The Acute Effects of Nicotine on Positive and Negative Affect in Adolescent Smokers

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Although adolescent cigarette smoking remains a critical public health concern. As many as 80% of tobacco users begin smoking before they are 18. Whereas adolescent smoking in the United States appears to have peaked in the mid-1990s (Johnston, O'Malley, Bachman, & Schulenberg, 2005b), recent data suggest that the rate of decline in adolescents’ use of cigarettes has been decelerating over the past several years (Johnston, O'Malley, Bachman, & Schulenberg, 2005a). In fact, among eighth graders, smoking rates have plateaued, potentially a bad sign for future smoking trends among young adults. In short, if the trend in early initiation of cigarette smoking continues, approximately 5 million children who are living today will die prematurely because they began to smoke cigarettes during adolescence. As significant as this public health problem is, however, surprisingly little is known about the motivational processes subserving adolescent smoking.

Given the notable health risks posed by the use of tobacco, research on the determinants of adolescent smoking is urgently needed, as it can inform prevention, treatment, and policy at multiple levels.

Although there has been some problem in clearly determining the underlying mechanisms that explain why tobacco smoking is reinforcing among adolescents, there is strong reason to believe that most adult smokers smoke, at least in part, as a way of regulating affect. Indeed, some of the most influential models of addictive behavior have emphasized the importance of aversive affective states precipitating drug use, coupled with the notion that drug use assuages such emotional distress (e.g., Siegel, 1983; Wikler, 1973; see Kassel et al., 2006, for a discussion of negative affect [NA] and addiction). Such sentiments have also been well articulated within the stress–coping (Wills & Shiffman, 1985) and self-medication models (Kchantzian, 1997) of substance use. Consistent with these conceptualizations, a large literature on smoking motives (Shiffman, 1993) and smoking expectancies (Brandon, Juliano, & Copeland, 1999) reliably demonstrates that the majority of adult smokers attribute their smoking to its reputed ability to calm them when stressed and, more generally, reduce NA (e.g., Ikard, Green, & Horn, 1969; McKennell, 1970; Spielberger, 1986; see Kassel, Stroud, & Paronis, 2003). Thus, smoking as an anxiolytic tool emerges as the most widely endorsed motive among adult smokers, particularly among those who are nicotine dependent (Shiffman, 1993).

However, less is known about the motives governing adolescent cigarette smoking. Although it is commonly thought that early smoking is governed more by peer and social factors (e.g., Ferguson et al., 1992; Wang, FitzHugh, Eddy, Fu, & Turner, 1997) than by attempts at mood regulation, there are relatively few data to

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support these assumptions. In fact, several studies have suggested that motives linked to affect regulation may take on significance earlier than previously believed (Dozois, Farrow, & Miser, 1995; Johnson et al., 2005; McNeill, Jarvis, & West, 1987; see also Chassin, Presson, Rose, & Sherman, 2007, for an interesting take on adolescents’ views of nicotine addiction). In particular, these studies have suggested that a significant proportion of adolescents attribute their smoking to relaxation and anxiolytic motives. However, we are unaware of any studies of adolescent smokers that have assessed the acute effects of smoking on emotional response under controlled laboratory conditions. Such an approach is critical to shedding light on the processes that subserve smoking behavior among adolescents. As such, the primary goal of the present study is to assess the acute effects of nicotine, as administered via tobacco cigarettes, on both positive affect (PA) and NA in a sample of young smokers.

Do Adolescents Smoke to Regulate Affect?

The pathways to becoming a smoker are clearly complex and governed by a host of genetic, social, pharmacological, and psychological determinants (Jamner et al., 2003; Kassel, Weinstein, Skitch, Veilleux, & Mermelstein, 2005). In fact, social factors, such as peer affiliations and peer socialization (e.g., Oetting & Donnemeyer, 1998), have emerged as perhaps the most potent and reliable predictors of smoking initiation and experimentation. Yet there is also reason to believe that among the many adolescents who try cigarettes, those who progress to regular smoking status, as well as nicotine dependence, are more likely to report heightened levels of stress and NA (Chassin, Presson, Sherman, Corty, & Olshavsky, 1984; Stein, Newcomb, & Bentler, 1996) as well as experience numerous manifestations of psychopathology associated with affective distress, including depression (e.g., Brown, Lewinsohn, Seeley, & Wagner, 1996; Escobedo, Reddy, & Giovino, 1998; Koval, Pederson, Mills, McGrady, & Carvajal, 2000) and anxiety (e.g., Patton et al., 1996; Sonntag, Wittchen, Hofler, Kessler, & Stein, 2000). Correspondingly, it becomes critical to distinguish the processes that govern smoking initiation and experimentation from those that underlie progression to nicotine dependence (Colby, Tiffany, Shiffman, & Niaura, 2000; Kassel, 2000; Shadel, Shiffman, Niaura, Nichter, & Abrams, 2000).

On the basis of findings from both cross-sectional and longitudinal studies, many researchers have inferred that because adolescents who experience significant levels of affective distress are more likely to smoke, they must do so because smoking necessarily alleviates NA. However, as we have argued elsewhere (Kassel & Hankin, 2006; Kassel et al., 2003), one must be careful not to instantiate causal (within-subject) mechanisms on the basis of results derived from cross-sectional (between-subjects) analyses. Although there is a dearth of empirical work devoted to answering the question of whether smoking genuinely influences emotional response in adolescents, several studies have offered some insight into the motives associated with adolescent smoking. Although they are not a direct indicator of nicotine dependence, the subjective effects experienced by smokers likely reflect the role of nicotine (and other constituents of tobacco smoke) in governing smoking behavior. For example, McNeill et al. (1987) found that 82% of a sample of 170 female adolescent smokers reported experiencing at least one of five specified subjective effects of smoking. Feeling calmer was the most frequently endorsed effect, and daily smokers were more likely to report this than nondaily smokers (64% vs. 38%, respectively). Moreover, the likelihood of experiencing at least one withdrawal symptom when trying to quit was greater among those who reported feeling calmer when smoking (84% vs. 40%, respectively). Other subjective effects of smoking received relatively little endorsement, with 34% experiencing dizziness and lightheadedness, 15% describing feeling sick, 1% feeling “high,” and 8% experiencing greater alertness.

The importance attributed to relaxation motives is echoed in findings by Dozois et al. (1995) and Nichter, Nichter, Vuckovic, Quintero, and Ritenbaugh (1997), who similarly found that smoking to relax and stress reduction were commonly reported motives among adolescent smoking initiates. Recent studies by Johnson et al. (2003, 2005) also point to the significant endorsement of emotional reinforcement motives, as a large proportion of adolescent smokers attributed their smoking to its ability to facilitate affect regulation. Correspondingly, Stevens, Colwell, Smith, Robinson, and McMillan (2005) found that the motive most frequently endorsed by their sample of 721 adolescent smokers was smoking in response to NA. Moreover, in support of previous findings (Miller, Hemenway, & Rimm, 2000), this study revealed that adolescents whose smoking was predominantly cued by NA were significantly more likely to have future smoking intentions as well as evidence significantly less self-efficacy to quit smoking, relative to adolescents who reported other reasons for smoking.

Taken together, these studies strongly suggest that many—perhaps even most—adolescents smoke both in response to and in an effort to alleviate NA. However, although such findings may be compelling, the conclusions that can ultimately be drawn from them are limited because of the highly subjective and retrospective nature of the data. Controlled laboratory studies would be useful to determine whether smoking exerts genuine anxiolytic and NA-reducing effects (although even controlled laboratory studies that use self-report as the primary index of affect ultimately rely on subjectivity as well). Although we acknowledge the ethical constraints associated with administration of nicotine to minors (Eisenberg & Balster, 2000; Moolchan & Mermelstein, 2002), such information is nonetheless crucial to further our knowledge of the effects of nicotine in new smokers.

Given the theoretical importance of appetitive, positive reinforcement processes in governing drug use (e.g., Stewart, de Wit, & Eikelboom, 1984; Wise, 1998), it is also surprising that examination of the effects of smoking on PA has received such short shrift in both the adolescent and the adult smoking literatures. Indeed, understanding the extent to which drugs influence reward processes as well as negative reinforcement mechanisms is critical to delineating the motivational landscape underlying substance abuse and dependence. Moreover, as there is now ample reason to believe that PA and NA are independent constructs (not simply opposite sides of a bipolar continuum; e.g., Watson & Tellegen, 1985), it is important to note that whereas delineating the immediate precipitants, or cues, of smoking behavior is critical with respect to both theory development and intervention efforts, such knowledge ultimately has no bearing on the question of whether smoking genuinely reduces NA (see Kassel et al., 2003, for a discussion of this issue).
1985; Watson, Wiese, Vaidya, & Tellegen, 1999), it becomes important for drug researchers to examine the impact of drugs on both PA and NA, as it is conceivable that drugs may exert independent effects on each.

In sum, it is clear that many adolescent smokers attribute their smoking to its alleged ability to reduce NA. However, we are unaware of any previous laboratory investigations of nicotine’s influence on affect in adolescent smokers (although see Corrigall, Zack, Eissenberg, Belsito, & Scher, 2001, who assessed the effects of smoking on other subjective parameters). Because expectancies of NA reduction can actually influence nicotine’s effects on emotional response to a stressor (Juliano & Brandon, 2002), we also measured smoking expectancies relevant to affect regulation. On the basis of the assumption that as individuals approach or have reached a state of nicotine dependence, they are motivated to smoke, in great part, to stave off or escape aversive symptoms of nicotine withdrawal (e.g., NA; see Baker, Piper, McCarthy, Majeskie, & Fiore, 2004), we also assessed nicotine dependence. Correspondingly, we measured craving at the study’s outset, guided by the belief that craving represents a critical component of the withdrawal syndrome (Baker et al., 2004; Kassel & Shiffman, 1992) and, as such, complements the measure of nicotine dependence. Finally, we incorporated a measure of PA because so little is known about how nicotine may influence PA, or reward processes, in adolescents. Thus, we examined the acute effects of nicotine, as administered via tobacco cigarettes, on PA and NA in a group of light-smoking adolescent smokers. Measures of smoking expectancies, nicotine dependence, and craving were also included as possible moderators of any observed nicotine effects. Finally, we included a comparison group of nonsmokers who did not receive nicotine.

Method

Participants

This study was approved by the Institutional Review Board at the University of Illinois at Chicago. Given that most of the study participants were under 18 years of age, such individuals also provided signed parental consent forms, in addition to their own signed assent. Because of the potentially sensitive nature of the study (i.e., administration of nicotine via cigarettes to minors), we took great care in ensuring that all participants and their parents understood the objectives of the study and the requests being made of the participants. No participant was mandated to smoke as a part of study participation. Rather, adolescents were given the opportunity to smoke “as much or as little” of the cigarette as they so desired.

Forty-five adolescent smokers and 27 nonsmokers were recruited from the Chicago greater metropolitan area as part of their participation in a larger study. Participants received either monetary compensation ($45) or, if they were university students (n = 35), course credit for their participation in this one-visit study. Participants were between 15 and 18 years of age; to qualify as smokers, they were required to have smoked for at least 4 weeks and to smoke a minimum of one cigarette a week but no more than five cigarettes a day on average. Nonsmokers must never have smoked at all. Thus, our intention was to assess the acute effects of nicotine in a relatively young, novice group of smokers as well as to include a comparison group of nonsmokers. Participants who qualified as smokers were then randomly assigned to one of two experimental groups: a high-yield (HY) cigarette condition or a denicotinized (DN) cigarette condition.

Cigarettes

To ensure standardization in nicotine and tar yields within the respective nicotine conditions, we used research cigarettes (Ultra-tech/Lifetech, Inc., Lafayette Hill, PA) containing .06 mg nicotine/17.9 mg tar (DN) or 1.14 mg nicotine/15.9 mg tar (HY) nicotine levels (cf. Juliano & Brandon, 2002). As previously reported by Pickworth, Fant, Nelson, Rohrer, and Henningfield (1999), the DN cigarettes deliver no appreciable amount of nicotine. All participants were led to believe that they would be receiving and smoking a regular nicotine-yield cigarette.

Measures

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS is a widely used and psychometrically valid self-report measure that assesses state (how one feels “right now”) PA (10 items, e.g., “excited,” “alert,” “enthusiastic”) and NA (10 items, e.g., “upset,” “nervous,” “irritated”). The scales have been shown to be highly internally consistent, largely uncorrelated, and stable at appropriate levels over a 2-month time period. In the present study, the obtained reliability (alpha) coefficients ranged from (across the two measurement periods, respectively) .74 to .75 (NA) and from .85 to .90 (PA).

Smoking Expectancies Questionnaire (Wahl, Turner, Mermelstein, & Flay, 2005). The Smoking Expectancies Questionnaire is a 13-item questionnaire that taps four domains of smoking expectancies specifically applicable to adolescent smokers. For the present analyses, we used only the Negative Affect Management (NAM; 4 items; α = .72) and the Boredom Relief (BR; 3 items; α = .78) subscales, as these measures were most directly related to our interest in nicotine’s effects on affect. The Smoking Expectancies Questionnaire has demonstrated sound psychometric properties and predictive validity (Wahl et al., 2005).

Nicotine dependence. Nicotine dependence was assessed with a modified version of the Fagerstrom Tolerance Questionnaire (MFTQ; Fagerstrom, 1978), specifically designed to measure dependence in adolescent smokers (Prokhorov et al., 2000). Previous findings indicate that this measure is valid and applicable to adolescent smokers (Prokhorov et al., 2000; α = .71).

Cigarette craving. Craving was measured with the six-item Craving subscale of the Shiffman Jarvik Withdrawal Questionnaire (Shiffman & Jarvik, 1976). This self-report questionnaire has been widely used and has excellent psychometric properties. In the present study, we obtained an alpha coefficient of .82.

Other smoking behavior. All smokers were asked how recently they last smoked a cigarette (to the nearest quarter hour) and how many cigarettes they had smoked on the study day prior to coming to the lab.

Cigarette ratings. At the study’s end, all participants completed a brief questionnaire querying them about the “harshness,” “strength,” and “pleasantness” of the research cigarette they smoked (Kassel & Unrod, 2000). Response options ranged from 1 (not at all) to 4 (very much so).
Procedure

Upon their arrival at the laboratory, all participants completed either informed consent or assent and baseline self-report questionnaires, after which the details of the procedure were reiterated verbally. Participants who were under 18 years old also provided signed parental consent forms. Participants who qualified as smokers were then given the opportunity to smoke a research cigarette provided by the experimenter and were blind to the nicotine content of the cigarette. Smokers took, on average, 10 min to smoke their cigarette. To maintain parallelism across sessions for both smokers and nonsmokers, we asked all nonsmokers to simply sit for 10 min during this same time period. Both smokers and nonsmokers were given access to several emotionally neutral magazines.

After being instructed to smoke, in an ad libitum manner, as much or as little of the cigarette as they wanted, participants lit the cigarette and then inserted it into a mouthpiece used to assess smoking topography via the Clinical Research Support System (Plowshare Technologies, Baltimore, MD; see Kassel et al., 2007, for a detailed analysis of the smoking topography data).2 Just prior to (Time 1) and immediately after smoking the cigarette (Time 2), participants completed the PANAS. All participants provided baseline expired air breath samples (with the smokers providing a second sample immediately after smoking the research cigarette) that were assessed for alveolar carbon monoxide (CO) levels with a Vitalograph EC 50 CO monitor. At the study’s end, participants were debriefed, compensated, and, if they were smokers, given referrals to smoking cessation programs.

Results

Sample Characteristics

Participants who met criteria as smokers were randomized into either the DN (n = 23) or the HY (n = 22) experimental group, with 27 nonsmokers serving as a comparison group. Participant characteristics can be found in Table 1. The sample was ethnically diverse, consisting of 36% Caucasians, 27% Asian/Pacific Islanders, 16% Hispanics, 12% African Americans, and 9% others. One-way analyses of variance (ANOVA) and chi-square tests revealed that the three experimental groups were comparable in terms of age, sex, proportion of community participants to student participants, and baseline PA and NA (as assessed with the PANAS). Correspondingly, among the smokers only, no differences emerged between participants in the two nicotine conditions on years smoked, days smoked per week, cigarettes smoked per day, level of nicotine dependence, or perceived harshness and strength of the experimental cigarettes, although smokers did rate the HY cigarettes as slightly more pleasant than the DN cigarettes (p < .05; cf. Juliano & Brandon, 2002). Moreover, as previously reported (Kassel et al., 2007), those who smoked the DN cigarette took more puffs per cigarette relative to those in the HY nicotine condition (p < .05, ηp² = .11).3 Both nicotine groups evidenced similar scores on the NAM and BR smoking expectancy subscales.

Taken together, then, our sample was made up of smokers who smoked an average of 20 cigarettes a week and had been smoking for just over 2 years. Their scores on the MFTQ were also indicative of very low levels of nicotine dependence (M = 2.15, SD = 0.33). Finally, analyses revealed no differences among the community and college student participants in terms of age (ηp² = .01), sex (ηp² = .01), how many days a week they smoked (ηp² = .03), number of cigarettes smoked per day (ηp² = .06), or emotional responsivity with respect to change in NA (ηp² = .03) and PA (ηp² = .04). Thus, the study sample included young, relatively light smokers and comparably matched—in terms of demographics and baseline affect ratings—nonsmokers.

CO Manipulation Check

To ascertain whether smokers and nonsmokers could be differentiated on the basis of their expired air CO scores, we conducted a one-way ANOVA on baseline CO levels across the three experimental groups. Results indicated a significant effect, F(2, 69) = 12.48, p < .001 (ηp² = .26). Post hoc testing revealed that whereas participants in both nicotine conditions exhibited comparable baseline COs (HY, M = 8.5, SD = 1.52; DN, M = 10.33, SD = 1.80), smokers evidenced significantly higher COs relative to nonsmokers (M = 1.70, SD = 1.16), n(69) = −4.52, p < .001. We then assessed whether participants in the two nicotine conditions experienced comparable boosts in CO as a result of smoking a cigarette. Results of a 2 (HY vs. DN) × 2 (time: pre- vs. postcigarette CO) repeated measures ANOVA revealed a main effect for time, F(1, 44) = 135.40, p < .001 (ηp² = .76; indicating that all smokers had, indeed, inhaled smoke from the cigarette), and a near significant trend for the Time × Nicotine condition, F(1, 44) = 3.66, p = .06 (ηp² = .08), suggesting that those who smoked the DN cigarette manifested slightly greater CO boosts (M = 9.50, SD = 4.72) than did those who smoked the HY cigarette (M = 6.82, SD = 3.76). Because those participants who smoked the DN cigarette took more puffs per cigarette than those who smoked the HY cigarette (see Kassel et al., 2007), the marginal group differences in CO observed in the present study may be attributable, at least in part, to group differences in puffs per cigarette. However, inclusion of puff number as a covariate in this same analysis yielded little effect on outcome, F(1, 43) = 3.10, p < .09 (ηp² = .07).

Correlational Analyses

We next proceeded to conduct correlational analyses among the primary study variables (see Table 2). For the purposes of these analyses only, we created a proportion-of-change score for both PA and NA, respectively, by subtracting Time 1 affect scores from

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2 As described in Kassel et al. (2007), we assessed several smoking topography indices, including number of puffs per cigarette, puff volume, puff duration, interpuff interval, and maximum flow rate (velocity) per puff. Significant group differences (between the DN and HY cigarettes) emerged for total puff number, total interpuff interval, and total flow rate. However, the latter two indexes reflect the more important differences observed in total puff number. Hence, only puff number is incorporated into the present article. Also, 10 additional participants are included in the analyses described herein.

3 We report partial eta-squared effect size estimates to document the magnitude of theoretically and/or clinically meaningful effects—ηp² = SS_effect/(SS_effect + SS_error); they yield estimates comparable to a squared partial correlation from multiple regression models. Cohen (1992) has defined squared partial correlations of .02, .15, and .35 as small, medium, and large effects, respectively.
Time 2 scores and dividing by the Time 1 score (see Blumenthal, Elden, & Flaten, 2004). Several interesting findings emerged. First, craving was significantly correlated with nicotine dependence (MFTQ), NA management expectancies (NAM), boredom relief expectancies (BR), CO boost, and change over time in NA. Moreover, the MFTQ demonstrated significant correlations with recency of smoking (the more dependent the participant was, the more recently he or she had smoked), number of cigarettes smoked on the study day, and NA management expectancies. Taken together, these findings are compelling and suggest that, even among these young and light smokers, signs and symptoms of nicotine dependence (albeit at low levels) were evident and correlated in meaningful ways with other dependence-related constructs. For instance, the positive association between the MFTQ and NAM may not be particularly surprising, as there is ample reason to believe that smoking to relieve NA is the most predominant attribution made by smokers (Kassel et al., 2003) and can actually serve as a marker of nicotine dependence in itself (Shiffman, 1993; Wahl et al., 2005). What is of great interest, though, is the emergence of these associations in such light smokers.

Interestingly, and consistent with the findings above, we observed that recency of smoking was positively correlated with baseline NA, such that the longer it had been since a participant smoked, the greater was his or her baseline NA. Increases in CO
attributable to smoking in the lab also proved important, as such boosts were related to (a) number of cigarettes smoked on the study day (the more cigarettes the participants smoked—perhaps indicative of dependence—the greater was the CO increase) and, in a somewhat paradoxical fashion, (b) recency of smoking, such that the more recently one had smoked—again, perhaps reflecting degree of dependence—the greater was his or her CO boost. Finally, it is important to note that baseline NA was related to subsequent change in NA. As was observed with baseline craving, higher levels of initial NA were associated with larger decreases in NA over time, suggesting that the greater the baseline NA was, the more motivated the person was to smoke, resulting in a larger pre cigarette—postcigarette decline in NA.

All in all, these findings provide reassuring validity data regarding the MFTQ as a measure of nicotine dependence in young smokers. Scores on this measure were significantly correlated with recency of smoking, expectation of negative reinforcement, and craving scores and predicted which smokers would experience the greatest relief of NA in response to smoking an HY cigarette. Hence, these correlational analyses appear to organize important data relevant to smoking motivation in these young, light smokers.

Analyses Assessing Change in PA and NA

To determine whether the three experimental groups varied in their change in affect over time, we conducted separate 3 (group: nonsmokers, HY smokers, and DN smokers) × 2 (time: PANAS 1 vs. PANAS 2) mixed model ANOVAs on PA and NA, respectively. Results from the PA ANOVA revealed a significant main effect for time, F(1, 69) = 33.58, p < .001 (ηg 2 = .33), as well as a significant Group × Time interaction, F(2, 69) = 8.95, p < .001 (ηg 2 = .21). These effects are depicted in Figure 1. Averaged across all experimental groups, PA decreased significantly from Time 1 to Time 2. Post hoc tests of the observed interaction effect revealed that among nonsmokers, there was no change in NA, F(1, 26) = 0.07, p = .80 (ηg 2 = .00). Whereas participants in the HY nicotine condition experienced a significant decrease in NA, F(1, 21) = 8.60, p = .008 (ηg 2 = .29), those in the DN condition evidenced a nearly significant drop in NA, F(1, 22) = 3.90, p = .06 (ηg 2 = .08).

Given the observed strong associations between baseline craving and smoking expectancies, CO boost, nicotine dependence, and change in NA, we reran these same analyses on change in NA among smokers only, including craving as an independent variable. Results revealed that, whereas no significant Group × Time interaction was evident, F(1, 41) = 0.00, p = .99 (ηg 2 = .00), a significant Craving × Time interaction did emerge, F(1, 41) = 8.57, p = .006 (ηg 2 = .17), as well as a significant three-way (Craving × Time × Group) interaction, F(2, 41) = 4.29, p = .02 (ηg 2 = .17). Follow-up tests showed that among those who smoked the HY cigarette, a Craving × Time interaction was evident, F(1, 19) = 7.49, p < .02 (ηg 2 = .28), indicating that greater NA reduction was observed among those who reported high craving. Among the DN smokers, no such interaction effect was observed, F(1, 21) = 1.81, p > .10 (ηg 2 = .11).

In summary, for nonsmokers, their affect (both PA and NA) tended to be quite stable over the 10-min time period. Smokers, however, experienced significant reductions in PA, regardless of the nicotine content of their cigarette. Smokers in the HY condition also experienced significant decreases in NA, whereas those who smoked the DN cigarette evidenced a nearly significant drop in NA. However, these observed effects with respect to change in NA were clearly influenced by levels of baseline craving, particularly among those who smoked the HY cigarette.

The Relation of Nicotine Dependence and Smoking Expectancies With Change in PA and NA

To further explore the observed findings with respect to nicotine’s effects on both PA and NA, we proceeded to conduct several moderation analyses. We dichotomized (via median splits) the nicotine dependence and smoking expectancy scores to determine whether the relationship between change in affect and nicotine yield differed as a function of these potential moderating variables. Thus, we ran a series of mixed model ANOVAs in which PA and NA, respectively, at Times 1 and 2 served as the within-subject, repeated measures variables and

\[ \eta^2_g = .59 \]. Thus, regardless of the nicotine content of the cigarette, all smokers experienced significant reductions in PA.

Identical analyses were run on change in NA and resulted in a significant main effect for time, F(1, 69) = 8.68, p = .004 \( \eta^2_g = .21 \), as well as a marginally significant Group × Time interaction, F(2, 69) = 2.92, p = .06 \( \eta^2_g = .08 \); see Figure 2. Thus, averaged across all three experimental groups, NA significantly fell from Time 1 to Time 2. However, post hoc tests of the observed interaction effect revealed that among nonsmokers, there was no change in NA, F(1, 26) = 0.07, p = .80 \( \eta^2_g = .00 \). Whereas participants in the HY nicotine condition experienced a significant decrease in NA, F(1, 21) = 8.60, p = .008 \( \eta^2_g = .29 \), those in the DN condition evidenced a nearly significant drop in NA, F(1, 22) = 3.90, p = .06 \( \eta^2_g = .08 \).
the MFTQ, NAM, and BR served as the respective predictor variables (with nicotine condition—i.e., group—entered into all models). Results for the three PA analyses revealed no significant main or interaction effects (all $\eta^2_p < .07$).

With respect to change in NA, BR was not a significant predictor of change, nor did it interact with nicotine condition to predict change (all $\eta^2_p < .02$). However, analyses of both the MFTQ and the NAM yielded significant findings. Regarding the MFTQ, a significant MFTQ × Group × Time interaction emerged, $F(1, 41) = 4.12, p < .05$ ($\eta^2_p = .09$). As can be seen in Figure 3, those who scored high on the MFTQ and who smoked the HY cigarette derived the largest reduction in NA, $F(1, 11) = 13.55, p = .04$ ($\eta^2_p = .55$). By contrast, those with high MFTQ scores who smoked the DN cigarette experienced no significant change in NA, $F(1, 10) = 1.12, p > .30$ ($\eta^2_p = .10$). Thus, among those in the high MFTQ group, significant differences were detected between the HY and DN cigarette conditions, $F(1, 21) = 4.79, p = .04$ ($\eta^2_p = .19$). Among those in the low MFTQ group, no differences in NA across time were observed between the two cigarette conditions ($\eta^2_p = .05$).

Regarding the influence of NAM on change in NA, a significant NAM × Group (nicotine condition) × Time interaction was similarly evident, $F(1, 41) = 10.34, p = .003$ ($\eta^2_p = .20$). Inspection of Figure 4 reveals that, comparable to what was observed with the MFTQ analyses, those who scored high on the NAM (i.e., held strong beliefs that smoking relieves NA) and who smoked the HY cigarette derived the largest reduction in NA, $F(1, 11) = 17.29, p = .002$ ($\eta^2_p = .61$). Those with high NAM beliefs who smoked the DN cigarette derived no significant reduction in NA, $F(1, 11) = 0.16, p > .70$ ($\eta^2_p = .01$). Hence, among those in the high NAM group, significant differences were observed between the HY and DN cigarette conditions, $F(1, 22) = 9.95, p = .005$ ($\eta^2_p = .31$). Examination of those participants in the low NAM group revealed a marginally significant interaction effect, $F(1, 19) = 3.18, p = .10$ ($\eta^2_p = .14$), such that low NAM smokers derived a slightly greater reduction in NA when smoking a DN cigarette, $F(1, 10) = 4.37, p < .07$ ($\eta^2_p = .30$), relative to the HY cigarette, $F(1, 9) = 0.02, p > .80$ ($\eta^2_p = .00$).

**Discussion**

Despite the fact that adolescent smoking continues to pose a serious public health concern, relatively little is known about the motivational processes governing smoking initiation and subsequent development of nicotine dependence. Moreover, although a burgeoning literature suggests that many adolescents attribute their smoking to its alleged ability to facilitate affect regulation (e.g., Johnson et al., 2003), we are unaware of any previous controlled laboratory studies that have assessed the acute effects of smoking (or nicotine) on emotional response in this vulnerable population. As such, the current study represents the first to examine the effects of nicotine on both PA and NA in adolescents.

Our findings provide persuasive evidence that smoking a cigarette reduces NA in adolescents. It is important to note, however, that the extent of that observed reduction appears to be dependent on several key factors, including the nicotine content of the cigarette, level of dependence, level of baseline craving, and smoking expectancies. In light of the fact that demonstration of NA reduction attributable to smoking and/or nicotine has certainly proven difficult in older, more dependent smokers (see, e.g., Conklin &
Perkins, 2005; Kassel et al., 2003)—findings that ultimately cast doubt on negative reinforcement models of drug motivation—the present results, obtained in young, relatively light smokers, are most compelling. Moreover, our findings strongly suggest that the observed NA reduction may be due, in great part, to alleviation of withdrawal symptomatology. Indeed, implication of withdrawal is supported by the association of NA reduction with nicotine dependence and baseline craving. Hence, such observations are important in that they provide evidence that even neophyte, light smokers may experience significant levels of nicotine dependence and may be more motivated to smoke for withdrawal relief than might once have been supposed (see Kassel, 2000). Finally, it is important to note that the extant literature implicating nicotine dependence in young smokers rests almost entirely on questionnaire studies, not real-time reactions to smoking under relatively controlled conditions.

On the Specificity of Affect

The findings are, in many respects, both interesting and perplexing. First, we observed that all smokers, regardless of whether they smoked an HY or a DN nicotine cigarette, experienced reductions in both PA and NA. It is important to note, however, that nonsmokers experienced virtually no change in PA and NA across the same 10-min time period. Thus, the notion that affect (be it positive or negative) simply drifts downward over time can probably be ruled out. The findings nonetheless raise the question of how a drug could reduce both PA and NA simultaneously. As noted earlier, some comfort can be derived from influential conceptualizations of affect asserting that PA and NA are independent constructs, not simply opposite ends of a bipolar continuum (Watson & Tellegen, 1985; see also Perkins, Jetton, & Keenan, 2003, for an interesting discussion of these issues within the realm of nicotine research). Indeed, the observed correlation between baseline PA and NA in our study was 0.1. When viewed in the context of such theoretical and applied levels of analyses, the pattern of findings observed in the present study is perhaps less disconcerting than at first glance.

In sum, regardless of the nicotine content, smoking a cigarette appeared to reduce both NA and PA in adolescent smokers. The fact that smoking assuaged NA is, indeed, consistent with the majority of self-report studies assessing smoking motives among adolescent smokers (e.g., Dozois et al., 1995; Johnson et al., 2005). As noted earlier, however, there are scant data with respect to determining the influence of smoking and nicotine on PA in adult smokers, let alone adolescent smokers. It is conceivable that, in concert with reports indicating that early experiences with smoking are often perceived as aversive (Eissenberg & Balster, 2000), certain aspects of smoking may genuinely diminish feelings of PA. It is also worth noting, though, that PA, as measured by the PANAS, contains only high-activation (arousing), positively valenced items (Watson et al., 1988). Therefore, it is plausible that the reduction in PA observed in the present study among those who smoked either HY or DN cigarettes may, in fact, reflect an increase in low-arousal aspects of PA (e.g., relaxation or calm). Such an interpretation would certainly be consistent, again, with a wealth of self-report data suggesting that smokers find smoking relaxing (Dozois et al., 1995; McNeil et al., 1987). Yet another possibility is that the smokers simply did not like the research cigarettes very much and that this experience influenced their experience of PA (but less so NA). At odds with such an idea, however, are findings from correlational analyses revealing no association between the cigarette ratings (harshness, strength, and pleasantness) and PA (all rs < .15).

Finally, although the PA–NA model views PA and NA as separate constructs, it still subsumes a variety of aversive affective states (e.g., anger, contempt, and nervousness) under the rubric of NA and a host of positive affective states (e.g., excited, enthusiastic, and inspired) under the rubric of PA (Watson et al., 1988). The basic emotions viewpoint posits a discrete number of evolutionarily derived and biologically based emotional states (e.g., happiness, sadness, anger, disgust, and fear), in lieu of two overarching affective dimensions (e.g., Ekman, 1984; Johnson-Laird & Oatley, 1992). Indeed, there is growing evidence in support of basic-emotion-specific brain activity (Murphy, Nimmo-Smith, & Lawrence, 2003; Phan, Wager, Taylor, & Liberzon, 2004). This raises the intriguing possibility that diverse drugs of abuse, including nicotine, may differentially affect these distinct emotion substrates. Therefore, one implication for future drug research is that it examine the effects of drugs, such as nicotine, on basic emotions rather than limiting its scope to the broader constructs of NA and PA (see also Barrett, 2006; Russell, 2003).

The Moderating Role of Nicotine Dependence and Smoking Expectancies

Our findings revealed that regardless of the nicotine content of the cigarette smoked, all participants experienced reductions in both PA and NA. It is true that with respect to NA, those who smoked the DN cigarette experienced only a nearly significant decline (r^2 = .08) in NA. Nonetheless, we do not want to hold too rigid an interpretation of this finding. One implication of these results is that the act of smoking a cigarette alone may account for its effects on emotional response. This may be particularly true for adolescent smokers, many of whom have perhaps not yet progressed to nicotine dependence (although see DiFranza et al., 2000). Correspondingly, the DN cigarette might have acted as an effective placebo (cf. Robinson, Houtsmuller, Moolchan, & Pickworth, 2000), such that the very belief that one was smoking a normal cigarette yielded changes in affect comparable to those derived from the HY cigarette. (Remem er that participants’ ratings of cigarette strength and harshness did not differ across nicotine conditions).

In addition, as noted earlier, the expectations one holds for drug effects can, in themselves, influence the actual derived effects (e.g., Hull & Bond, 1986; Juliano & Brandon, 2002). Therefore, we were interested in examining whether expectancies related to nicotine’s effects on affect regulation—in this instance, boredom relief and NA management—might yield independent or interactive effects on PA and/or NA. We were similarly interested in assessing whether nicotine dependence also acted as a moderator. Our thinking was that as individuals approach or have reached a state of nicotine dependence, they may be motivated to smoke to stave off or escape aversive symptoms of nicotine withdrawal (e.g., negative affect; see Baker et al., 2004).

Our results showed that none of the assessed independent variables influenced PA either directly or in interaction with nicotine yield. However, several interesting findings emerged with respect
to change in NA. Those who both held strong beliefs that smoking facilitates NA management and smoked the HY cigarette experienced the greatest reductions in NA. By contrast, if smokers held relatively low expectations that smoking assuages NA and smoked the HY cigarette, they experienced no meaningful change in NA. A similar patterning of findings was found for the MFTQ measure. Those who were more nicotine dependent and who smoked the HY cigarette experienced the largest reductions in NA. Last, baseline craving similarly emerged as a predictor of subsequent reductions in NA among those who smoked the HY cigarette.

Again, given that, as far as we are aware, this is the first study to examine the acute effects of nicotine on self-reported affect in adolescent smokers, these findings certainly need to be replicated. Nonetheless, the observation that nicotine dependence, craving, and expectancies of NA management all exerted a significant influence on reducing NA only among those who smoked the HY nicotine cigarette is most interesting. One interpretation is that, on the basis of prior experience and learning—limited though it might have been in this sample of young, light smokers—these adolescents have come to pair the experience of smoking nicotine cigarettes with NA reduction (which, in turn, might have helped to shape their NA management expectancies). As such, they benefited from this reduction in NA only when they smoked the cigarette containing a pharmacologically active dose of nicotine and held high expectancies for NA reduction.

Finally, the findings from this study may, perhaps, be most parsimoniously interpreted within a withdrawal-relief framework (Baker et al., 2004; Kassel et al., 2006). Hence, it is conceivable that the smokers were in a state of mild withdrawal when allowed to smoke—an idea not inconsistent with their self-reports of craving (mean score of 25.5, with a range of 13–37)—and that what was observed (at least with respect to NA) was indicative of withdrawal relief resulting from smoking a cigarette. Indeed, dependence—even low levels, as evidenced in this sample of very light smokers—may be related to the tendency to experience more severe withdrawal, as manifested by craving (Baker et al., 2004). As such, the presence of craving might be associated with greater NA reduction among such smokers. Consistent with such an interpretation are the findings that craving was significantly correlated with subsequent change in NA (r = −.38) and that when it was included as an independent variable, craving predicted downward shifts in NA. Moreover, baseline NA, although only modestly associated with craving, was also significantly correlated with subsequent reduction in NA (r = −.49).

In addition, it is important to note that the causal pathways underlying any predictors or moderators of the observed reduction in NA warrant further empirical scrutiny. For example, we observed that NA regulation expectancies moderated the reduction in NA but did so only in response to smoking an HY, versus a DN, cigarette. The question arises as to why such expectancies did not also exert their effects through a placebo (DN) cigarette. Perhaps the answer lies in the manifest correlations among NA management expectancies, craving, and nicotine dependence. That is, it is possible that some of the association of these expectancies with NA reduction was really due to their shared variance with dependence and consequent withdrawal influences. Further research with larger numbers of young smokers is clearly needed to elucidate such motivational pathways.

Methodological Considerations

Several limitations of the study need to be acknowledged. First, we used a between-subjects design, such that each participant was exposed to only one of the two nicotine conditions. A more statistically powerful approach would use a repeated measures, within-subject design, which ultimately allows participants to act as their own control. Second, participants were asked to smoke a research cigarette provided to them by the experimenter in lieu of smoking their own typical brand. In concert with the artificiality of the laboratory environment as well as smoking the cigarette through a mouthpiece, this approach might have weakened the ecological (external) validity of our findings. Third, those in the HY condition rated their cigarettes as more pleasant relative to those who smoked the DN cigarettes. Whereas this finding is certainly not without precedent (Juliano & Brandon, 2002), it does reflect an inherent limitation in the use of placebo cigarettes.

It is also important to note that, because the adolescents in this study were such light smokers, we did not control for time since last cigarette. Thus, whereas one would typically attempt to standardize potential withdrawal-related motivation to smoke among heavier, adult smokers, we did not feel it necessary to do so with this particular sample. Moreover, we feared that we were to ask subjects to smoke on their arrival at the laboratory and then smoke again, for instance, 50 min later (cf. Kassel & Shiffman, 1997), we would risk inducing aversive reactions to smoking. However, we did assess length of deprivation and found it to correlate in meaningful ways with nicotine dependence (r = −.40) and baseline NA (r = .34).

Finally, inclusion of a no-smoke condition for the smokers would ultimately make comparisons between the nonsmokers and smokers more meaningful. As it is, we can only conclude that whereas the nonsmokers experienced no change in either PA or NA, the smokers did, regardless of the nicotine content of the cigarette. Thus, although our results may be interpreted as suggestive of smoking effects, they do not constitute conclusive evidence. Of course, it is always possible that some other, unmeasured variable may differentiate smokers from nonsmokers and account, at least in part, for the observed differences in affective outcome. Yet some reassurance can be taken from the findings that no differences emerged between the smokers and nonsmokers on baseline measures of affect, despite the fact that, at least among adults, smokers typically evidence more affective distress in general relative to nonsmokers (Lasser et al., 2000).

Summary

In the first study to assess the acute effects of nicotine on affect in adolescent smokers, it was found that smoking a cigarette—regardless of the nicotine content—led to reductions in both PA and NA. The most marked reductions in NA, however, were observed among those who smoked the HY cigarette. Nonsmokers, who served as a comparison control group, evidenced no change in affect. It is important to note that NA management expectancies as well as nicotine dependence emerged as modera-
tors of these effects. Moreover, baseline craving levels were also associated with subsequent declines in NA directly attributable to nicotine. Although we acknowledge that conducting laboratory research with adolescent smokers presents daunting pragmatic, ethical, and even legal challenges, such research is nonetheless critical to shedding light on the underlying reinforcing mechanisms governing adolescent cigarette smoking. This study represents a first step in what we hope will prove to be a long line of research aimed at better understanding the affective determinants of smoking in this vulnerable population. In sum, a far more systematic and theory-based approach to delineation of smoking–affect relationships is needed (see Kassel et al., 2006). Such an approach not only will help clarify these complex associations but will also inform the prevention and intervention efforts that are so sorely required to stem the tide of adolescent smoking.

References


