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Nicotine-dependence-varying effects of smoking events on momentary mood changes among adolescents

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HIGHLIGHTS

- Smoking results in higher positive affect at low-to-medium nicotine dependence.
- Smoking results in lower negative affect only at very low nicotine dependence.
- Smoking does not result in affect changes at high levels of nicotine dependence.
- Role of positive reinforcement in early stages of addiction is supported.
- Role of negative reinforcement at later stages of addiction is not supported.

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ABSTRACT

Introduction: Theories of nicotine addiction emphasize the initial role of positive reinforcement in the development of regular smoking behavior, and the role of negative reinforcement at later stages. These theories are tested here by examining the effects of amount smoked per smoking event on smoking-related mood changes, and how nicotine dependence (ND) moderates this effect. The current study examines these questions within a sample of light adolescent smokers drawn from the metropolitan Chicago area (N = 151, 55.6% female, mean 17.7 years).
Instruments: Ecological momentary assessment data were collected via handheld computers, and additional variables were drawn from a traditional questionnaire.
Methods: Effects of the amount smoked per event on changes in positive affect (PA) and negative affect (NA) after vs. before smoking were examined, while controlling for subject-averaged amount smoked, age, gender, and day of week. ND-varying effects were examined using varying effect models to elucidate their change across levels of ND.
Results: The effect of the amount smoked per event was significantly associated with an increase in PA among adolescents with low-to-moderate levels of ND, and was not significant at high ND. Conversely, the effect of the amount smoked was significantly associated with a decrease in NA only for adolescents with low levels of ND.
Conclusions: These findings support the role of positive reinforcement in early stages of dependent smoking, but do not support the role of negative reinforcement beyond early stages of smoking. Other potential contributing factors to the relationship between smoking behavior and PA/NA change are discussed.

1. Introduction

Cigarette smoking poses a significant threat to public health as the primary cause of preventable deaths in the U.S. (Armour, Woolery, Malarcher, Pechacek, & Husten, 2005; Mokdad, Marks, Stroup, & Gerberding, 2004). A major component of cigarettes' widespread negative consequences is their addictiveness. Nicotine dependence (ND) impacts 50% of U.S. adults, and its prevalence has remained stable or even increased over several decades (Goodwin, Keyes, & Hasin, 2009). ND is a

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major factor predicting continued smoking (DiFranza et al., 2002; Ip et al., 2011) and failed quit attempts (Haddock, Lando, Klesges, Talcott, & Renaud, 1999; Piper et al., 2011). Though ND has traditionally been thought to require several years of regular smoking, relatively recent findings have shown that adolescents can experience ND at very light and infrequent smoking (DiFranza et al., 2000; O'Loughlin et al., 2003); this early-emerging ND strongly predicts future smoking behavior (Dierker & Mermelstein, 2010; DiFranza et al., 2002). Understanding the etiology of ND is important for smoking prevention and cessation efforts.

Theoretical work on ND has postulated that positive and negative reinforcements develop and maintain regular smoking behavior (Baker, Brandon, & Chassin, 2004; Tiffany, Conklin, Shiffman, & Clayton, 2004). Initially, the sensory rewards of smoking are thought to contribute to positive reinforcement of smoking (Russell, 1971), and the hedonic effects of nicotine are thought to help establish repeated self-administration of nicotine (Koob, 1996; Wise, 1988). Repeated doses of nicotine, however, lead to tolerance and withdrawal symptoms (Ahmed & Koob, 1998; Baker et al., 2004; Watkins, Koob, & Markou, 2000), triggering the process of negative reinforcement. That is, abstaining from nicotine triggers negative affective states and increased stress responses (Dani & Heinemann, 1996; Koob, 1996; Watkins et al., 2000), and negative reinforcement occurs upon smoking to relieve the resulting withdrawal symptoms (Dani & Heinemann, 1996; Koob, 1996; Russell, 1971; Tiffany et al., 2004; Watkins et al., 2000). Thus, positive reinforcement is thought to contribute to early stages of nicotine addiction, and negative reinforcement is hypothesized to take over as the driving force maintaining addicted, chronic smoking behavior (Russell, 1971; Tiffany et al., 2004).

Ecological momentary assessment (EMA) data is a relatively recently-developed assessment method in which data are collected very close in time to when events occurred, which reduces recall bias (Moskowitz & Young, 2006). EMA is commonly collected via "electronic interviews" on handheld computers, once to several times per day. EMA has been successfully used in several different populations (e.g. healthy adults, children, the elderly, and individuals with depression) (Moskowitz & Young, 2006), and in many smoking studies, examining e.g. affect states (Hoeppner, Kahler, & Gwaltney, 2014), situational risks (Mitchell et al., 2014), and time to lapse (Wilson et al., 2014).

Previous research using EMA data has examined issues related to reinforcement in individual smoking episodes. One study of adolescents found that positive affect (PA) is higher, and negative affect (NA) is lower, after smoking events compared to random non-smoking periods, and that these differences became more consistent for heavier smokers (Hedeker, Mermelstein, Berbaum, & Campbell, 2009). Another study found that smoking is associated with significant increases in PA and decreases in NA, and that these smoking-related mood changes became more consistent as individuals increased their smoking (Hedeker & Mermelstein, 2012). However, these studies evaluated these effects across levels of smoking frequency rather than ND. Thus, these studies do not directly address the role of reinforcement processes in shaping nicotine addiction, since ND can vary greatly across individuals with a given level of smoking frequency. In particular, it is possible that the changing roles of positive and negative reinforcements over stages of addiction may represent moderation of these reinforcement processes by ND.

The current study aimed to test the theories that positive reinforcement decreases, and negative reinforcement increases, with greater ND; that is, that ND is a moderator of these reinforcement processes. This study took advantage of a cohort of adolescents oversampled for novice and light smokers, who provided EMA data on smoking events and PA/NA. Additionally, an innovative varying effect model (VEM) was used, which empirically estimates nonlinear trends in varying coefficients, rather than requiring a specification of a particular type of trend (e.g. linear, quadratic) (Tan, Shiyko, Li, Li, & Dierker, 2012; TVEM SAS Macro Suite (Version 2.1.0) [Software] [Software], 2012; Yang, Tan, Li, & Wagner, 2012). In contrast to most VEM models which traditionally examine time-varying effects (e.g. Selya et al., 2012), this study presents a new application of the VEM to dimensions other than time, namely ND. While time-varying effect models examine the interaction of a variable with time, the current study examines the interaction with ND. This allows the current study's examination of whether the effect of smoking behavior (the amount smoked per self-reported EMA smoking prompt) on smoking-related mood changes (changes in PA and NA after vs. before smoking) differs across the spectrum of ND, such that the effect on PA increases and the effect on NA decreases across participants with greater ND.

2. Methods

2.1. Participants

The sample was drawn from the larger Social and Emotional Contexts of Adolescent Smoking Patterns Study (SECASPS), and was selected as shown in Fig. 1. All 9th and 10th graders at 16 Chicago-area high schools completed a brief screener survey (N = 12,970). Students were eligible to participate in the study if they are classified as: 1) former experimenters (smoked in the last year, but not in the last 90 days, and smoked <100 cigarettes/lifetime); 2) current experimenters (smoked in the past 90 days but smoked <100 cigarettes/lifetime); and 3) regular smokers (smoked in the past 30 days and smoked >100 cigarettes/lifetime). Invitation/recruitment packets were mailed to eligible students and their parents, as well as a random sample of never-smokers (N = 3654). Of those invited and who provided written parental consent and student assent, 1263 (34.6%) completed the baseline measurement wave.

A random subset of the baseline participants also completed the EMA component (N = 461, 36.5%). To be eligible for the EMA, adolescents had to report smoking in the year prior to baseline (N = 947). Ninety-two percent of those invited to participate in the EMA agreed and enrolled. Those who participated did not differ from non-participants on demographics or smoking behavior. Both the EMA component and the traditional (non-EMA) questionnaire took place over several waves spanning 24 months; however, the present study uses only the 24-month assessment, because it contains the widest distribution of ND scores across participants, allowing for more accurate effect estimates.

Of the baseline EMA sample, participants through 24 months (N = 385) relative to those who dropped out by 24 months (N = 76) did not differ by gender, race/ethnicity, age, or GPA at baseline. However, EMA nonparticipation at 24 months was higher among youth whose parent did not complete the extensive parent questionnaire at baseline ($X^2 = 7.97$, d.f. = 1), $p = .005$. EMA non-participants at 24 months also reported a greater number of days smoked in the past 30 days at baseline ($M = 5.1$ days, $SD = 8.81$ vs. $M = 7.8$, $SD = 10.48$; t-test $p = .038$).

The final sample was adolescents who reported at least one smoking event in the 24-month EMA assessment (N = 151), and includes only smoking prompts since change scores in PA/NA are not available for random prompts. Demographic and smoking characteristics of this final sample are shown in Table 1.

2.2. Data collection procedures

At each wave, the traditional survey was given first using paper-and-pencil questionnaires and in-person interviews, and the EMA component was administered the following week. EMA procedures have been described previously (Hedeker, Mermelstein, Berbaum, & Campbell, 2009). Briefly, EMA participants carried a hand-held computer with them at all times for one full week. They were asked to initiate an "electronic interview" immediately after every "smoking event"