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Delay Discounting as a Mediator of the Relationship between Perceived Stress and Cigarette Smoking Status in Adolescents

Sherecce Fields[a], **Kristen Leraas**[a], **Christine Collins**[a], and **Brady Reynolds**[a,b,*]
[a]Research Institute at Nationwide Children's Hospital

[b]Department of Pediatrics The Ohio State University

Abstract

There has been a wealth of research providing evidence for the relationship between stress and cigarette smoking during adolescence. Despite this knowledge, little is known about possible behavioral mechanisms by which stress exerts its influence on the decision to smoke. This study sought to examine one such behavioral characteristic, delay discounting, that may mediate the relationship between stress and cigarette smoking. Delay discounting generally refers to the discounting of value for outcomes because they are delayed; and high rates of delay discounting have been linked to impulsive behavior. For the current research, adolescent smokers (n = 50) and nonsmokers (n = 50) were compared using a self-report measure of perceived stress and a laboratory assessment of delay discounting. Smokers tended to report higher levels of stress and to discount more by delay, and there was a significant association between reported stress and delay discounting. Additionally, delay discounting mediated the relationship between stress and cigarette smoking status. These results suggest that discounting by delay may be a behavior through which stress exerts influence on an adolescent's decision to smoke.

Keywords

perceived stress; delay discounting; cigarette smoking; adolescents

INTRODUCTION

Cigarette smoking has been linked to a number of illnesses such as cancer, heart disease and lung disease (US Department of Health and Human Services, 1994), and smoking is considered the top preventable cause of death in the United States (US Public Health Service, 2000). Across the lifespan, smoking is most prevelent between 18 and 25 years of age (Center for Disease Control, 2006); however, smoking initiation tends to occur earlier during adolescence (Byrne & Reinhart, 1998). As such, it is important to identify factors that may affect the initiation of smoking in adolescent populations.

One factor that is consistently linked with cigarette smoking is stress. In the adult literature, stress is a significant correlate of smoking behavior (Maquin & Gilbert, 1996; Steptoe et al., 1996), and stress also may play an important role in adolescent smoking behavior (Mitic et al., 1985; Dugan et al., 1999). For example, adolescent girls who reported more daily hassles (an index of stress level) were more likely to report having ever smoked (Guthrie et al., 2001). Also, stress appears to be related to the intention to smoke (Booker et al. 2004); and

*Corresponding Author Brady Reynolds, PhD, Research Institute at Nationwide Children's Hospital, Department of Pediatrics, The Ohio State University, 700 Children's Drive, J1401, Columbus, OH 43205, USA, Phone: 614-722-3549, Fax: 614-722-3544, Reynolds.421@osu.edu.

more recent longitudinal analyses have extended this finding to show that developmentally early stress is associated with lifetime smoking (Booker et al., 2008).

The relationship between stress and adolescent cigarette smoking is also seen throughout different stages of smoking (i.e. initiation, relapse, etc.). For instance, there is an association between stress and smoking initiation: self-reported stress at baseline is a significant predictor of future smoking among samples of nonsmokers (Voorhees et al., 2002; Byrne & Mazanov, 2003; Finkelstein et al., 2006). One study specifically set out to determine the directionality of the relationship between stress and smoking in adolescents (Wills et al., 2002). Stress predicted increased smoking over time, but there was no evidence that initiation of smoking influenced level of stress. Collectively, these findings support the hypothesis that stress may influence the initiation of cigarette smoking in adolescent populations.

While the relationship between stress and smoking is well established, more research is needed to better understand mechanisms that may mediate this relationship in adolescents. There are several different theories linking stress to substance abuse, mostly centered on the rewarding properties of the substances (e.g., Shiffman, 1982; Koob & Le Moal, 1997). One model, the stress-vulnerability model (Sinha, 2001), suggests that stress may directly influence substance abuse or may indirectly influence substance abuse by leading to maladaptive responses to the environment. A behavioral attribute that may fit this second possibility is delay discounting. Delay discounting describes the extent to which an individual discounts the value of an outcome because of a delay to its occurrence. Delay discounting is considered a form of impulsive behavior and is associated with a variety of addictive behaviors, including cigarette smoking (Bickel & Marsch, 2001; Reynolds, 2006a). In studies with adults, cigarette smokers discount more (i.e., perform more impulsively) than nonsmokers (Bickel et al., 1999; Mitchell, 1999; Reynolds, 2006b). This finding also has been replicated in samples of adolescent smokers and nonsmokers (Audrain-McGovern et al., 2004; Reynolds et al., 2007).

Such cross-sectional findings do not address the question of whether high rates of delay discounting predict future smoking or whether smoking itself may increase rate of delay discounting. Using a retrospective method, one study has shown that higher rates of delay discounting were associated with earlier age of first cigarette use (Kollins, 2003). A more recent study that examined delay discounting in adolescent daily smokers, experimenters (defined as having tried smoking for the first time within three months of participation), and never smokers found that the daily smokers and experimenters discounted significantly more than the never smokers but did not themselves differ (Reynolds & Fields, submitted for publication). This finding indicates that high rates of delay discounting predate substantial use of nicotine in high-risk adolescents and therefore may be a risk factor for smoking. Similarly, recent longitudinal research investigating the temporal precedence of delay discounting and smoking has shown that delay discounting predicted smoking initiation, but smoking did not significantly change rates of delay discounting over time (Audrain-McGovern et al., 2009). These findings provide support for the hypothesis that high rates of delay discounting may influence initiation of cigarette smoking.

Concerning the possible relationship between stress and delay discounting, it has been suggested that stress exposure could interfere with cognitive performance -particularly those processes associated with self-regulation (i.e., sustained attention or behavioral inhibition; Cohen, 1980; Muraven & Baumeister, 2000). In fact, stress increases impulsivity as measured by a self-report inventory (Mooney et al., 2008) and decreases self-control as defined by behavioral inhibition (see review; Muraven & Baumeister, 2000). While no studies to date designate a specific relationship between stress and delay discounting, some

research indicates that other decision-making variables, such as risky decision-making, are associated with stress (Fishbein et al., 2006). Also, several studies provide evidence that what might be considered stressful events (e.g., holding hand in cold water) can increase impulsive choice using a delayed choice paradigm (Flora et al., 1992; Flora & Wilkerson, 2003).

As an attempt to understand better one possible mechanism through which stress exerts its influence on cigarette smoking during adolescence, the current study examined associations between perceived stress, delay discounting, and cigarette smoking status in adolescents. The results presented here for delay discounting between smokers and nonsmokers have been reported previously, with smokers discounting more by delay than nonsmokers (Reynolds & Fields, submitted for publication); however, data related to perceived stress have not been previously reported. We hypothesized that perceived stress would differentiate adolescent smokers and nonsmokers, with smokers reporting higher levels of stress. Further, it was hypothesized that delay discounting would significantly mediate the relationship between stress and smoking status in adolescents.

METHODS

Participants

Participants in this study were adolescent smokers and nonsmokers, recruited from the central Ohio area through posted advertisements, newspaper advertisements, and word of mouth referrals. An initial phone screening was conducted to determine eligibility. To qualify, participants were required to be between 13 and 17 years of age and self-report smoking four or more cigarettes per day for at least the preceding three months (smokers) or never smoking (nonsmokers). Once at the laboratory, each participant provided samples of breath and urine to verify smoking status. The breath sample was tested for CO content using a Micro 4 Smokerlyzer (Bedford Scientific, Kent, United Kingdom), and the urine sample was tested for cotinine content using a homogenous enzyme immunoassay (Graham-Massey Analytical Labs, New haven, CT). Self-reported smokers were required to have cotinine levels of ≥200 ng/ml. Nonsmokers were required to have CO levels of ≤5 ppm and cotinine levels of ≤50 ng/ml.

Dependent Measures

Perceived Stress Scale (PSS; Cohen et al., 1983)—The PSS is a 14-item questionnaire designed to measure the degree to which situations in one's life, as well as one's individual coping style, are considered stressful. Items are measured on a 5-point scale (0 = never to 4 = very often) and included questions such as "how often have you been upset because of something that happened unexpectedly," "how often have you been able to control irritations in your life," "how often have you felt difficulties were piling up so high that you could not overcome them," etc. Positively worded items are reversed scored. Scale scores range from 0 to 70, with higher total scores representing higher levels of perceived stress. Past research has found that the PSS has good internal consistency (Cronbach's alpha estimates ranging between 0.84 and 0.86) and test-retest reliability (r = .85; Cohen et al., 1983).

Question-Based Delay-Discounting Measure (DDQ; Richards et al., 1999)—For this measure, participants were presented choices between $10 available after a specified delay (i.e., 1, 2, 30, 180, or 365 days) and a smaller amount available immediately (e.g., "would you rather have $10 in 30 days or $2 now?"). This computerized task used an adjusting amount procedure (adjusting the immediate amount in increments of ± $0.50) to derive indifference points between the delayed standard and immediate adjusting options for

each of the five delays assessed. An indifference point reflected the smallest amount of money an individual chose to receive immediately instead of the delayed standard amount ($10) at the specific delay. The choice questions were presented in a randomized order determined by the computer program. Participants were told that their answers to the questions were important because at the end of the session one question would be randomly selected and honored—resulting in either immediate or delayed money. From all participants' choices, a random number generator (available via the web) was used to select a choice for payout. If a delayed choice was selected, it was mailed to the participant based on the specified time of delay. See Reynolds et al. (2003) for participant instructions for the DDQ.

Procedure

All data collection took place in a human-behavior laboratory at the Research Institute at Nationwide Children's Hospital, Department of Pediatrics, The Ohio State University. Institutional Review Board approved consent and assent forms were reviewed and signed by all participants. Following consent/assent, participants were tested for breath CO levels and then completed a brief demographic questionnaire and the self-report measures as well as a widely used measure to estimate IQ, the Kaufman Brief Intelligence Test – Second Edition (KBIT2; Kaufman & Kaufman, 2004). Following completion of self-report measures, participants completed several laboratory behavioral tasks, with task order counterbalanced across participants. Upon completion of laboratory tasks, participants were escorted to a restroom where they provided a urine sample that was later assayed for cotinine content. Participants were then debriefed and paid for their participation, which was partially calculated based on laboratory behavioral-task performance. All laboratory sessions were conducted between the hours of 12:00 h and 19:00 h.

Statistical Analyses

An area-under-the-curve (AUC) method, as specified by Myerson et al. (2001), was used to characterize data from the DDQ. From the AUC method, smaller AUC values reflect greater discounting and impulsivity. The AUC data were inspected for normality using Shapiro-Wilk tests and were transformed using a log-10 function to improve normality. In order to facilitate interpretation of group differences in delay discounting, the resulting discounting parameter for each group (smokers and nonsmokers) was used to calculate the time needed for a 50% reduction in reward value (ED50), as specified by Yoon & Higgins (2008).

All analyses were performed using SPSS 17.0. Demographic characteristics were compared using one-way ANOVAs for continuous variables and Chi-square tests for categorical variables. To examine rate of delay discounting as a mediator between perceived stress and smoking status, a series of regression analyses were used as outlined by Baron and Kenny (1986). According to this approach, stress should be significantly related to smoking status (step 1). Rate of delay discounting should also be significantly related to stress (step 2). Finally, rate of delay discounting should be significantly related to smoking status and eliminate or significantly decrease the relationship between stress and smoking status when its effects on smoking status are first removed (step 3). If rate of delay discounting mediates the relationship between stress and smoking status, the coefficient for the relationship between stress and smoking status should be significantly reduced from the first equation to the third equation. To test the significance of any observed mediation, the estimated mediated effect was divided by its standard error (as outline by MacKinnon, 2008), and this value was compared with a normal curve distribution to determine significance.

In step 1, stress was regressed on smoking status using a binary logistic regression. In step 2, stress was regressed on delay discounting using ordinary least squares regression. In step 3,

stress and delay discounting were regressed on smoking status using a binary logistic regression.

RESULTS

Participants

Participant demographic data are presented in Table 1. Smokers were slightly older than nonsmokers in this sample [F (1, 98) = 6.24, $p < .05$]. No significant differences were found between smokers and nonsmokers for ethnicity [$X^2 = 6.21$,*NS*], annual household income [F (1, 92) = 2.09, *NS*] or gender [$X^2 = 0.50$, *NS*]. As expected, smokers had significantly higher CO [F (1, 98) = 153.63, $p < .001$] and cotinine [F (1, 97) = 258.72, $p < .001$] levels compared to the nonsmokers, thus providing verification of smoking status classifications.

Group Differences

Smoking status effects were found for the PSS, DDQ and the KBIT. Specifically, for the PSS [F (1, 98) = 4.59, $p <.05$], smokers (M = 26.8, SD = 5.60) had significantly higher scores than nonsmokers (M = 24.2, SD = 6.32). Also, for the DDQ [F (1, 97) = 16.132, $p < .001$], smokers (*Median AUC* = 0.154) discounted significantly more than nonsmokers (*Median AUC* = 0.470), which has been reported previously (Reynolds & Fields, submitted for publication). When ED50 values were examined, smokers discounted the value of the delayed reward by 50% after approximately six days (ED_{50} = 5.967), whereas nonsmokers discounted the value of the delayed reward by 50% after 116 days (ED_{50} = 116.01). Lastly, for the KBIT [F (1, 98) = 19.62, $p < .001$], smokers (M = 87.76, SD = 14.22) had significantly lower scores than nonsmokers (M = 100.44, SD = 14.40).

Meditational Analyses

Steps 1-3 were assessed to establish paths a, b, c, and c’ (see Figure 1) as described above. The first equation, in which smoking status was regressed on perceived stress (path c), was significant; and the odds ratio (1.074) for this equation indicated that a one point increase in perceived stress was associated with a 7.4% greater likelihood of smoking. The second equation, in which delay discounting was regressed on perceived stress (path a), was significant. In the third equation, smoking status was regressed on delay discounting (path b) and perceived stress (path c’). The coefficient associated with the relationship between delay discounting and smoking status (controlling for perceived stress) was significant, and the odds ratio (0.166) indicated that a one point decrease in delay discounting AUC value was associated with an 83.4% greater likelihood of smoking. Finally, the coefficient associated with perceived stress in the third equation (path c’) was not significant. The mediation effect was significant at the $p < .05$ level. To determine if an alternate path may be indicated, the meditational analysis was rerun with smoking status as the mediating variable and delay discounting as the outcome variable. There was no substantial mediation effect found for this analysis; therefore the causal assumption of the original meditational analysis, i.e., that stress may influence delay discounting, was supported.

Finally, the smokers and nonsmokers differed in average age and IQ; therefore, all of the previous analyses were explored again controlling for group differences in these variables as covariates. After controlling for age and IQ, paths a and c were no longer statistically significant; however delay discounting remained a significant predictor of smoking status even after controlling for age and IQ.

DISCUSSION

The current study examined the association between perceived stress, delay discounting, and cigarette smoking status in adolescents. Based on the results of this study, stress was a significant predictor of cigarette smoking in adolescents. This finding is consistent with what would be expected based on previous research examining cigarette smoking in adolescents (Dugan et al., 1999; Booker et al., 2004). More importantly, it was hypothesized that delay discounting would be a significant mediator of the relationship between stress and smoking status in adolescents. Results indicated that delay discounting does appear to mediate this relationship in adolescents. That is, the tendency to discount value because of delay may be one mechanism by which increased stress increases the likelihood of smoking.

These findings lend support to the stress-vulnerability model posited by Sinha (2001), which suggests that stress may influence substance abuse through maladaptive responses to the environment. If we were to consider the current results in the context of the stress-vulnerability model, these results would suggest that when adolescents are under stress, they shift to a more immediate-oriented mindset (as reflected by more impulsive delay discounting). The immediate motivation may be to relieve stress, and such individuals may seek out ways to do so without considering the long-term consequences of their actions. There is some evidence to support the hypothesis that emotional distress works against an individual's typical impulse control patterns to shift from a more long-term focus on distal goals to a short-term focus on immediate rewards. For example, in studies involving adults, it has been shown that when subjected to stressful laboratory conditions, participants responded by performing more impulsively on a variety of tasks (Tice et al., 2001). However, there is no reconciliation as to the mechanism behind this shift to impulsivity. As was mentioned earlier, it has been suggested that stress exposure could interfere with cognitive performance (Cohen, 1980; Muraven & Baumeister, 2000). Perhaps stress has effects on cognitive systems that underlie a variety of behavioral dimensions, with delay discounting being only one such dimension. Future research may be necessary to more explore this phenomenon fully, and to understand it better,.

The current findings provide evidence that delay discounting may influence the manner in which stress affects smoking status, or the decision to smoke during adolescence. However, due to the cross-sectional nature of this research, causal interpretations must be qualified in that other confounding variables may be important to consider. However, delay discounting has been shown to fluctuate, or to exhibit a state-like quality, in response to environmental manipulations. For example, delay discounting in pathological gamblers differs across gambling and non-gambling contexts, suggesting that this change in environments has an effect on how much an individual discounts the value of future outcomes (Dixon et al., 2006). Also, as mentioned earlier, research has shown increases in discounting behavior (using real-time assessment procedures) caused by laboratory induced stress (Flora et al., 1992; Flora & Wilkerson, 2003) and sleep deprivation (Reynolds & Schiffbauer, 2004). Such findings are consistent with perceived stress increasing delay discounting. However, more detailed prospective work is needed with adolescents at risk of smoking to determine (a) if stress increases delay discounting in this population and (b) if any such stress-related changes in discounting increase the risk liability for initiating smoking.

Establishing linkages between perceived stress, delay discounting, and cigarette smoking during adolescence could provide a more specific mechanism (i.e., delay discounting) on which to focus smoking prevention strategies. For example, individuals at risk for smoking initiation or relapse due to stress may not be responsive to interventions that target long-term goals or health outcomes (i.e., future lung cancer or heart disease). These individuals may be better served with interventions addressing more immediate or short-term goals, such as

having more money when not smoking or increased acne caused by smoking (especially for adolescents). In fact, one study showed that discounting decreased significantly for individuals participating in a contingency management program where smoking reductions were reinforced on a more regular basis (Yi et al., 2008). Perhaps, more immediate oriented treatment approaches (e.g., contingency management) would be more effective for individuals attempting to quit smoking during highly stressful life situations—by virtue of the possible effects of stress to reduce tolerance for delays (i.e., delay discounting).

For the current study, delay discounting was no longer a significant mediator of the relationship between perceived stress and smoking status when participant age and IQ were controlled as covariates. This finding indicates that these variables may account for the observed mediation through shared variance with perceived stress and delay discounting. While this is an important consideration when interpreting these results, this finding does not eliminate delay discounting as a mediator, but rather qualifies that other participant characteristics are important to keep in mind and may play causal roles. However, of these variables, it is notable that delay discounting is the only variable that can be considered a behavior. As such, findings related to delay discounting may provide comparatively more information for the tailoring of cigarette-smoking prevention or treatment strategies (as described above), even if rate of delay discounting is partially driven by a person's age and IQ.

In conclusion, consistent with other studies, we report that perceived stress is associated with cigarette smoking status in adolescents. However, the association between stress and smoking status appears to be mediated by delay discounting. Delay discounting provides a behavioral process that might be addressed clinically with programs designed to target more immediate outcomes versus more distal ones. However, future prospective studies are needed to further define causal relationships between stress, delay discounting, and cigarette smoking during adolescence.

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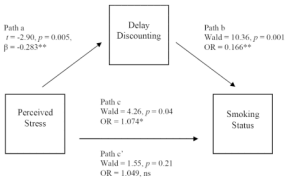

Figure 1.

Mediated model for perceived stress (PSS), delay discounting (DDQ), and smoking status. Standardized regression coefficients (β) and odds ratios (OR) are presented (*p < .05, **p < .01).

Table 1

Demographics

Demographics	Smokers	Nonsmokers
Age [years; *M*(*SD*)]	15.66 (1.06)	15.12 (1.10)*
Gender (n; male:female)	17:33	17:33
Ethnicity (n; white:black:other)	22:26:2	23:22:5
Median Annual Household Income [*M* (*SD*)][a]	$50,766 ($24,520)	$58,933 ($29,967)
Carbon Monoxide [ppm; *M* (*SD*)]	11.04 (7.49)	1.90 (1.33)*
Cotinine [ng/ml; *M* (*SD*)]	1277.00 (832.82)	1.58 (8.81)*

Note.

[a]The median annual household income was calculated based on average income for census track of the participant's residence.

*Significantly different from smokers ($p < .05$).