Delay discounting in college cigarette chippers

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Individuals who smoke cigarettes regularly but do not become dependent on them provide a unique opportunity for studying the factors that inhibit drug dependence. Previous research on this population, sometimes referred to as 'cigarette chippers', showed that they did not differ from regular smokers in terms of smoking topography (e.g. puff number and duration) and circulating nicotine levels, but that they did show more self-control according to answers on a questionnaire. We evaluated the generality of this finding using a behavioral choice procedure. The participants were undergraduate students (*n* = 71), who were regular smokers, chippers, or nonsmokers. In the choice procedure, one option was a smaller but sooner amount of money, and the other option was a larger but delayed amount of money. Under these conditions, preference for the sooner smaller amount implies that the later larger monetary amounts were discounted. It is widely assumed that the rate of discounting provides an operational definition of impulsivity. In one version of the procedure, the money was hypothetical. In a second version, each choice had a chance of producing an actual monetary outcome. When there was an actual monetary outcome, regular smokers were more likely to choose the sooner but smaller monetary option than chippers and nonsmokers. For all participants, the rate of discounting decreased as the magnitude of the monetary outcomes increased, and for smokers and chippers the differences in discount rates in the two versions of the delayed outcome procedure were the same. These findings are consistent with the view that chippers are less impulsive than smokers. Quantitative aspects of these findings led to the hypothesis that discount rates decrease as a negative power function of the monetary value of the options. This result establishes an analogy between delay discounting experiments and psychophysical experiments. Results from two earlier studies support the analogy. *Behavioural Pharmacology* 17:669–679 © 2006 Lippincott Williams & Wilkins.

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Introduction

'Chippers' was initially a slang term for occasional heroin users. More recently, its domain has expanded to include those who smoke cigarettes regularly but do not become addicted to them. For instance, the entry 'chippers' in PsycINFO (12 July 2006) produced a list of 21 articles and two PhD dissertations on cigarette smoking. The significance of chipping is two-fold. First, the phenomenon helps make the point that addiction does not depend solely on drug exposure. Second, as chippers regularly consume 'addictive' drugs but do not become addicted, they provide important clues regarding factors that protect against drug abuse. For instance, according to Zinberg and his colleagues (1977), heroin chippers avoided addiction because of socially mediated processes. They participated in behavioral practices ('rituals') that promoted controlled heroin use and subscribed to a group ethos that frowned on excessive and unsafe drug consumption.

The factors protecting cigarette chippers against dependence are not well understood. In a series of experiments by Shiffman and his colleagues, chippers and dependent smokers were indistinguishable in terms of the topography of smoking, nicotine metabolism, and the cardiovascular effects of smoking (e.g. Shiffman, 1989; Shiffman *et al.*, 1992, 1994; Brauer *et al.*, 1996). Similarly, the two groups did not differ in terms of their responses to questionnaires that measured exposure to stress, social support, and the ability to cope with stress (Kassel *et al.*, 1994). Their responses, however, to a questionnaire that asked about daily activities, such as food choices, physical exercise, and spending habits, did differ. The chippers' responses indicated greater self-control in everyday life (see Table 2) (Kassel *et al.*, 1994). This result suggests that individuals differ in terms of a general capacity for self-control, and it is this capacity that allows chippers to smoke cigarettes without becoming dependent on them.

We tested the generality of the questionnaire results in two behavioral procedures. Both offered the participants a series of choices, and in both one option was a sooner but smaller amount of money and the other option was a later but larger amount of money. Beyond this common

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structure the procedures, however, differed. In one, the money was hypothetical, the amounts were relatively large, and the delays were quite long. In the other, each choice could produce an actual monetary outcome, the amounts were relatively small, and delays were relatively short. For convenience, the type of reward, 'hypothetical outcomes', and 'actual outcomes' will name the procedure. However, it should be kept in mind that these identifiers are labels and not explanations. For example, performance in the two versions of the delayed choice task differed, and the evidence (below) favors the view that the differences were due to difference in the magnitude of the outcomes.

The rationale for using delay discounting to measure impulsivity has two parts. First, on the basis of several watershed papers, published in the 1970s, it has become widely accepted that preference for the sooner/smaller reward in delay discounting tasks is a robust behavioral index of impulsivity (e.g. Rachlin and Green, 1972; Ainslie, 1974, 1975). Second, in both the hypothetical and actual outcome procedures, preference for the sooner/smaller outcome is correlated with higher levels of drug use (e.g. Bickel *et al.*, 1999; Kirby *et al.*, 1999). For instance, heavy smokers, heavy drinkers, and heavy illicit drug users are more likely than nondrug using controls to choose sooner/smaller hypothetical rewards and sooner/smaller actual rewards (Vuchinich and Simpson, 1998; Bickel *et al.*, 1999; Kirby *et al.*, 1999; Mitchell, 1999). Thus, the questionnaire findings (Kassel *et al.*, 1994) predict that chippers will choose the sooner/smaller reward less frequently than regular smokers in both delay discounting procedures. We tested this prediction.

In contrast to previous research on chippers, the participants in the present study were college undergraduates. This may limit the variation in delay discounting performance and in smoking itself. As the participants are younger, even regular smokers will not have extensive smoking histories. Similarly, the requirements for entry into college, especially an elite college, are likely to narrow the range of individual differences that influence performance in the delay discounting task. On the other hand, if significant correlations do emerge despite these limitations, the results will demonstrate that the delay procedure is a particularly sensitive measure of the decision-making correlates of drug use.

In addition to the delay discounting choice procedure, the students completed the Barratt Impulsivity Scale questionnaire (Patton *et al.*, 1995) and an academic procrastination scale questionnaire (Solomon and Rothblum, 1984). Responses on the Barratt questionnaire are correlated with illicit drug use (e.g. Heyman and Dunn, 2002) and smoking (e.g. Mitchell, 1999), and Mazur (1996) has made an interesting point that procrastination is a form of impulsivity in that it typically involves substituting an activity that yields relatively immediate rewards for one that yields relatively delayed rewards (e.g. cleaning your room instead of starting in on a term paper). Consequently, it was of interest to test whether chippers and smokers also differed in terms of these measures.

Thus, this report extends research on chippers and delay discounting in at least two ways. First, the delay-discounting task has not been used to evaluate differences between chippers and regular drug users. Second, college students have not been used to evaluate possible differences between chippers and regular drug users. On the basis of earlier studies, the expected outcome was that in the delayed choice procedure, smokers would discount future outcomes at higher rates than nonsmokers and chippers.

Methods

Participants

The participants were Harvard undergraduates: 31 nonsmokers, 19 smokers, and 21 chippers. Group assignment was based on the rate of smoking. Participants who reported not having smoked more than 100 cigarettes were classified as 'nonsmokers', participants who smoked more than one but less than 40 cigarettes a week were classified as 'chippers', and participants who smoked 40 or more cigarettes per week were classified as 'smokers'. These criteria were based on what the students said about their smoking habits and classification rules in previous research on smoking. For instance, individuals who were identified as chippers often reported that their smoking was tied to their social life. They smoked a pack or so on the weekend with friends and also had an occasional cigarette on weekdays. This approach results in weekly totals that are similar to those used in earlier studies of cigarette chippers. For instance, Shiffman (1989) and Shiffman *et al.* (1992, 1994) defined 'chippers' as those who smoked one to five cigarettes a day at least 4 days a week, that is, 4–35 cigarettes a week.

Participants were recruited by flyers posted in living and public areas on campus. Volunteers gave written informed consent, according to the guidelines of Harvard's Institutional Review Board. They were tested individually and were reimbursed for participating. The reimbursement depended on the participant's choice in the actual delay procedure. Participants who chose the 'sooner' reward earned $9.00; those who selected the later reward earned between 10 and 29 dollars.

Apparatus and procedure

The participant was seated across from the experimenter at a small table. The session consisted of a series of questionnaires and the two choice tasks. These were completed in the following order: consent form, demographic questionnaire (age and academic concentration), hypothetical discounting task, Barratt Impulsivity Scale questionnaire (Version 11; Patton *et al.*, 1995), Procrastination Assessment Scale-Students questionnaire (Solomon and Rothblum, 1984), a smoking pattern questionnaire, the Fagerstrom Test for Nicotine Dependence (Heatherton *et al.*, 1991) questionnaire, and the actual delay discounting task. The questionnaires and delay discounting tasks were administered as described in previous studies. The particulars are as follows.

Delay discounting for hypothetical rewards

The procedure was modeled on the methods described by Bickel and his colleagues (1999). The participant faced three cards and was read the following instructions:

> In this task I am going to ask you to make a series of hypothetical decisions between monetary alternatives. As you can see there are three sets of cards in front of you. The cards on your left will offer you an amount of money to be paid right now. The amount will vary from card to card. The card on your right will always say $1000, but its payment is delayed for an amount of time that is specified on the center card. It is your job to tell me which option you would prefer. You will be given one practice trial. I will flip the cards for you. Do you have any questions?

The delay periods were 1 week, 1 month, 6 months, 1 years, 3 years, 5 years, and 10 years. As noted above, these periods were associated with a $1000 (hypothetical) reward. The magnitudes of the immediately available option were 10, 50, 100, 200, 400, 500, 600, 700, 800, 900, and 950 dollars. In alternating order, participants started with the shortest delay 1 week, or the longest delay 10 years. For each delay, the amount of the immediately available choice was varied in ascending or descending order, with the direction alternating from delay to delay. The rationale for ordering the choice trials was to locate the delay at which preference for the sooner and later outcomes switched. As described below, the crossover point can be used to estimate the participant's rate of discounting.

Delay discounting for actual rewards

The procedure for actual rewards was based on the one developed by Kirby and his colleagues (1999). Participants were informed that they would actually receive one of their choices. They were read the following instructions:

> In this task I am going to ask you once again to make a series of decisions about monetary alternatives. However, unlike the first task, this time you will receive one of the amounts that you choose. I will write down all of your preferences on a numbered sheet. Once you have finished the task, I will ask you to pick a number out of a hat. The number you choose will be the number of the question for which you will actually receive your choice. If you picked the delay reward on that particular question, I will deliver it to you after the specified amount of time. If you picked the immediate reward, I will give that to you before you leave today. Now it is your job to tell me which option you would prefer. I will flip the cards for you.

The sooner option was fixed at $9 and was available at the end of the session. It was paired with 13 later-larger amounts: 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 25, and 29 dollars. Each of these amounts was offered at 17 different delays: 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 18, 20, 22, 26, and 30 days. As in the hypothetical delay procedure, the amounts were systematically increased or decreased for each delay period. For the first delay, the amounts increased, for the next delay the amounts decreased, and so on. For half the participants, delays converged toward the middle from the ends: 1 day, 30 days, 2 days, 26 days, and so on. For the other half, the delays moved outward from the middle to the ends: 10 days, 12 days, 8 days, 14 days, and so on. The amounts were combined with the delays to produce 111 choice trials. (Not all possible delay and amount combinations were used.)

Each of the participant's choices was numbered (1–111). At the end of the session, the participant drew a number from 1 to 111 at random. The response on the choice trial corresponding with the number was then paid out. If the choice was for the delayed but larger amount, the money was put into an envelope that the participant addressed. In all cases, the money was delivered on the specified day. If the randomly selected number identified a trial in which the participant had selected the sooner reward, the participant was handed $9.

Method for measuring 'impulsivity': the discount rate (k)

The pattern of choices in delay discounting experiments is described by an equation first introduced by Chung and Herrnstein (1967) and later modified by Mazur (1987). The equation has the form:

$$V = A/(1 + kD), \tag{1}$$

where V is the value of the reward, as determined by preference, A is the amount of the reward, D is the delay from the present to the moment of consumption, k is a fitted parameter. This parameter is the principle dependent variable. It summarizes the degree to which a participant discounts future rewards ('rate of discounting'), and it is widely interpreted as a measure of impulsivity. For instance, since k increases as preference for the smaller/sooner reward increases, individuals with larger ks will end up with less as measured from the perspective of the longest delay in the series of choices. Another way to think about this parameter is to note that as discount rate increases, the impact that delay makes on choices increases.

The parameter k was calculated by estimating the amount and delay combinations at which the participants were equally likely to choose the smaller-sooner and larger-later rewards. This was determined by the trial at which the participant switched preference. For instance, if the participant is indifferent between two options then we can write an equality that allows us to solve for k. At a point bracketed by the switch, the following equalities hold:

$$A_1/(1 + kD_1) = A_2/(1 + kD_2) \tag{2a}$$

then

$$k = (A_1 - A_2)/A_2D_1, \tag{2b}$$

where the subscript 1 designates the larger/later reward, the subscript 2 identifies the sooner/smaller reward, D_2 is set to zero (as the sooner reward is available now), and Eq. (2*b*) is obtained by rearrangement. This approach yields an estimate of k for each delay interval. For example, there were seven estimates of k for each participant in the hypothetical delay task and 17 estimates for each participant in the actual delay procedure. If a participant did not switch preference within a series of delays, he/she was assigned the smallest value of k that would produce all sooner/smaller choices or the largest value of k that would produce all later/larger choices, as appropriate. Participants however, rarely failed to switch within a series of varying delays.

Barratt Impulsivity Scale

The Barratt Impulsivity Scale (Patton *et al.*, 1995) is widely used in drug research. In some but not all studies, Barratt scores were correlated with scores on choices measures (e.g. Mitchell, 1999; Heyman and Dunn, 2002). The questionnaire focuses on topics that correspond to everyday understandings of impulsivity, such as planning, attention, caution, and susceptibility to boredom. Questions concerning employment were removed, as they were not relevant to most undergraduates.

Procrastination Assessment Scale-Students (Solomon and Rothblum, 1984)

The questionnaire uses a five-point scale to assess the extent to which students believe they fail to allot sufficient time to academic tasks and the degree to which this failure bothers them. The academic tasks include test preparation, reading assignments, and term papers.

Smoking questionnaires

There were two smoking questionnaires. One, that we developed, obtained information on the level, pattern, and circumstances associated with smoking. The second was the 'Fagerstrom Test for Nicotine Dependence' (e.g. Heatherton *et al.*, 1991). This is a widely used scale for measuring dependence on smoking.

Results

Smoking level and dependence scores

Table 1 shows how many cigarettes were smoked each week and the dependence scores. Chippers smoked on average 12 cigarettes/week; regular smokers smoked on average 97 cigarettes a week. The ranges were nonoverlapping (as had to be the case given the classification criteria). The Fagerstrom Dependence Scores for these two groups also proved to be nonoverlapping. Only three chippers had scores greater than zero, and the average scores differed by about a factor of 10. These comparisons imply that Fagerstrom cigarette dependence ratings were strongly correlated with the rate of smoking. Figure 1 shows that this was the case. The correlation between the two measures was $r = 0.83$. Linear and sigmoid functions fit the data equally well, but the sigmoidal function is the more sensible relationship given that the Fagerstrom Scale has a minimum and a maximum.

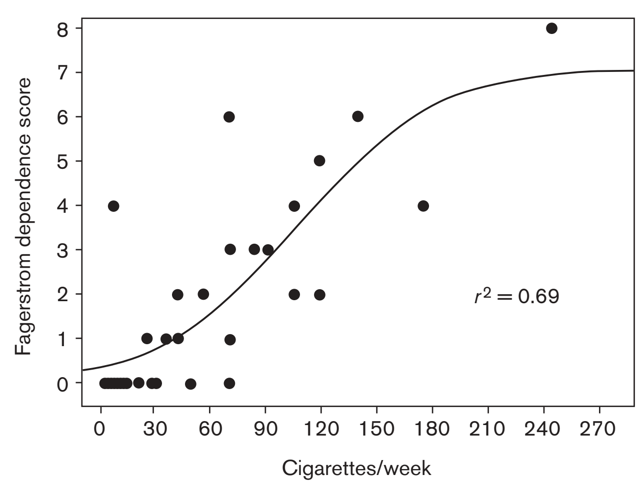
Delay discounting

Performance in the two delay discounting procedures differed. We have referred to the procedures as 'hypothetical' and 'actual'. As was pointed out, the procedures,

Table 1 Smoking level and Fagerstrom Dependence Scores

	Chippers	Smokers
Cigarettes/week (range, SD)	12 (2–36, 12.5)	97 (42–245, 52.2)
No. of years smoked	2.9 (1.6)	3.1 (1.7)
Fagerstrom Score	0.3 (0–4, 0.9)	3.2 (0–8, 2.2)

Fig. 1



Fagerstrom Scores are displayed as a function of cigarette consumption for chippers and smokers. The curve traces out the best fitting two-parameter sigmoidal function.

however, also differ in terms of the magnitudes of the monetary outcomes and the delay durations. Thus, the name 'hypothetical' and 'actual' should be interpreted as labels and not as an explanation for the differences in performance.

Delay discounting parameters for actual outcomes

For each of the three groups (nonsmokers, chippers, and smokers), the distribution of delay-discounting parameters, *k*s, was asymmetrical, with the longer tail stretching to the right. The log-transformed, base 10, distribution of the *k*s for each group was symmetrical, approximating a normal distribution. Consequently, statistical tests involving the parameter *k* were conducted with the logged values. Table 2 lists the parameters along with the Barratt and procrastination questionnaire scores (the other impulsivity measures). The untransformed *k* values are also included as this scale is likely to be more familiar to most readers. Statistical tests, however, are based on the logged values.

Figure 2 shows the discounting rates for actual monetary rewards for each group. As predicted by earlier studies, discount rate differed as a function of smoking history [$F(2,68) = 5.4$, $P < 0.01$)]. Smokers discounted future rewards about three times more steeply than did nonsmokers and about two times more steeply than did chippers. Post-hoc tests (Fisher's least significant difference test) showed that these paired comparisons were also significant, with $P < 0.002$ for nonsmokers and $P < 0.05$ for chippers. To aid greater understanding, the left *y*-axis lists the untransformed discount rates and the right *y*-axis lists the logged discount rates. (As a number increases from 0 to 1.0, the absolute magnitude of its logarithm decreases.)

Delay discounting for hypothetical outcomes

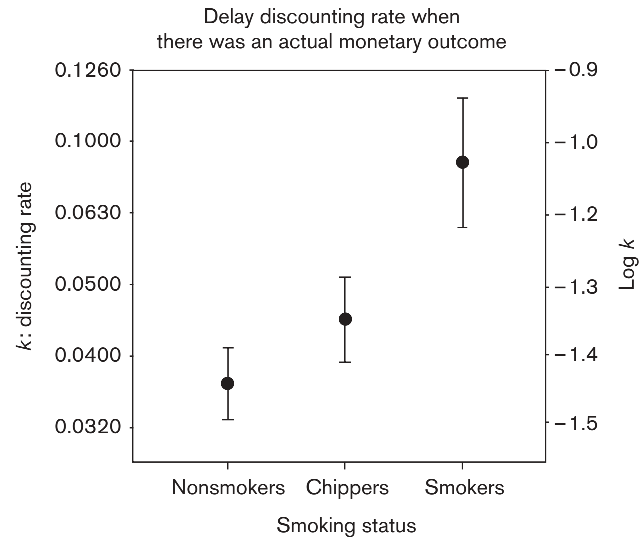
Figure 3 compares discounting rates in the two procedures. Discount rates were lower when the consequences were strictly hypothetical. (This difference can also be described in terms of the monetary magnitudes or delay intervals used in the two procedures, as noted above and again in the Discussion section of this report.) For chippers and smokers, the differences were nearly identical. Both groups discounted future actual outcomes about 10 times more steeply than hypothetical outcomes.

Table 2 Dependent measures, means, and medians

	Nonsmoker	Chipper	Smoker
Barratt (SD)	56.1 (9.6)[a]	64.3 (13.5)	64.4 (7.7)
Procrastination	27.2 (6.7)	31.4 (9.3)	29.8 (9.1)
Log *k*, actual \$	−1.44 (0.05)	−1.35 (0.06)	−1.13 (0.09)[b]
Log *k* hypothetical \$	−2.04 (0.13)	−2.32 (0.12)	−2.11 (0.16)

[a]Significantly different than chipper and smoker Barratt scores ($P < 0.05$, see the text for details).
[b]Significantly different than nonsmoker and chipper discount rates ($P < 0.002$ and $P < 0.05$, respectively, see the text for details).

Fig. 2



Discounting rates for the nonsmokers, chippers, and smokers. Statistical analyses were conducted on the logs of the discount rates. As the antilog scale is more familiar, it is shown on the left.

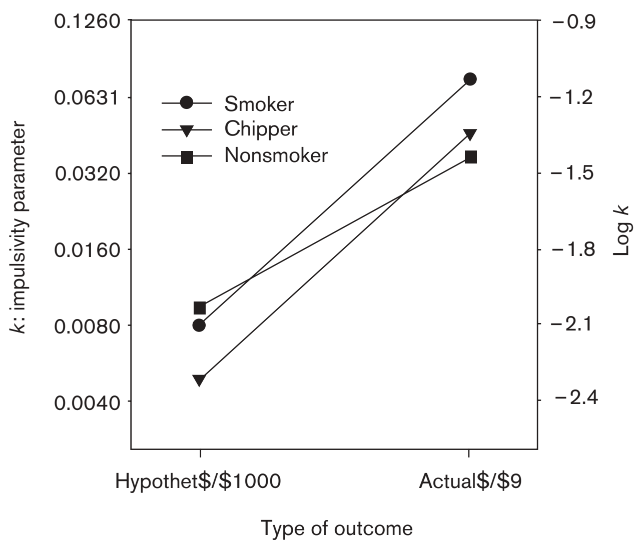
That performance differed by about the same amount for the two groups explains why the lines joining the data points are parallel. The same criterion reveals that this constant ratio result did not apply to nonsmokers. Although nonsmokers also discounted actual outcomes at a higher rate, the increase was by about a factor of five not 10. As a result, when outcomes were strictly hypothetical, the nonsmokers ended up with the highest discount rates. As is pointed out in the Discussion section of this paper, this result is inconsistent with the results from the actual condition and with results from previous studies. With this discrepancy came an increase in variability particularly among the smokers, and overall the coefficient of variation increased by about 23% in the hypothetical outcome condition (see Table 2). Consequently, there was no simple relationship between smoking history and discount rate when the options were strictly hypothetical, and differences between the groups in this condition were not statistically significant.

Figure 3 implies that discount rates in the two choice procedures were correlated. For the entire sample (nonsmokers, chippers, and smokers), the correlation between the two sets of *k*s was 0.363 ($P < 0.002$). If nonsmokers, are not included in the analysis, however, the correlation increases to 0.470.

Barratt questionnaire

Responses to the Barratt Impulsivity questionnaire varied according to the respondent's smoking history. Nonsmokers had the lowest impulsivity scores (56.1), whereas chippers and smokers had higher and virtually

Fig. 3



Discounting rate as a function of smoking history and the two discounting procedures. The left-hand set of points was obtained in the condition in which the outcomes were strictly hypothetical and the delayed amount was '$1000'. The right-hand set of points was obtained in the condition in which each choice might produce an actual outcome. The immediate amount was $9. For smokers and chippers, the lines connecting the data points are parallel because discount rates for these two groups differed by the same amount in the two procedures (about a factor of 10 or one log unit). See the Discussion section for comments on this finding.

identical scores (64.3 and 64.1, respectively). These differences were significant [$F(68,2) = 6.0$, $P < 0.005$], and post-hoc comparisons (Fisher's least significant difference) showed that the scores for nonsmokers were significantly lower than the scores for chippers ($P < 0.005$) and smokers ($P < 0.005$).

Academic procrastination

The procrastination scores were slightly lower for nonsmokers (27.2) than for chippers and smokers (29.8 and 31.5, respectively). The differences, though, were not statistically significant [$F(68,2) = 1.74$, NS].

Gender

Two-thirds of the nonsmokers were women, and two-thirds of smokers were men. The group's sex proportions, however, did not differ significantly from the overall proportions of men and women at a 0.05 level according to the χ^2 criterion [$\chi(3) = 2.24$, NS]. Although group sex proportions did not differ significantly, their magnitude suggests that sex may have influenced the relationship between smoking level and delay discounting rate. We tested this hypothesis by comparing the discount rates for men and women, and by reassessing the relationship between smoking level and discount rate (k) while controling for sex differences (analysis of covariance with sex as a dummy variable).

In the strictly hypothetical delay task, women tended to discount at a higher rate than men [$t(69) = 0.06$], whereas in the task in which there was an actual monetary outcome, men tended to discount at a slightly higher rate than women. The difference, however, was small and not significant [$t(69) = 0.12$].

Analysis of covariance with sex as the covariate produced the same pattern of findings as the analysis of variance. When the choices were for actual monetary outcomes, ks varied by smoking level [$F(2,67) = 4.5$, $P < 0.02$], and sex did not have a significant effect [$F(1,67) = 0.3$, NS]. When choices had strictly hypothetical consequences, the sex-adjusted means showed roughly the same relationships as in Table 2 and Fig. 3. In summary, statistically controling for sex did not remove the correlation between delay discounting (for an actual outcome) and rate of smoking.

Sex also did not influence answers on either the Barratt or the procrastination questionnaires. The scores on the Barratt were nearly identical for men and women, with both groups averaging about 61.0. The scores on the procrastination probe differed by less than half a standard deviation for men and women.

Academic concentration

As the participants were students, it is reasonable that academic concentration might have been a factor, particularly in regard to academic procrastination scores. The participants were classified as humanities, social science, or science concentrators. Procrastination scores were highest for humanities majors and lowest for science majors [$F(68,2) = 3.0$, $P = 0.06$]. No other measure, however, showed either a trend or a significant effect as a function of field of study.

Relationships between the measures

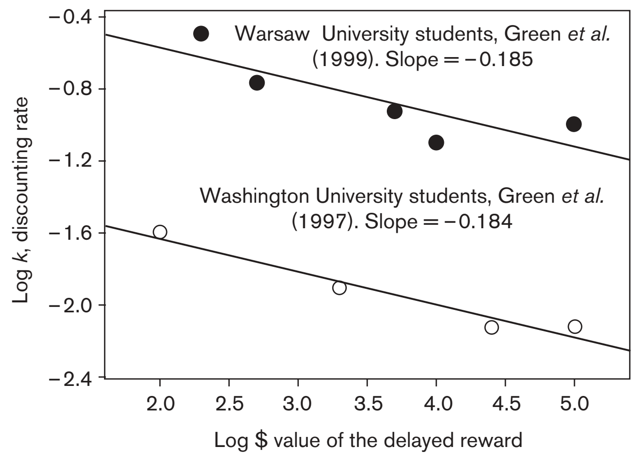
Table 3 summarizes the correlations between the various measures. In general, the intercorrelations were weak. Not counting the two smoking measures (Fagerstrom Scale and cigarettes per week, $r = 0.84$), only the correlations between actual and hypothetical discount rates and between actual discount rates and responses on the Barratt questionnaire exceeded 0.30. The correlations were also run for each group separately. This did not reveal any disparities except perhaps for procrastination. For instance, across groups, the correlation between discounting rates in the two procedures varied from 0.38 to 0.48, but for procrastination and discounting rate in the actual outcome procedure, the correlation varied from −0.17 to 0.43. None of the correlations, however, remained significant when the sample size decreased so that it is difficult to interpret the meaning, if any, for the procrastination results.

Table 3 Correlations among the dependent measures

	Hypothetical *k*	Actual *k*	Barratt	Procrastination	Cigarettes/ week
Hypothetical *k*					
Actual *k*	0.363*				
Barratt	0.167	0.327*			
Procrastination	0.183	0.153	0.137		
Cigarettes/ week[a]	0.008	0.145	0.029	0.061	
Fagerstrom[a]	0.068	0.138	0.011	0.007	0.835*

[a]Chippers and smokers.
*$P<0.05$, Bonferroni 'corrected'.

Fig. 4



This graph tests the generality of the parallel line effect (see Fig. 3), as applied to data from Green *et al.* (1997, 1999). On *x*-axis is the magnitude of the immediately available outcome. On *y*-axis is the discount rate. The predictions were (i) that a straight line would fit the log values of the two measures and (ii) that it was possible for individuals to discount outcomes at different rates yet show similar changes in the rate of discounting. The graph shows that the straight lines provided a good fit of the relationship between the log values and that for the two populations, the rate of change in discounting was the same to the second decimal point.

Discussion

The initial motivation for using two discounting procedures was to increase the chances of detecting differences between smokers and chippers. As predicted in both the actual and hypothetical outcome version of the experiment, smokers discounted at higher rates than did chippers. In the hypothetical outcome procedure, however, the differences were not statistically significant (because of an increase in variability), and nonsmokers discounted at higher rates than did smokers. This is discrepant with earlier research and with their performance in the actual outcome procedure. Unexpectedly, the between-procedure (within-subject) differences were about the same size for chippers and smokers. When there was the chance of an actual outcome, both groups discounted future rewards more steeply by about a factor of 10. Although first pointed out in this paper, this between-condition parallel line (constant ratio) effect is not new. We found an earlier case by combining the results from two publications by the same research group (Green *et al.*, 1997, 1999). In these two studies, the discounting procedure was virtually identical but one experiment was carried out in Poland and the other in the United States. Polish subjects discounted future hypothetical monetary outcomes more steeply than did the American subjects. Most interestingly, when the discount rates were graphed as a function of monetary value, as in Fig. 3, the lines are nearly perfectly parallel (see Fig. 4). The result is noteworthy because of its unexpected orderliness, because it may lead to an explanation of the 'inverse magnitude effect', a well established but heretofore unexplained phenomenon, and because it may show the way to a better understanding of the determinants of choice in delay discounting procedures. In the remainder of this section, we focus on both the differences between chippers and smokers and the parallel line effect.

That there were group differences in delay discounting under the conditions of this study deserves attention for several reasons. First, it shows that individual differences play a role in chipping. This result is consistent with the questionnaire findings (Kassel *et al.*, 1994) cited in the Introduction, and it complements earlier research that emphasized the role of social influences on heroin chipping (Zinberg *et al.*, 1977). Second, smoking history was related to discounting rates even though differences in smoking history were not large compared relatively with previous studies. For instance, in the experiments that served as the model for this report, smoking rates were about 50% higher and Fagerstrom Dependence Scores were usually about 100% higher (Bickel *et al.*, 1999; Baker *et al.*, 2003). Third, differences in smoking levels predicted choice even though the participants did not differ in terms of educational achievement, which is currently the strongest demographic correlate of smoking (see, e.g., US Department of Health & Health Services, 1990, 1994). Together, the results suggest that delay discounting is a particularly sensitive measure of one or more of the psychological correlates of smoking.

Group differences, procedure differences, and the parallel line effect

The results for regular smokers and chippers in the two versions of the delayed choice task were consistent with the predictions that motivated this study and earlier research. Furthermore, when outcomes were strictly hypothetical, nonsmokers discounted future outcomes at about the same rate as did smokers. This result is inconsistent with earlier research and with the behavior of these same participants when the outcomes were not strictly hypothetical. No obvious reason exists for these discrepancies. It, however, can be pointed out that relative to the other two groups, discount rates for the nonsmokers differed less in the two versions of the task. This could mean that nonsmokers were better at estimating their behavior when choices paid off. This would produce the observed pattern of behavior.

Sixty-five of the 71 participants discounted future monetary outcomes more steeply when there was a chance that their choices would actually pay off. As the procedures differed in terms of type of outcome, the magnitude of the outcomes, and the durations of the delay intervals, any one variable or any combination of the variables might account for the differences in discount rates. Although we did not address this issue experimentally, an analysis is possible. The large literature on delay discounting includes studies that provide information on two of the variables. This research says that the differences in the magnitudes of the monetary outcomes provide the most likely explanation for why discount rates were so much higher in the actual outcome procedure. Some of the key findings are as follows.

Considering first the type of reward, Johnson and Bickel (2002) and Madden and his colleagues (2003) evaluated the influence of type of monetary reward on discounting rate. There were two conditions. In one, the monetary outcomes were hypothetical; in the other, each choice could produce a monetary outcome. This was arranged in much the same way as in this experiment. After the experiment was over, a trial was selected at random, and the participant obtained what he/she chose on that trial. Importantly, the hypothetical and actual amounts were the same so that the only difference was the opportunity for an actual payoff. This proved of no consequence. The discount rates for hypothetical and real monetary outcomes were about the same.

In contrast to the actual/hypothetical distinction, there is no shortage of support for the interpretation that differences in the magnitude of the outcomes led to different discount rates. In studies with hypothetical and actual monetary outcomes, rate of discounting reliably decreased as the values of the options increased (e.g. Green *et al.*, 1997, 1999; Kirby *et al.*, 1999; Johnson and Bickel, 2002). The finding is so widespread and it has a name, 'the inverse magnitude effect', and is a topic of theoretical interest (e.g. Loewenstein and Prelec, 1992; Grace and McLean, 2005). It is possible, of course, that the results from these earlier studies do not apply to the present report as the variations in magnitude were always within one type of reward, whereas in the present experiment magnitude varied across types of reward. As pointed out above, the magnitude effect, however, holds for both actual and hypothetical monetary outcomes.

Finally, it is possible that the differences in discount rates in the two procedures were due to the differences in the delays. This is a logical possibility but has no theoretical or empirical support. Hence, the most likely hypothesis is that the differences in discount rate in the actual and hypothetical outcome conditions were due in part or whole to the reward magnitude differences. The analysis and data presented next add further support to the magnitude interpretation.

The parallel line effect (Fig. 3) may shed light on the well established but unexplained finding, just introduced, that in human studies discount rate decreases as the magnitude of the outcomes increase (the inverse magnitude effect). The explanation is based on the interpretation that the differences in discount rates reflected, at least in part, the differences in the magnitudes of the future outcomes and a possible link between delay discounting and Stevens's (1975) power law for sensory phenomena. In addition, we show below that the parallel line effect is not really a new finding but replicates earlier, albeit unrecognized, results.

Figure 3 shows between-group differences accompanied by within group-similarities. Smokers discounted at higher rates than did chippers, but both groups discounted actual future outcomes about 10 times more steeply than hypothetical ones. This means that smokers and chippers disagreed as to the future value of a specific amount of money, say \$29 in 30 days and \$1000 10 years later, yet were in almost perfect concurrence as to the value of the ratio of \$29/\$1000 at various future dates. This way of stating the results suggests that the subjective value of money, at least when presented as a future outcome, changes in a characteristic fashion as a function of its magnitude. S.S. Stevens's power function law for sensory experience provides a mathematical account of how this could come about.

Stevens (1975) found that sensory phenomena were related by a power function to their physical counterparts. For instance, loudness was related by a power function to sound pressure (decibels) and similarly the sensation of brightness was a power function of measures of light energy (lumens). Moreover, the exponent of the power function took different characteristic values for different physical continua. For instance, loudness has an exponent of about 0.67, visual length has an exponent of about 1.0, and painful electric shock has an exponent of about 3.5. Assume for a moment that the same sort of relationship holds for discount rate and the monetary value of a future reward:

$$k_{ni} = a_n A_i^{-x}, \qquad (3a)$$

where k_{ni} is the discounting rate for participant n, A_i is the magnitude of the future reward, a_n is a constant that reflects individual differences (which may in turn be a function of circumstances), and x is an exponent that is characteristic of the task (e.g. making decisions about future monetary outcomes), which has a negative sign to capture the fact that as the amount of money gets larger, the discount rate gets smaller. Now if Eq. (3*a*) is re-expressed in logarithmic coordinates, it becomes

$$\log k_{ni} = \log a_n + -x \log A_i. \qquad (3b)$$

A graph of this equation plots as a straight line. Accordingly, a graph of this equation for two or more individuals will plot as parallel lines with a common slope, $-x$, and different intercepts (values of a_n, holding all else the same). Similarly, a graph of this equation for two or more groups that differ in some systematic way will also plot as parallel lines (holding all else equal). This graph would look like the chipper and smoker results displayed in Fig. 3.

Although Fig. 3 is consistent with Eqs (3*a*) and (3*b*), it is not an adequate test because there are just two data points. To establish a more rigorous test, we searched the literature for studies in which the participants differed in some systematic way, yet were exposed to identical or nearly identical conditions. Two experiments (introduced above) by Leonard Green and Joel Myerson and their colleagues met these criteria. One group of participants consisted of students attending the Warsaw University in Poland (Green *et al.*, 1997). The other group of participants consisted of students attending the Washington University in St Louis (Green *et al.*, 1999). Rewards were hypothetical, each participant was confronted with a series of delayed choices, and the values of the future rewards associated with each series varied from 100 to 100 000 dollars. Equation (3*b*) predicts that the slopes will be similar but that the intercepts may differ. Figure 4 shows the results.

The slopes were the same to the second decimal point. This may be a rather remarkable coincidence. On the other hand, it is precisely the result predicted in Fig. 3 and the power function analysis.

The attention so far has been on the slopes. We can also ask about the significance of the difference in the intercepts. The difference in intercepts corresponds to the fact that the Polish students discounted the same monetary prospects more steeply; they had less future value. Given the differences in the Polish and American economies, this suggests that there may also be an inverse relationship between economic well-being and discount rate. In support of this point, a consistent finding is that discount rates are higher as economic conditions worsen (e.g. Green *et al.*, 1996, 1997, 1999; Kirby *et al.*, 2002). For instance, in research, that was also conducted in Poland, discount rates were higher when the outcomes were specified in a currency that was subject to higher rates of inflation (Ostaszewski *et al.*, 1998). Similarly, in a study conducted in the United States, discount rates increased as income decreased (Green *et al.*, 1996). Applying these results to the inverse magnitude effect, it may be the case that participants 'feel' richer when they are making decisions about larger amounts of money or, somewhat similarly, perhaps they think about larger amounts in ways that are correlated with greater wealth, such as allocating more to savings than to spending, even when the outcomes are hypothetical. Whatever the psychology mediating the inverse magnitude effect, Figs 3 and 4 make the interesting point that there is a characteristic relationship between discount rate and monetary value just as there is a characteristic relationship between the intensity of sensory experience and the intensity of its corresponding physical stimulus. In a recent theoretical paper, Rachlin (2006) came to similar conclusions and in doing so, like us, pointed to Stevens's power law.

Questionnaire results and correlations between different measures

Table 3 shows that the correlations between the various dependent measures were typically low. Only two of the 15 pairs were significant. This pattern may reflect limitations in the measures, not enough variation in the dimensions that the tests measured, or, perhaps, the nature of impulsivity itself. In support of the last point, studies that have compared different indices of impulsivity typically find weak correlations (e.g. Evenden, 1999; Lane *et al.*, 2003; Navarick, 2004; Reynolds *et al.*, 2006). For instance, Reynolds and his colleagues (2006) measured the correlations among some 14 different measures of impulsivity, including delay discounting. The coefficients ranged from about -0.08 to 0.12, values that are even lower than those that we report. Commenting on the weak intertest correlations, several researchers concluded that the word 'impulsivity' is used in a variety of ways, and that these different usages are not closely related (a 'multifaceted construct'; see Evenden, 1999; Lane *et al.*, 2003; Reynolds *et al.*, 2006).

However, not all of the questionnaire results in this study failed to reach significance. The correlation between the Fagerstrom Dependence Scores and cigarettes per week was above 0.80. This suggests that the degree to which one is dependent on cigarettes is closely related to the rate of smoking, particularly when the rate of smoking ranges from low to moderate.

Limitations

As the hypothetical choices always preceded the actual choices, it is reasonable to consider that order may have influenced choice. One way to test this idea is to compare the present results with those of earlier studies in which order could not have been a factor. For instance, when all choices were either hypothetical or entailed the possibility of an actual payoff there can be no order effect. As has been emphasized, under these conditions, heavy drug users had higher discount rates and discount rates decreased as the values of the options increased. This is precisely the pattern of findings in the present study so that order appears not to have mattered. Similarly, order cannot be used to explain the results under the strictly hypothetical condition as it came first.

The parallel line effect led to the suggestion that economic conditions influence performance in delay discounting studies. As noted, a number of research studies support this inference. Possibly then economics played a role in the present study. Although there is no evidence that this is so, the idea has yet to be tested. Other limitations, such as a narrow range of smoking levels, have been discussed.

Summary

The research introduced in this report provides new information on cigarette chipping and delay discounting. Like other researchers, we found a correlation between discount rate and drug use. The determinants of this correlation, however, are not obvious. The label 'impulsivity' seems too simplistic, and at the very least not the whole story. In support of this point, researchers have failed to find strong relationships between discount rates and established measures of impulsivity (e.g. Evenden, 1999; Lane *et al.*, 2003), and there is evidence that discount rate reflects economic conditions (e.g. Green *et al.*, 1996; Ostaszewski *et al.*, 1998). We, however, need not come to a better understanding of what performance in delay discounting tasks is actually measuring to draw clear conclusions from the present study. When one of the outcomes in the delay discounting task provided an actual monetary outcome, regular smokers discounted delayed monetary rewards at higher rates than did chippers and nonsmokers. Moreover, this occurred even though the participants did not vary in terms of education, which has become the major demographic correlate of smoking, and even though smoking itself did not vary much according to the standards of previous studies. Together these observations underscore the point that the delay discounting procedure is a robust method for assessing individual differences related to drug use. Put another way, that the procedure is useful is all the more reason for researchers to turn their attention to some of the issues that we have raised in the Discussion section. What are the determinants of delay discounting rates? What are the determinants of the inverse magnitude effect? And to what extent, if any, do differences in delay discounting reflect economic conditions?

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