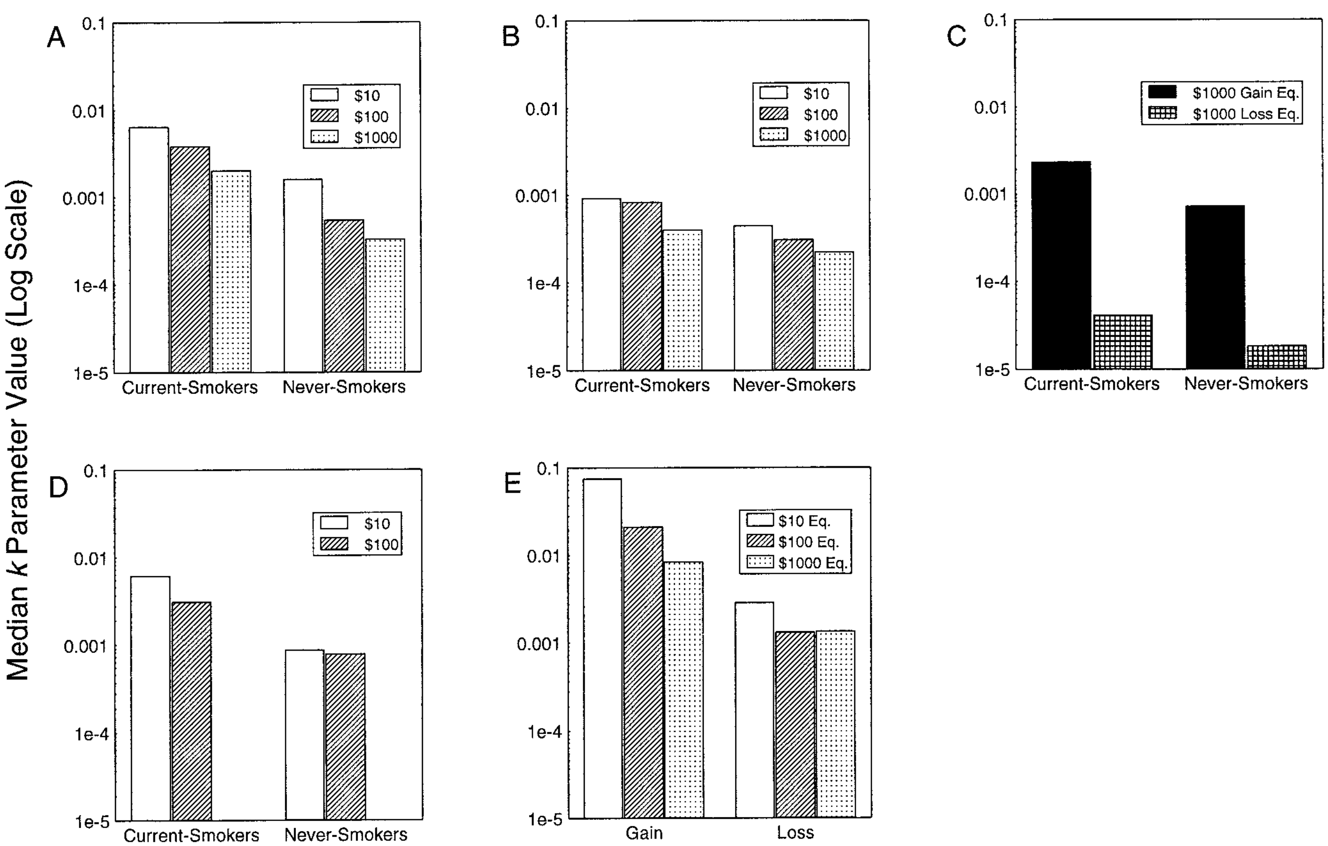

Figure 2. Median *k* values estimated from each group for each of the discounting conditions presented during Session 2. Eq. = Equivalence. A = hypothetical money gain; B = hypothetical money loss; C = hypothetical health; D = real money gain; E = hypothetical cigarettes.

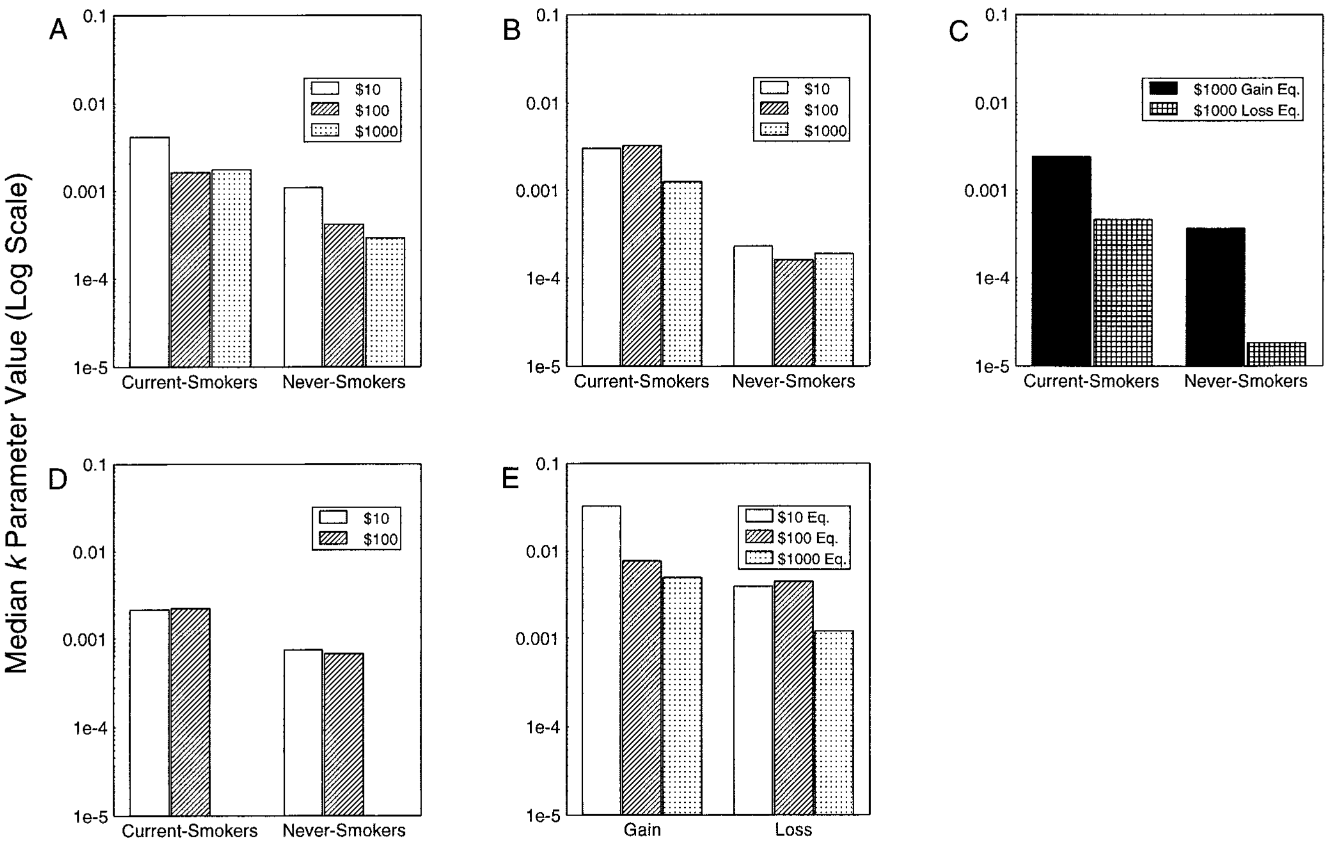

Figure 3. Median *k* values estimated from each group for each of the discounting conditions presented during Session 3. Session 3 was identical to Session 2 and occurred 1 week later. (See footnote 1.) Eq. = Equivalence. A = hypothetical money gain; B = hypothetical money loss; C = hypothetical health; D = real money gain; E = hypothetical cigarettes.

never-before smokers. The questions of interest were whether both groups exhibited a magnitude and a sign effect and whether delay discount rates differed between the two groups. A 2 (smoking status) × 2 (sign) × 3 (magnitude) mixed-factorial ANOVA was run on the delay discount rates for the hypothetical money outcomes. Table 3 shows the results of this analysis. The main effect of smoking status was significant. As can be seen in two upper left-hand graphs in Figure 2, current smokers delay discounted hypothetical money outcomes at a significantly higher rate than never-before smokers, regardless of the magnitude and sign of the monetary outcomes. The main effects of sign and magnitude were also significant. As can be seen in the two upper left-hand graphs in Figure 2, both groups delay discounted hypothetical money gains at a higher rate than hypothetical money losses, and they delay discounted smaller money outcomes at a higher rate than larger money outcomes.

Table 2
Correlations Between Demographics and Smoking Status and Obtained Natural Log k Values for Various Delay Outcomes

Status/Outcome	Age	Education	Income	IQ
Smoking status	.10	.40**	.33**	.35**
Obtained natural log k value				
$1,000 gain	−.21	−.21	−.19	−.34**
$1,000 loss	−.07	−.12	−.05	−.07
$1,000 equivalent health gain	−.18	−.20	−.13	−.09
$1,000 equivalent health gain	−.07	.09	−.10	−.07

** $p < .05$.

The second ANOVA tested for differences in delay discount rates of hypothetical health outcomes between current and never-before smokers. The questions of interest were whether both groups exhibited a sign effect and whether delay discount rates differed between the two groups. A 2 (smoking status) × 2 (sign) mixed-factorial ANOVA was run on the delay discount rates for the hypothetical health outcomes. Table 4 shows the results of this analysis. The main effect of sign was significant, but the main effect of smoking status was not significant. As can be seen in the upper right-hand graph in Figure 2, both groups delay discounted health gains at a higher rate than health losses. On average, the current smokers delay discounted both hypothetical health gains and losses at a higher rate than the never-before smokers, but this difference failed to reach statistical significance.

The third ANOVA tested the external validity of the hypothetical monetary outcome conditions. The questions of interest were whether delay discount rates differed across the real and hypothet-

Table 3
Results of the Analysis of Variance of the Delay Discount Rates for Hypothetical Money Outcomes

Effect	*df*s	*F*	*p*	*MSE*	Partial η^2	Power
Smoking status (A)	1, 58	8.54	<.01*	29.25	.13	.82
Sign (B)	1, 58	15.72	<.01*	13.82	.21	.97
Magnitude (C)	2, 116	10.79	<.01*	1.71	.16	.99
A × B	1, 58	0.36	.55	13.82	.01	.09
A × C	2, 116	3.58	.03	1.71	.06	.65
B × C	2, 116	3.04	.05	1.93	.05	.58
A × B × C	2, 116	0.81	.45	1.93	.01	.19

* $p < .025$.

ical monetary conditions, whether both groups showed a magnitude effect when evaluating both hypothetical and real monetary outcomes, and whether delay discount rates for real monetary outcomes differed between the two groups. A 2 (hypothetical vs. real) × 2 (magnitude) × 2 (smoking status) mixed-factorial ANOVA was run on the delay discount rates for the hypothetical and real monetary outcomes at the $10 and $100 magnitudes. Table 5 shows the results of this analysis. The main effects of smoking status and magnitude were both significant. As can be seen in the upper and lower left-hand graphs in Figure 2, the current smokers delay discounted monetary outcomes, across both hypothetical and real conditions, at a higher rate than the never-before smokers. Furthermore, both groups exhibited a magnitude effect across both the hypothetical and the real monetary outcomes. Finally, the main effect of hypothetical–real was not significant, suggesting that delay discount rates did not differ between the hypothetical and real monetary outcomes.

The fourth ANOVA tested for differences in delay discount rates between the hypothetical monetary outcomes and the hypothetical health outcomes. The questions of interest were whether delay discount rates differed across the two commodities, whether both groups showed a sign effect when evaluating either commodity, and whether delay discount rates for these outcomes differed between the two groups. A 2 (health vs. money) × 2 (sign) × 2 (smoking status) mixed-factorial ANOVA was run on the delay discount rates for the hypothetical $1,000 monetary outcomes and for the $1,000 health outcome equivalents. Table 6 shows the results of this analysis. The main effect of smoking status was significant; that is, current smokers delay discounted at a higher rate than never-before smokers. The main effects of money–health and sign were also significant, but there was a significant interaction between these two variables. The interaction was due to the fact that, after collapsing across both groups, monetary and health gains were delay discounted at similar rates, but health losses were delay discounted at a lower rate than monetary losses.

Another question of interest was whether current smokers exhibited a magnitude and sign effect when evaluating hypothetical cigarette outcomes. A 2 (sign) × 3 (magnitude) repeated measures ANOVA was run on the current smokers' delay discount rates for the hypothetical cigarette outcomes. Table 7 shows the results of this analysis. The main effects of sign and magnitude were both significant. As can be seen in the middle lower graph of Figure 2, the current smokers' delay discount rates for hypothetical cigarette outcomes were higher for gains than for losses and their delay discount rates were higher for smaller magnitudes than for larger magnitudes. The results, however, were complicated by a significant interaction between sign and magnitude. A linear contrast was run on the delay discounting rates for the gains and the losses across the three magnitudes. This linear contrast was significant for the hypothetical cigarette gains, $F(1, 29) = 27.27$, $p < .01$, but it was not significant for the hypothetical cigarette losses, $F(1, 29) = 0.23$, $p = .64$. This suggests that the interaction between sign and magnitude was due to the fact that the magnitude effect was more pronounced in the delay discount rates for the hypothetical cigarette gains than it was for the hypothetical cigarette losses.

To test whether current smokers' delay discount rates varied across the three commodities (money vs. health vs. cigarettes), a 3 (commodity) × 2 (sign) repeated measures ANOVA was run on their delay discount rates for the various commodities at the $1,000 magnitude for both gains and losses. Table 8 shows the results of this analysis. The main effect of commodity was significant. A post hoc Scheffé test revealed that current smokers' delay discount rates were the highest when evaluating cigarette outcomes (cigarette vs. money, $p = .03$; cigarette vs. health, $p < .01$) and the lowest when evaluating health outcomes (health vs. money, $p <$ 01), with delay discount rates for monetary outcomes falling in the

Table 4
Results of the Analysis of Variance of the Delay Discount Rates for Hypothetical Health Outcomes

Effect	*df*s	*F*	*p*	*MSE*	Partial η^2	Power
Smoking status (A)	1, 58	3.05	.09	9.84	.05	.41
Sign (B)	1, 58	29.83	<.01*	6.72	.34	1.0
A × B	1, 58	<0.01	.97	6.72	<.01	.05

* $p < .025$.

Table 5
Results of the Analysis of Variance of the Delay Discount Rates for Hypothetical and Real Money Outcomes

Effect	*df*s	*F*	*p*	*MSE*	Partial η^2	Power
Smoking status (A)	1, 58	10.77	<.01*	16.37	.16	.90
Hypothetical–Real (B)	1, 58	1.62	.21	2.43	.03	.24
Magnitude (C)	1, 58	11.29	<.01*	0.96	.16	.91
A × B	1, 58	0.08	.78	2.43	<.01	.06
A × C	1, 58	0.03	.86	0.96	<.01	.05
B × C	1, 58	4.34	.04	0.61	.07	.54
A × B × C	1, 58	0.60	.44	0.61	.01	.12

* $p < .025$.

middle (collapsing across sign). As the previous analyses found, the main effect of sign was significant, which shows that current smokers' delay discount rates were higher for gains than for losses, regardless of whether they were evaluating monetary, health, or cigarette outcomes.

Finally, to check the test–retest reliability of the delay discount rates, correlations were computed between the individual *k* parameters obtained during Session 2 and the individual *k* parameters obtained during Session 3. Table 9 shows these correlations for the current and never-before smokers. All of the correlations were strong and significant.

Discussion

The results of the present study reveal similarities and differences in delay discount rates between current cigarette smokers and never-before cigarette smokers. Both the current and never-before smokers' delay discount rates were higher for monetary and health outcomes that constituted a gain than for those constituting a loss (i.e., the sign effect). Current smokers' also exhibited a sign effect when they evaluated cigarette gains and losses. The sign effect has been shown in delay discounting by non–nicotine-dependent individuals, but this is the first study to demonstrate the sign effect in nicotine-dependent individuals. Thus, nicotine-dependent individuals, just like non–nicotine-dependent individuals, may be less impulsive when consequences are framed in terms of losses rather than gains.

This is also the first study to show that both nicotine- and non–nicotine-dependent individuals exhibit a magnitude effect when evaluating delayed outcomes. Both current and never-before smokers' delay discount rates were higher for outcomes that consisted of smaller magnitudes than outcomes that consisted of larger magnitudes. Both groups exhibited a magnitude effect when evaluating real and hypothetical monetary outcomes, and the current smokers also exhibited a magnitude effect when evaluating cigarette outcomes. However, for both groups, the magnitude effect was less pronounced when evaluating monetary losses compared with monetary gains and when evaluating real monetary gains compared with hypothetical monetary gains. The magnitude effect was also less pronounced when the current smokers evaluated cigarette losses compared with cigarette gains. Thus, although nicotine-dependent individuals may, in general, delay discount monetary outcomes at a higher rate than non–nicotine-dependent individuals, their discount rates decrease when making decisions concerning outcomes of larger magnitudes.

Both the current and never-before smokers delay discounted monetary losses at a higher rate than health losses. However, delay discount rates for monetary gains and health gains were not significantly different. This interaction between domain and sign is generally consistent with earlier findings by Chapman (1996). Thus, the evidence suggests that hypothetical money losses are delay discounted at a higher rate than hypothetical health losses. However, it remains unclear as to whether hypothetical health and money gains are delay discounted at different rates.

The two groups differed, however, in that delay discount rates for real and hypothetical monetary outcomes were consistently higher in the current smokers group than in the never-before smokers group. This was true for the evaluation of both gains and losses. These results are congruent with Bickel et al.'s (1999)

Table 6
Results of the Analysis of Variance of the Delay Discount Rates for Hypothetical $1,000 Monetary and $1,000 Health Equivalent Outcomes

Effect	*df*s	*F*	*p*	*MSE*	Partial η^2	Power
Smoking status (A)	1, 58	9.39	<.01*	14.98	.14	.85
Money–Health (B)	1, 58	12.87	<.01*	4.22	.18	.94
Sign (C)	1, 58	23.24	<.01*	9.35	.29	1.0
A × B	1, 58	4.00	.05	4.22	.06	.50
A × C	1, 58	.01	.92	9.35	<.01	.05
B × C	1, 58	8.18	.01*	3.41	.12	.80
A × B × C	1, 58	.05	.82	3.41	<.01	.06

* $p < .025$.

Table 7
Results of the Analysis of Variance of Current Smokers' Delay Discount Rates for Hypothetical Cigarette Outcomes

Effect	*df*s	*F*	*p*	*MSE*	Partial η^2	Power
Sign (A)	1, 29	15.42	<.01*	14.09	.35	.97
Magnitude (B)	2, 58	7.63	<.01*	2.17	.21	.94
A × B	2, 58	5.33	<.01*	1.83	.16	.82

* $p < .025$.

results in which current cigarette smokers delay discounted a hypothetical $1,000 reward at a higher rate than both never-before and ex-smokers. This higher rate of delay discounting by the current smokers was also evident for the health outcomes, but the difference failed to reach statistical significance.

Current smokers delay discounted cigarette gains and losses at a significantly higher rate than their respective monetary and health outcomes. These results add to the growing evidence that, for drug-dependent individuals, the value of their drug of dependence is delay discounted at a higher rate than other commodities such as money and health (Bickel et al., 1999; Madden et al., 1999; Odum et al., 2000).

Finally, the results suggest that the current and never-before smokers' delay discount rates did not systematically differ when evaluating hypothetical versus real monetary outcomes. Thus, having participants evaluate hypothetical monetary gains may serve as a valid measure of delay discount rates for real monetary gains in both nicotine- and non–nicotine-dependent populations.

The association between nicotine dependence and higher rates of delay discounting is particularly interesting because the direction of causation (assuming a causal relation exists) has yet to be determined. Thus, a most important question is whether nicotine dependence causes higher rates of delay discounting or whether people who delay discount outcomes at a high rate are more likely to become nicotine dependent. If nicotine dependence leads to an increase in rate of delay discounting, then, unfortunately, it appears to be pervasive; that is, rate of delay discounting is higher regardless of the commodity, sign, and magnitude being evaluated. On the other hand, if rate of delay discounting decreases with abstinence, then, hopefully, the decrease may also be pervasive.

One possible mechanism that may cause nicotine-dependent individuals to delay discount at a higher rate is experience with withdrawal symptoms. One recent study found that delay discount rates for both money and heroin were higher when opioid-dependent individuals were experiencing mild opioid withdrawal symptoms than after receiving a maintenance dose of buprenorphine (Giordano et al., 2002). Thus, delay discount rates in nicotine-dependent individuals may evolve with withdrawal symptoms. In other words, delay discount rates may increase with the development of withdrawal symptoms and may not decrease (to rates found in never-before and ex-cigarette smokers) until after a sufficient period of abstinence that no longer involves experiencing withdrawal symptoms.

Although delay discounting may be thought of as a measure of impulsivity, similar to questionnaire-based personality assessments, the two methods of assessing impulsivity are conceptually very different. Personality measures of impulsivity are solely an attempt to measure the construct of impulsivity. The delay discounting measure is not an attempt to assess the construct of impulsivity, instead it is simply a direct measure of the rate at which outcomes become devalued as they are delayed. Higher rates of delay discounting seem to be prevalent in populations that are typically described as impulsive, such as drug-dependent individuals, adolescents, problem gamblers, and nonhumans (i.e., rats and pigeons). Therefore, delay discounting may serve as a useful index of impulsivity. Whether delay discounting is a better predictor of actual behavior than personality measures of impulsivity is a question for future research.

Beyond serving as an index of impulsivity, delay discounting may be a potential mechanism behind impulsivity. Trait measures of impulsivity are global descriptions of behavior that are somewhat stable across relatively long periods of time. Delay discounting, on the other hand, describes specific preferences concerning the choice between immediate and delayed outcomes. These preferences do not appear to be global (e.g., they depend on the commodity and whether it is a gain or a loss) and they may change over relatively short periods of time (e.g., from the time of experiencing mild opioid withdrawal symptoms to after receiving a maintenance dose of buprenorphine; Giordano et al., 2002). Thus, delay discounting may not only provide a more comprehensive assessment of impulsivity than trait measures, but it may also serve

Table 8
Results of the Analysis of Variance of Current Smokers' Delay Discount Rates Across Monetary, Health, and Cigarette Outcomes

Effect	*df*s	*F*	*p*	*MSE*	Partial η^2	Power
Commodity (A)	2, 58	21.02	<.01*	4.81	.42	1.0
Sign (B)	1, 29	11.23	<.01*	12.04	.28	.90
A × B	2, 58	1.74	.19	4.52	.06	.35

* $p < .025$.

Table 9
Correlations Between the Individual k Parameters Obtained During Sessions 2 and 3

Delayed outcome	Current smokers	Never-before smokers
Hypothetical monetary gains		
$10	.74	.82
$100	.78	.87
$1,000	.71	.90
Hypothetical monetary losses		
$10	.63	.75
$100	.53	.89
$1,000	.50	.65
Real monetary gains		
$10	.77	.82
$100	.76	.77
Health		
Gains ($1,000 equivalent)	.44	.77
Losses ($1,000 equivalent)	.50	.77
Cigarette gains		
$10 equivalent	.70	
$100 equivalent	.59	
$1,000 equivalent	.75	
Cigarette losses		
$10 equivalent	.68	
$100 equivalent	.63	
$1,000 equivalent	.57	

Note. $p < .025$ for all of the correlations.

as an assessment tool that can reveal factors that increase or decrease impulsivity.

There are many questions concerning delay discounting and drug dependence that are worthy of further research. If drug dependence leads to higher rates of delay discounting, does this occur with all drugs? That is, drugs are often associated with different patterns of use and withdrawal symptoms, and these differences may dictate whether dependence on a given drug will lead to changes in rate of delay discounting. Furthermore, Green, Myerson and Ostaszewski, (1999b) found that older people (whose drug use was undetermined) delay discount hypothetical money rewards at a lower rate than younger people, which suggests some developmental changes in rate of delay discounting. Thus, another important question is whether drug dependence possibly stunts a developmental change in delay discounting or whether a lack of maturation in delay discounting leads to drug dependence. Answering these questions will require a procedure for measuring delay discount rates that produces reliable and externally valid results. The results of the present study suggest that the extant psychophysical procedure used to obtain delay discount rates may provide such results.

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