Nicotine & Tobacco Research, 2015, 1449–1455
doi:10.1093/ntr/ntv033
Original investigation
Advance Access publication February 8, 2015

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Increasing the Value of an Alternative Monetary Reinforcer Reduces Cigarette Choice in Adolescents

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Abstract

Introduction: Smoking can be conceptualized as an operant behavior maintained by the reinforcing effects of cigarettes. Changing the magnitude and availability of alternative reinforcers should shift behavior away from smoking. Adults' smoking behavior is sensitive to the magnitude and availability of alternative reinforcers; however, the extent to which the same is true for adolescents has not yet been shown in the laboratory.

Methods: To test the sensitivity of adolescent smoking behavior to changes in the magnitude of alternative reinforcement, we gave adolescents who abstained overnight the opportunity to make 20 choices between receiving two puffs of their usual-brand cigarette or money. The magnitude of the monetary reinforcer was varied across sessions in counterbalanced order ($0.00, $0.10, and $0.50).

Results: Results indicated that adolescents' choices for puffs decreased as a function of increasing monetary reinforcer magnitude, while money choices increased. This effect was moderated by baseline smoking level and by gender, such that heavier-smoking participants and males made more cigarette choices when the alternative monetary value was zero, and decreased their choices more steeply in response to increasing monetary value.

Conclusions: The current study validates a laboratory choice procedure for studying smoking in adolescents, and demonstrates that adolescent smoking behavior is sensitive to changes in the magnitude of concurrently available monetary reinforcers. The current paradigm can be adapted and applied to explore the effects of other variables that may affect cigarette choice in adolescents.

Introduction

Cigarette smoking is the leading cause of preventable death in the United States, and each day, an estimated 2000 adolescents become smokers.[1] The future health of young smokers can be greatly improved by understanding what can be done to change their smoking behavior and helping them to quit as early as they can. This urgent public health issue has led to a greater emphasis on understanding the determinants of adolescent smoking.

Smoking, like other forms of drug taking, can be conceptualized as an operant behavior.[2,3] In this framework, the drug is just one reinforcer among many potential reinforcers that an individual can allocate his or her behavior toward. Operant theory suggests that drug-taking behavior should be sensitive to the availability and magnitude of alternative reinforcers that are concurrently available in the individual's environment.[4,5] In laboratory studies with adults, smoking has been shown to be sensitive to alternative reinforcers,

and specifically, to decrease as a function of the availability and magnitude of monetary reinforcers.[6–9]

In contrast to adult smokers, the extent to which adolescent smokers' behavior may be sensitive to alternative reinforcers has not been thoroughly studied in the laboratory. Studies on other aspects of adolescent smoking behavior have demonstrated that adolescent smokers are unlike adult smokers in important ways. Compared to adult smokers, adolescents tend to have shorter smoking histories and lighter, more intermittent smoking patterns; yet dependence and withdrawal tend to be highly prevalent among adolescents.[10–12] Considering this discrepancy between generally low levels of smoking behavior and high levels of dependence in adolescent smokers,[13] findings from studies with adult smokers cannot be assumed to generalize to adolescents. In addition, cessation treatments with demonstrated efficacy in adults such as pharmacotherapies have met with limited success in adolescents.[14] Thus, there is a need for empirical, laboratory-based studies that demonstrate systematic, functional relationships between biological and environmental variables and adolescent smoking.

The primary purpose of the current study was to validate a laboratory paradigm of smoking choice behavior in adolescents. Such paradigms have been successfully used in adults to study the effects of many different variables on responding for cigarettes in adults; thus, a validated procedure in adolescents could be used to model an array of different variables that may affect smoking in this population. In the current experiment, we manipulated the magnitude of the available alternative reinforcer in order to determine if adolescent smoking behavior is sensitive to the magnitude and availability of alternative reinforcement. We used a within-subjects experimental paradigm similar to that used successfully with adults, in which participants in the laboratory made a series of choices between puffs of their usual brand of cigarette or varying amounts of money. We hypothesized that smoking choices would be systematically reduced as a function of increasing the value of the alternative, monetary reinforcer.

A secondary aim was to evaluate potential moderators of the effect of alternative reinforcement on smoking in this population. Specifically, we hypothesized that gender, individual smoking history variables, and baseline smoking level would moderate the effect of alternative reinforcement on smoking in this population. In adult smokers, women tend be less responsive to the pharmacological effects of nicotine while being relatively more susceptible to the sensory and non-pharmacological aspects of smoking, and women tend to have less success with smoking cessation treatments.[15] However, less is known about potential gender effects in adolescent smokers. Thus, we wished to determine if gender would moderate the effect of alternative reinforcement in these young smokers. Based on the adult literature, we hypothesized that girls would be less sensitive to the effects of alternative reinforcement. We also hypothesized that adolescents who had been smoking for fewer years and lighter smokers would be more sensitive to the effects of alternative monetary reinforcement, as they may be less dependent on nicotine and therefore may more easily shift their behavior away from smoking.

Methods

Recruitment, Screening, and Consent

Study participants were recruited using flyers and information sessions at local high schools in Rhode Island and Southeastern Massachusetts. Interested participants completed a brief, confidential screening interview by phone to establish initial study eligibility. After a description of the study was read to the participants, demographic information was gathered and participants were asked about their smoking and drug use histories, and pregnancy status. To be eligible, participants had to report daily smoking of five or more cigarettes per day for the prior 6 months or longer. Individuals were ineligible if they reported using other forms of tobacco or nicotine more than 4 days in the past month, if they reported daily drug or alcohol use in past month on the Timeline Follow Back (TLFB) (determined at baseline), or if they did not speak English. If female, participants could not be pregnant or breastfeeding (girls were informed that a pregnancy test was required and that parents would be informed if the test were positive). If a participant met inclusion criteria at screening, the first session was scheduled. Informed consent was obtained prior to research participation. Participants younger than 18 provided assent and were required to have parental consent. All procedures were approved by the Brown University Institutional Review Board.

Initial Session

Any questions about the procedures were addressed at this time and participants completed the measures and choice practice described below. Female participants were tested for pregnancy. No pregnancy tests were positive in this study. If any participant had been pregnant, the participant would have been notified, would have met briefly with a clinical psychologist for a medical referral, and study participation would have ended.

Baseline Measures

Participants completed a baseline interview which assessed: demographics; smoking history and patterns; dependence, craving, and withdrawal symptoms; motivation to change smoking, positive and negative affect; smoking expectancies, consequences and social influences; and other drug use. For brevity, only measures relevant to this report are described in detail below.

Biomarkers of Smoking Exposure

Saliva was collected to determine baseline levels of the nicotine metabolite cotinine; levels were determined by gas chromatography by an external lab (Salimetrics, LLC, State College, PA). A breath sample was also collected to determine expired alveolar carbon monoxide (CO) level. Participants were asked when they smoked their most recent cigarette.

Demographics

Participants completed a basic demographics form querying age, race, ethnicity, gender, and grade in school. Participants were also asked how much money they received from their parents, their job, or other sources each week; responses were summed to index average weekly "income" in dollars.

Smoking History

Participants retrospectively reported their age (in years and months) at the onset of key smoking milestones including first puff, first whole cigarette, and transition to weekly and daily smoking.

TLFB

The TLFB is a calendar-assisted retrospective recall of the number of cigarettes smoked each day; it has been validated for use with adolescents and its summary variables (eg, average cigarettes per

day) have been shown to have validity and high stability over time.[16] Daily smoking over the prior 30 days was assessed.

Modified Fagerström Tolerance Questionnaire

The Modified Fagerström Tolerance Questionnaire is a seven-item measure of nicotine dependence that has been adapted from the original Fagerström Tolerance Questionnaire[17] for use with adolescent smokers. It has been shown to have good internal consistency, high test-retest reliability and strong concurrent validity.[18] Possible scores range from 0 to 9. Cronbach's alpha for this sample was .63.

Choice Procedure

Participants were asked to sit in front of a computer on which two buttons were visible: one button was labeled "2 puffs" and the other was labeled "money." During the choice sessions, participants were instructed that they could make up to 20 choices between a specified amount of money and two puffs of their usual brand cigarette, a pack of which were provided in the room along with a lighter and ashtray. A choice was made by pressing the relevant button on the screen. If money was chosen, the cumulative amount of money earned up to that point was shown on the screen, and participants were told that they would receive the total amount earned at the end of the session. If puffs were chosen, the participant was instructed to light the cigarette and take two standard puffs from the cigarettes provided. The choice buttons were inactive for 2 minutes following each choice; after that, a new choice could be made. Participants were also instructed that they did not have to make all 20 choices, and completion of all 20 choices did not result in an early end to the sessions, which would last 2.5 hours regardless of their choice patterns. During the session, participants could read magazines or listen to music but could not sleep, talk on their cell phones, do homework, eat, or drink anything besides water; this was done to ensure that the session would constitute a closed economy in which the money alternative was not competing with other alternative reinforcers. Participants were also aware that a research assistant would be viewing the entire session through a two-way mirror to ensure compliance with the procedures.

Practice Session

In order to familiarize participants with the choice program and puffing procedures, during the initial session participants were seated in front of the computer and asked to make a series of choices for practice. The amount of money available per choice was $0.10. Participants were instructed to first make a choice for puffs. Then, participants were asked to make a choice for money, and were oriented to the on-screen counter which showed their total earnings for that session. Participants were then instructed to alternate between options until four choices for puffs and three choices for money had been made. Participants were given the $0.30 this procedure earned them immediately following the practice session.

Abstinence Criteria

Prior to each of the three experimental sessions, participants were required to remain abstinent starting the night before the session, beginning at midnight. Participants were told that their abstinence would be verified by asking them to sign an affidavit stating that they had complied with all procedures, and by providing a breath CO sample that was <10 ppm on the day of the session.

Sessions 2–4

Upon arrival to the laboratory, overnight abstinence was verified. Next, the research assistant administered the TLFB interview to determine cigarette and other tobacco product use on each day since the last session. Then, the choice procedure was administered as described above. Using a within-subjects design, the amount of money available for each monetary reinforcer choice in these sessions was $0.00, $0.10, or $0.50, with value order counterbalanced across participants. At the end of each session, participants were paid the amount of money they had earned during the choice procedure. All sessions occurred in the afternoon, with 3 to 7 days between each session. Participants were provided with taxi transportation to and from the laboratory if necessary.

Compensation

Participants were paid $125 for the time and effort involved in participating (including the overnight and next-day smoking abstinence that was required prior to the three choice sessions); payments were made via money order and mailed to the participant's home address following the final study session. In light of our analytic strategy (below), which only utilized choice data from study completers, a $50 gift card bonus was provided to participants who completed all four sessions within the allotted time frame and with no more than two rescheduled appointments.

Data Analysis Plan

Baseline characteristics were quantified using descriptive statistics, and characteristics of participants who completed the study were compared with those of participants who did not, using independent *t* tests for continuous variables and chi-square tests for categorical variables. Mean CO levels at the beginning of each session were compared to baseline CO using paired-samples *t* tests. Next, we used one-way repeated-measures analysis of variances to examine whether (1) the mean number of choices made for cigarettes and (2) the mean number of choices made for money differed across each of the categorical values of monetary reinforcer ($0.00, $0.10, and $0.50). Differences in the means of these two outcomes for each value of alternative monetary reinforcer were examined using pairwise contrasts with Bonferroni corrections. Differences were considered significant when $P \leq .05$.

In addition to the analysis of variance approach, we used multilevel modeling to examine the graded, linear effect of changes in monetary reinforcer value on the percentage of choices made for cigarette puffs. In these analyses, effects on percentage of total choices were determined, rather than number of choices for cigarettes or money, because several participants opted not to make all 20 choices. A multilevel modeling approach was chosen because the variances in cigarette choice percentages were asymmetric, which could result in biased *P* values. In addition, multilevel modeling also allowed us to explore moderators of cigarette puff choices at the $0.00 monetary reinforcer value and of sensitivity to increasing the value of the monetary reinforcer on cigarette choice. To explore these relationships, Level 1 modeled the percentage of choices made for cigarette puffs across values of alternative reinforcer (session), and Level 2 modeled hypothesized individual-level characteristics, to explore whether these characteristics were associated with either the percentage of cigarette choices when the alternative reinforcer value was $0.00, or the degree of change in cigarette choices as the value of alternative reinforcer increased. We employed an iterative, data-based strategy for examining the effects of the following

individual-level characteristics on these parameters: Gender, age when participants began smoking, the number of years of daily smoking, baseline smoking level (taken from the TLFB), Modified Fagerström Tolerance Questionnaire score, and an index of average weekly income. Thus, while we examined the effects of each of the variables, we removed those which did not significantly contribute to reducing variance either within or across individuals in order to keep the model as parsimonious as possible. All of these characteristics were time-invariant, and (aside from gender) all were centered at the grand mean. All analyses were conducted using SPSS Version 22 for Windows (IBM). Parameters were considered significant when $P \leq .05$.

Results

A total of 333 adolescents were screened and 211 (63%) were eligible. The most common reasons for ineligibility (which were not mutually exclusive) were smoking too few cigarettes per day (43%) followed by current use of non-cigarette forms of tobacco (20%) and not having been daily smokers for 6 months or more (19%). Of the 211 adolescents eligible, 191 (91%) initially agreed to participate, and 124 (68%) were ultimately enrolled. During the phone screen, three participants out of a total of 175 females screened reported that they were pregnant, and as such were not eligible to come in for the first session. A fourth participant was negative for pregnancy at the first session, but later called and reported that she was pregnant and subsequently withdrew from the study. No participants tested positive for pregnancy at the first session. Of the 124 participants, a final sample of 86 (69%) participants completed the study. Compared with participants who did not complete the study, those who completed all four sessions were slightly younger (M = 16.3 years, SD =1.36, compared to M = 16.9 years, SD = 1.45; t = –2.32, P = .02) and had lower baseline cotinine levels (M = 156.43 ng/mL, SD = 128.42 compared to M = 215.77 ng/mL, SD = 149.58; t = –2.25, P = .03), but did not differ significantly on gender, grade, smoking history or pattern variables. Of completers, 54% were female, 80% identified as white, 12% identified as Latino, 2% identified as Black, 5% identified as a race not listed or more than one race, and 1% identified as Native American.

Manipulation Check

Compared to breath CO levels at the start of Session 1 (M = 10.66 ppm, SD = 6.8) breath CO levels were significantly reduced at the start of Session 2 (M = 3.44 ppm, SD = 2.11), 3 (M = 3.77 ppm, SD = 2.09), and 4 (M = 3.74 ppm, SD = 2.09; all P's < .001). Of participants who completed the study, five had to be rescheduled (each only one time) for failing their CO test during Sessions 2–4.

Choices for Puffs and Money as a Function of Alternative Reinforcer Magnitude

Figure 1 shows the number of choices for cigarette puffs and money as a function of alternative money reinforcer value. The repeated-measures analysis of variance indicated that there were significant effects of monetary reinforcer amount on mean choices for cigarette puffs [F(2,170) = 40.91, P < .001] and money [F(2,170) = 49.38, P < .001]. Post-hoc pairwise comparisons showed that the number of cigarette choices at each pair of reinforcer amounts were significantly different (all P's < .01); the same was true of money choices (all P's < .001).

Effects of Alternative Reinforcer Magnitude and Potential Moderators

In the multilevel modeling growth-only model, monetary reinforcer value was significantly negatively associated with the percentage of choices for cigarette puffs (β = –58.10, P < .001), indicating that participants made fewer choices for puffs as the value of the alternative reinforcer increased. In addition, both intercepts (Wald Z = 3.97, P < .001) and slopes (Wald Z = 2.66, P = .008) in this model had significant variance components, indicating that choices for puffs in the absence of a competing reinforcer, and degree of decrease in puff choice with increasing reinforcer value, varied significantly across individuals. As such, these were allowed to vary randomly. Next, gender, age when participants began smoking, number of years of daily smoking, Modified Fagerström Tolerance Questionnaire score, weekly spending money, and baseline smoking rate were added to the model. As all variables except for gender and baseline smoking rate were nonsignificant, the nonsignificant terms were dropped and the model was re-estimated. See Table 1 for results.

Intercept Predictors (Smoking Levels at $0.00 Reinforcer)

Gender was significantly associated with percentage of choices for puffs when no monetary reinforcer was offered, such that males made 15% more choices for puffs than females (Figure 2). Baseline cigarettes per day, as measured by the TLFB, was also significantly associated with choices for cigarettes when no alternative reinforcer was offered, such that one standard deviation increase in baseline smoking was associated with a 2% increase in choices for cigarettes.

Slope Predictors (Change in Smoking Across Increasing Alternative Reinforcer Values)

A significant session by gender interaction emerged, such that males decreased their percent choices for puffs more steeply, on average, as the monetary reinforcer value increased, compared to females. Baseline smoking also interacted with session, and this interaction was plotted and probed using the Johnson-Neyman technique.[19,20] The effect of monetary reinforcer value on the percentage of puff choices was significant at all observed values of baseline smoking. Those with high baseline levels of smoking (+1 SD, β = –48.6, P < .001) responded more to competing monetary reinforcers of increasing amounts, compared with those at mean and low (–1 SD, β = –42.92, P < .001) levels of baseline smoking (Figure 3). Interestingly, the relationship between baseline smoking and percent choices for cigarettes was only significant below values of $0.25, suggesting that alternative reinforcers above this value may attenuate the influence of heavier baseline smoking level on choice to smoke in an abstinence-reinforcement paradigm.

Discussion

Adolescent smoking remains a crucial public health concern, and innovations in both laboratory and intervention science are needed to move the field forward and, most importantly, to make a difference in the future health of young people. The present results demonstrate that adolescents' choices for cigarette puffs can be decreased by increasing the magnitude of alternative monetary reinforcement in a laboratory-based choice procedure. The systematic, functional relationship between smoking and alternative reinforcer magnitude provides validation of this laboratory experimental paradigm for

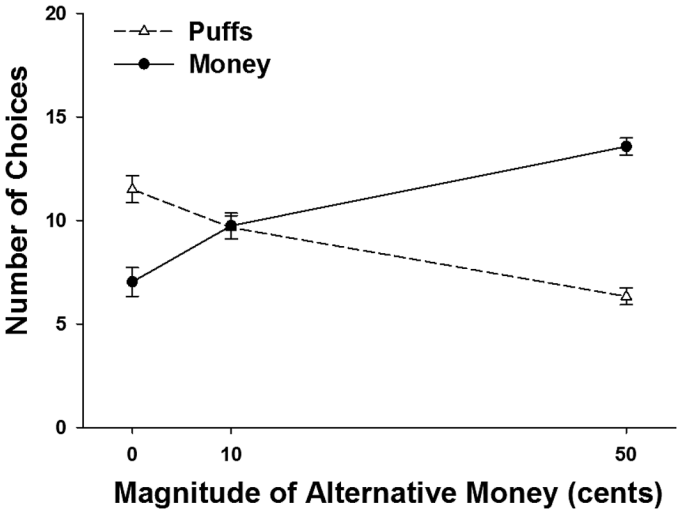

Figure 1. Number of choices for puffs of a cigarette and money as a function of monetary reinforcer value. Error bars represent standard error of the mean.

Table 1. Multilevel Model of Percentage of Choices for Cigarette Puffs Across Values of Alternative Reinforcers

Predictor	*B*	*SE*	*P*	95% CI
Intercept	53.68	4.06	<.001	45.61% to 61.76%
Gender	14.84	6.06	.016	2.79% to 26.89%
Baseline smoking	1.59	0.66	.019	0.27% to 2.91%
Slope				
Alternative reinforcer value[a]	−45.76	8.42	<.001	−62.50% to −29.02%
Gender × reinforcer value	−27.02	12.56	.034	−52.00% to −2.04%
Baseline smoking × reinforcer	−2.84	1.37	.042	−5.57% to −0.10%

CI = confidence interval.
[a]The effects of alternative reinforcer values ($0.00, $0.10, and $0.50) were examined across sessions.

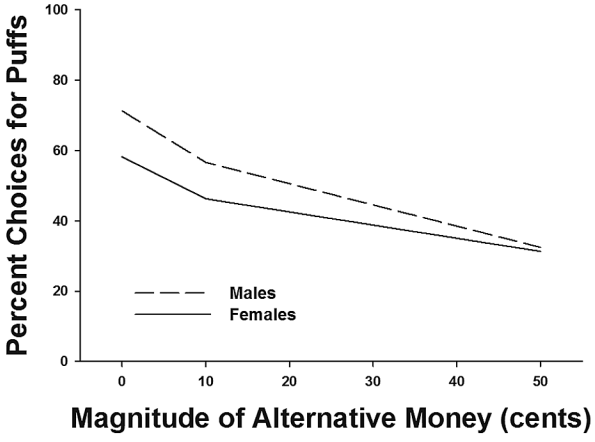

Figure 2. Percentage of choices for cigarettes by session and gender.

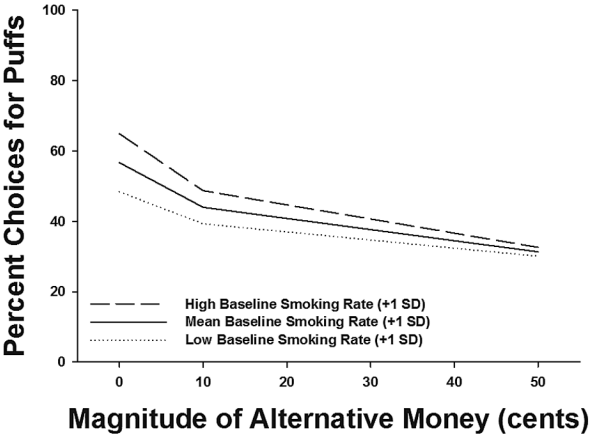

Figure 3. Percent of choices for cigarettes as a function of monetary reinforcer value and baseline smoking levels.

assessing the reinforcing efficacy of cigarette smoking in adolescents and thus fills in an important gap in the literature on adolescent smoking.

Validation of this laboratory-based procedure for studying cigarette choice in adolescents allows the current paradigm to be adapted and applied to explore the effects of many other variables that can affect the reinforcing efficacy of cigarettes. In adults, these other variables have included the effects of increasing the effort required to obtain puffs,[9] providing access to free puffs,[21] administering potential medications or other treatments for smoking cessation,[8,22,23] and examining effects of illicit or commonly-prescribed drugs on smoking behavior.[24,25] Furthermore, the current paradigm could be adapted to compare the reinforcing efficacy of conventional cigarettes and very low nicotine content cigarettes in adolescents, which would be of interest for tobacco regulatory science.[22] All of

these variables, and others, remain to be explored in adolescents in the laboratory.

Our finding that female adolescents' smoking behavior may be less sensitive than that of male adolescents to the value of alternative money reinforcers, is novel and deserves further attention. Gender differences in adolescent smoking are understudied. It is known that male adolescents tend to be more physically dependent on nicotine,[26] although in the current study we found that dependence did not moderate price sensitivity or baseline choices, suggesting that higher dependence did not underlie this gender difference. However, our ability to determine whether dependence moderated outcomes was limited because participants in this study were required to smoke at least five cigarettes per day. There are also gender differences among adolescent smokers in reasons for wanting to quit, with appearance and social factors endorsed more often for girls, suggesting that the relative weights of biological and environmental determinants of smoking behavior are different for males and females.[27,28] Among adult smokers, women may be somewhat less responsive to alternative reinforcement-based treatments for smoking.[29] Such treatments have been successfully tested for feasibility and preliminary efficacy in adolescent smokers; however, to our knowledge none have yet explored the potential effects moderating effects of gender on the effectiveness of this type of treatment.[30–32] Our results may provide preliminary evidence that gender may influence treatment outcome even in adolescent smokers; however, more research is needed to determine the generality of this effect.

We found that heavier-smoking adolescents and males chose to smoke more when the value of the monetary reinforcer was $0.00, indicating that these two populations had a high initial demand for cigarettes. Our prior laboratory-based work with adolescents using a behavioral economic purchase task found that adolescents who demonstrated higher demand intensity (number of cigarettes purchased when the cost is $0) were more dependent on nicotine than those with lower cigarette demand intensity.[33] What is notable in the current study, however, is that levels of cigarette choice were robustly suppressed in heavier-smoking and male participants despite their initially high levels. In other words, despite initially high intensity demand for cigarette puffs, demand was suppressed to similar levels in all groups, regardless of initial levels of smoking, by the highest monetary reinforcer amount. In short, although males and heavier smokers chose puffs more often in the $0.00 session compared to the average participant, in both groups a relatively small amount of alternative money was enough to decrease smoking in these groups to levels similar to those of the average participant.

In addition to the tested variables, other developmental variables may have contributed to the effect seen in the current study. Impulsivity, the tendency to value immediate rewards over delayed rewards even when the delayed reward is of higher value, is strongly related to drug taking in adults. In general adolescents show greater impulsivity than adults; and among adolescents, greater impulsivity is related to the trajectory of smoking over time, and decreased cessation success.[34,35] The current paradigm, in which the option to smoke is immediately available on every trial, may therefore be especially affected by the level of impulsivity of the participant. Adolescent impulsivity is driven by neurobiological functions that are continuing to develop as they age. In particular, adolescents process salient incentives differently than adults, and have more trouble inhibiting responses.[36] The changing neurobiology of adolescents underscores the need for studying this population distinctly from adults, and creating a through body of knowledge specific to the variables that may differentially affect the smoking behavior of this vulnerable population.

Generalization from the current study should be undertaken cautiously, given a limitation of our sample. Because we wished to provide adolescents the opportunity to smoke in laboratory, we excluded lighter smokers in order to reduce their risk. Many adolescent smokers smoke fewer than five cigarettes daily, or smoke intermittently.[37] Furthermore, heavier smokers who were enrolled in this study were less likely to complete all study sessions. Thus, our sample may not be representative of all adolescent smokers. A strength of the current study sample, however, is that it contains a range of ages (from 14–19), without over-representing 18 and 19 year olds.

Laboratory-based assessments of drug use have formed the foundation of successful and widely disseminated treatments, such as contingency management, while contributing to our basic knowledge of the underlying behavioral processes that contribute to the maintenance of drug taking. Precise, parametric understanding of whether and to what extent an environmental variable can shift drug taking behavior is a powerful tool for predicting real-life behavior and for developing effective treatments.[2,3] The strong body of laboratory-based research on smoking in adults has led to great improvements in our understanding of the determinants of smoking in adults. We expect that a thorough and rigorous body of empirical evidence will continue to be developed for adolescent smokers.

Funding

The study was funded by a grant from the National Institute on Drug Abuse (1R01DA16737) awarded to SMC. Manuscript preparation was supported in part by grant number T32 AA007459 from the National Institute on Alcohol Abuse and Alcoholism (TBW) and grant number T32 DA016184 from the National Institute on Drug Abuse and 1K01CA189300 from the National Cancer Insitute (RNC).

Declaration of Interests

None declared.

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