Original Investigation

Early tobacco smoking in adolescents with externalizing disorders: Inferences for reward function

Will M. Aklin, Eric T. Moolchan, David A. Luckenbaugh, & Monique Ernst

Abstract

Introduction: Tobacco smoking is the leading preventable cause of mortality in the United States, and 90% of regular smokers initiate smoking before age 18 years. Factors that confer risk for chronic smoking include psychiatric factors, such as externalizing disorders, and potentially related neurobiological substrates, such as reward function. The present study examined the relationship between the externalizing disorders and the temporal progression of smoking among adolescent smokers.

Methods: Data were from 64 adolescents who requested smoking cessation treatment and included information on developmental smoking trajectory, number of cigarettes per day, and Fagerström Test for Nicotine Dependence score. This sample was assessed carefully for psychiatric disorders. Analyses examined the relationships between externalizing psychiatric disorders and smoking trajectory.

Results: Adolescents with an externalizing disorder consumed more tobacco in the first 2 years of smoking than those without a disorder. There were no differences in speed of progression between groups, which may index a distinct functional pattern of reward systems that confers vulnerability for tobacco dependence.

Discussion: These data are discussed in terms of potential predictors of early smoking behavior that can inform interventions for adolescents with externalizing behaviors and tobacco dependence. They also provide some hypotheses for how the development of chronic smoking can be influenced by specific patterns of reward responses.

Introduction

Tobacco smoking remains the leading preventable cause of mortality in the United States (Centers for Disease Control and Prevention [CDC], 2008). Evidence shows that smoking initiation most often occurs during adolescence; 90% of regular smokers started smoking by age 18 (CDC, 2008). Smoking initiation early in life leads to higher degrees of addiction and makes quitting smoking more difficult (Moolchan, Frazier, Franken, & Ernst, 2007). Despite the known consequences associated with smoking, many adolescents continue to smoke. These data highlight the need for public health and clinically based efforts to better understand and curtail early youth smoking behavior.

Researchers have begun to identify factors that shape an adolescent's decision to smoke, including psychosocial and psychiatric factors (Biglan & Severson, 2003; Moolchan, Ernst, & Henningfield, 2000). As a group, externalizing disorders (i.e., conduct disorder [CD], attention-deficit/hyperactivity disorder [ADHD], and oppositional defiant disorder [ODD]) may provide a strong clinical indicator of vulnerability for smoking initiation in adolescence (Elkins, McGue, & Iacono, 2007). Studies have shown that earlier onset of smoking is a greater challenge to smoking cessation among adolescent smokers with psychopathology, particularly disruptive behavioral disorders (Bagot et al., 2007; Moolchan et al., 2007).

Several overarching theories have been developed to explain these associations. The first theory suggests that adolescents with externalizing disorders have a distinct biological vulnerability to engage in and continue to smoke (i.e., mental health disorder leads to smoking; Jessor & Jessor, 1977). Another theory implicates environmental variables as potential mediators

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of the influence of externalizing disorders on smoking behavior (Botvin, 2004). Mostly in reference to ADHD, researchers point to the self-medication model as a possible link between smoking and psychopathology. Specifically, studies have reported that nicotine improved attention and adolescents and adults may use smoking as a way to mitigate attention and arousal deficits (e.g., Whalen, Jamner, Henker, Gehricke, & King, 2003). However, this formulation does not apply to ODD or CD, which do not present specific symptoms related to attention. Overall, adolescents with disruptive behavior disorders are at high risk for preventable tobacco-related health harm, for which early interventions are needed (Moolchan et al., 2007).

From a neural systems perspective, increased risk for tobacco use may reflect a vulnerable reward system in individuals with externalizing behavior problems. The individual's developmental trajectory of smoking may provide valuable information about the contribution of reward function to the initiation of tobacco addiction and to the pathophysiology of externalizing disorders. Particularly, increased smoking consumption without a more rapid progression to dependence in youth with an externalizing disorder, compared with healthy youth, may signal a hyposensitive reward system. Such a pattern would be consistent with the allostatic model of addiction described by Koob (2002). This model is based on the idea of a higher threshold of activity (e.g., set point) of the reward system that necessitates enhanced stimulation to maintain homeostasis. Alternatively, a more rapid progression to tobacco dependence might support the notion of a hypersensitive reward system in which the individual spirals up to higher levels of consumption. A better understanding of the characteristics of reward-related behaviors and susceptibility to tobacco dependence may help to focus hypotheses regarding the neurobiological substrates for the risk of tobacco initiation and progression and their potential interaction with environmental factors in adolescents with externalizing disorders.

Thus, this exploratory study had two goals. The first goal was to investigate the relationship between externalizing disorder status and indices of smoking initiation, including age at first puff, age at first cigarette, number of cigarettes the first day of smoking, and number of cigarettes the first 2 years of smoking. Specifically, we hypothesized that adolescents with an externalizing disorder would evidence earlier smoking initiation and higher intensity of early smoking behavior, compared with adolescents without an externalizing disorder. The second goal was to examine the relationship between externalizing disorders and progression from smoking initiation to daily smoking (i.e., as a behavioral proxy for dependence).

Methods

Participants

A total of 64 adolescent smokers aged 13–17 years from the Baltimore, MD, area were included in the current analysis (for participant demographic characteristics, see Table 1). Participants were selected based on the absence of psychiatric diagnoses other than ADHD, ODD, or CD. Adolescent smokers were recruited from 1999 to 2003 through several forms of advertisement, including radio, television, newspaper, community outreach, and word of mouth. Participants were included in the study only if they reported smoking at least 10 cigarettes/day, scored at least 5 on the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991), reported good general health, and demonstrated motivation to quit smoking (scoring at least 5 on a 10-point scale). The study was approved by the National Institute on Drug Abuse Institutional Review Board. Parents provided consent for their adolescents to participate, and each adolescent signed an assent form after the study was explained fully and all questions answered.

Data collection was undertaken as part of a larger study with two main goals: (a) smoking cessation treatment trial (Moolchan et al., 2005) and (b) the relationship between externalizing disorders and treatment resistance (Bagot et al., 2007). The latter study showed that severity of externalizing symptoms predicted continued smoking despite participation in cessation treatment. The findings from the present study extend to the contribution of psychiatric diagnoses of ODD, ADHD, and CD to the development of tobacco dependence as indexed by changes over time in the number of cigarettes smoked per day over the 2 years following the first puff.

Instruments and procedures

After a brief phone screen, preeligible participants were invited to the clinic for two assessment visits. During the screening visits, participants underwent a physical examination and provided information about their family history and current or past psychiatric disorders.

Psychiatric diagnoses were based on the semistructured, computerized version of the Diagnostic Interview for Children and Adolescents (Reich, 2000), which was administered by a trained interviewer. The Child Behavior Checklist for parental report (Achenbach, 1991) and Youth Self-Report for adolescent self-report (Achenbach & Dumensi, 2001) were used to quantify severity of externalizing symptomatology. Adolescents with and without an externalizing disorder (ADHD, ODD, or CD) were included in the present analysis. Individuals diagnosed with a mood or an anxiety disorder, psychosis, or abuse of substances other than tobacco and marijuana were excluded.

Developmental smoking trajectories, cigarettes per day, and FTND scores were obtained through self-report at the time of treatment request. The FTND is a widely used six-item questionnaire that assesses tobacco dependence and has well-established psychometric properties (Hendricks, Prochaska, Humfleet, & Hall, 2008). Adolescents also provided information about their smoking history (e.g., "How old were you when you smoked your first cigarette?," "How old were you when you took your first puff?," and "At what age did you begin smoking daily?"). They were asked to recall the number of cigarettes they smoked on the first day of smoking and the average number of cigarettes they consumed daily during the first 2 years of smoking. Trained research staff used life events as anchors (e.g., birthday, New Year's, and significant events) to facilitate participants' recall.

Data analyses

Pearson correlations were used to evaluate relationships among (a) number of cigarettes smoked on the first day of smoking, (b) age at first puff, and (c) age at first full cigarette, with the goal of determining whether these early markers were related to later

Table 1. Demographic information and primary variables of interest across externalizing and nonexternalizing groups

	Externalizers (N = 32)			Nonexternalizers (N = 32)			Test statistic		
	Number of subjects	%		Number of subjects	%		χ^2	df	p
Demographics and disorder status									
ADHD	4	13		0	0				
CD	9	28		0	0				
ODD	25	78		0	0				
Gender (% female)	24	75		23	72		0.08	1	ns
Race (% White)	19	59		27	84		4.95	1	.03*
	Number of subjects	M	SD	Number of subjects	M	SD	t		
Smoking indicators									
Age	32	14.94	1.48	32	15.47	1.34	1.50	62	ns
Age at first puff	31	10.10	2.27	26	10.54	2.10	0.76	55	ns
Age at first cigarette	32	10.97	1.98	31	11.61	1.17	1.57	61	ns
Age at daily smoking	31	12.42	1.46	28	12.89	1.26	1.33	57	ns
Age at treatment	31	15.00	1.46	27	15.52	1.28	1.43	56	ns
Cigarettes smoked on first day	32	1.34	0.60	32	1.47	0.72	0.76	62	ns
Cigarettes smoked per day	32	18.66	8.34	32	16.97	5.15	−0.97	62	ns
Years of smoking	32	3.31	1.87	32	2.91	1.42	−0.98	62	ns
Packs of cigarettes per day									
Year 1	31	1.08	0.71	31	0.77	0.51	−1.95	60	ns
Year 2	27	1.28	0.74	28	0.98	0.52	−1.73	53	ns
Year 3	15	1.13	0.69	7	0.93	0.35	−0.73	20	ns
Year 4	16	1.63	0.74	11	1.23	0.26	−1.70	25	ns
Externalizing symptoms and behaviors									
Externalizing symptoms (CBCL)	32	21.31	11.62	32	13.91	9.70	−2.77	62	ns
Externalizing symptoms (YSR)	32	23.66	9.90	32	15.91	6.20	−3.76	62	.00**
Aggressive behaviors (CBCL)	32	14.34	8.36	32	9.16	6.58	−2.76	62	ns
Aggressive behaviors (YSR)	32	15.53	7.43	32	10.09	4.40	−3.56	62	.01**
Delinquent behaviors (CBCL)	32	6.97	4.01	32	4.75	3.76	−2.28	62	.03*
Delinquent behaviors (YSR)	32	8.13	3.42	32	5.81	2.66	−3.02	62	.04*
Self-reported measures of dependency									
Fagerström Test for Nicotine Dependence	32	7.28	1.42	29	6.86	1.06	−1.30	59	ns
Motivation to quit	32	8.89	1.37	32	8.38	1.50	−1.44	62	ns

Note. ADHD, attention-deficit/hyperactivity disorder; CD, conduct disorder; ODD, oppositional defiant disorder; CBCL, Child Behavior Checklist; and YSR, Youth Self-Report.

*p < .05; **p < .01. All test statistics were nonsignificant (ns, p > .05).

smoking (i.e., average cigarettes per day in the first and second years). Group comparisons (externalizers vs. nonexternalizers) were performed using unpaired t tests.

The primary analysis was designed to examine the effect of externalizing diagnosis on the trajectory of cigarettes per day from the first year to the second year of smoking. We created a model looking at time (Year 1 vs. Year 2), externalizing disorders (externalizers vs. nonexternalizers), and their interaction. An analysis of variance (ANOVA) could be used to examine this data but that approach might be inaccurate if variances across or correlations among cells in the model differ (Gueorguieva & Krystal, 2004). Schwarz's Bayesian criteria were used to determine whether compound symmetry (assumed in ANOVA models) or another covariance structure was the best fit to the data. This procedure suggested that a first-order autoregressive covariance structure was the best fit. Since a standard ANOVA was not indicated, we conducted a linear mixed model with restricted maximum likelihood estimation.

A secondary analysis using the same model included covariates to evaluate further the relationship of externalizing diagnosis to later smoking. Only cigarettes per day on the first day of smoking was included because it was the only variable correlated with both first and second year cigarettes per day.

Normality was examined using the Kolmogorov–Smirnov test. Nonnormal data were log transformed. However, since these transformations did not improve the distributions for any variables, the original data were used for all analyses. All p values were two tailed, and the statistical threshold was set at a p level of less than .05.

Results

Preliminary analyses

Descriptive data for demographic variables and primary variables of interest are provided in Table 1. A total of 32 participants

(50% of the entire sample) were diagnosed with an externalizing behavior disorder. The most frequent diagnosis was ODD ($n = 25$, 78%). Four adolescents (13%) met criteria for ADHD; three of those adolescents (75%) also met criteria for ODD. Nine adolescents (28%) met criteria for CD.

Relationship between primary smoking indicators

Table 2 shows the relationships among the measures of early smoking and cigarettes per day. Only the number of cigarettes smoked on the first day of smoking was related to the number of cigarettes smoked per day in the first and second years of smoking. However, age at first puff and first full cigarette was unrelated. We found no statistically significant group (externalizers vs. nonexternalizers) differences on the following variables: (a) number of full cigarettes smoked on the first day of smoking, (b) age at first puff, or (c) age at first full cigarette. Contrary to our hypothesis, these findings suggest that smoking initiation did not start earlier for adolescents with externalizing disorders compared with those without such disorders.

Relationship between externalizing disorders and smoking progression

To examine externalizing group status and progression from smoking initiation to daily smoking (as a behavioral proxy for dependence), we used a linear mixed model (Table 3). The effect of time alone showed a significant increase in smoking from Year 1 to Year 2. As hypothesized, the effect of externalizing disorder alone indicated that participants with an externalizing disorder smoked more than those without an externalizing disorder. However, the interaction between time and group was not significant. This finding indicates that the progression of smoking from Year 1 to Year 2 was similar for the externalizing and nonexternalizing groups, even after controlling for the amount smoked on the first day.

Discussion

The present investigation examined the relationship between the presence of externalizing disorders and the severity of early smoking consumption among adolescents who were seeking cessation treatment. In addition, the pattern of progression of smoking behavior during the first 2 years of smoking could shed some light on the function of the reward system in adolescents with an externalizing disorder. A hypersensitive reward system would lead to quicker progression from initiation to daily smoking, whereas an allostatic model (higher reward threshold)

could underlie a normal or slower progression from initiation to daily smoking combined with heavier cigarette smoking.

Findings confirmed our hypothesis of higher tobacco consumption in externalizer compared with nonexternalizer youth. However, rate of progression to regular cigarette consumption was similar between groups. This pattern of early smoking history that combines higher smoking density without faster progression across stages of addiction suggests a neurobiological model of addiction that may characterize externalizing disorders. An alternative explanation for heavier smoking in adolescents with an externalizing disorder could be self-medication, particularly to remediate attention problems. However, the relatively small proportion of subjects with ADHD in this sample (13%) makes this proposition unlikely. Future work should examine this research question with a larger sample of adolescents across a variety of externalizing disorders.

Two basic types of reward-related mechanisms have been proposed to underlie drug addiction, and these models are based on opposite assumptions. One mechanism describes a hyperactive reward system that results in the search for more rewarding stimuli. The other posits a hypoactive system that requires more reward exposure to maintain homeostasis. The latter model, also called allostatic model, has been proposed by Koob (2002). Such a framework would predict enhanced reward consumption without leading to faster progression across addictive stages (e.g., Koob, 2002; Spear, 2000), which is consistent with the smoking trajectory pattern reported here among adolescents with an externalizing disorder compared with those without such a disorder.

The literature suggests that externalizing disorders may be associated with deficits in reward function. For example, Haenlein and Caul (1987) proposed the idea that ADHD is characterized by a core deficit in motivational processes that affect goal-directed behaviors through delay aversion and enhanced motivation to act (e.g., Castellanos & Tannock, 2002; Ernst et al., 2003; Sonuga-Barke, 2003). With regard to CD, research on reward systems has been directed more specifically toward the overlapping condition of psychopathy. Findings suggest decreased susceptibility to punishment, perhaps resulting from deficits in processing emotional stimuli, particularly negative stimuli like distress cues (Blair, 1999, 2001). Data on sensitivity to rewards are mixed, with some

Table 2. Relationship between primary smoking indicators of interest

	1	2	3	4	5
1. Cigarettes per day (Year 1)					
2. Cigarettes per day (Year 2)	.86**				
3. Cigarettes on first day	.52**	.41**			
4. Age at first puff	−.25	−.13	−.26		
5. Age of first cigarette	−.19	−.15	−.08	.67**	

Note. **$p < .001$. All statistics were nonsignificant ($p > .05$).

Table 3. Linear mixed models examining time by externalizing diagnosis

	Test statistics
Model 1	
Time	$F(1, 54) = 14.20^{**}, d = 1.03$
Externalizing (DICA)	$F(1, 60) = 3.16, d = 0.46$
Time × externalizing	$F(1, 54) = 0.60$
Model 2	
Time	$F(1, 55) = 14.58^{**}, d = 1.03$
Externalizing (DICA)	$F(1, 59) = 5.70^{*}, d = 0.62$
Time × externalizing	$F(1, 55) = 0.61$
Cigarettes smoked on first day	$F(1, 59) = 21.34^{**}$

Note. DICA, Diagnostic Interview for Children and Adolescents.
$^{*}p < .05$; $^{**}p < .001$. All test statistics were nonsignificant ($p > .05$).

work indicating reduced sensitivity to appetitive stimuli (e.g., Blair, 1999) and others reporting increased reward sensitivity (Sharp, van Goozen, & Goodyer, 2006; van Goozen & Cohen Kettenis, 2004). Despite the paucity of literature on reward function in ODD, which predominated in our sample, similar motivational deficits appear to have been identified in this disorder (van Goozen & Cohen Kettenis, 2004). Taken together, these findings indicate that externalizing disorders manifest behavioral signs of altered reward system function.

From a developmental perspective, adolescence is a unique period of peak vulnerability for engaging in substance abuse (Ernst, Pine, & Hardin, 2006; Spear, 2000). Adolescents are at greater risk than adults for initiating substance use and progressing toward dependence (Chambers, Taylor, & Potenza, 2003). This vulnerability for drug addiction may rely on features of reward function similar to those characterizing externalizing disorders. Therefore, examining normative neurodevelopmental changes in reward function may prove helpful to understand mechanisms underlying the liability of externalizing disorders for addiction. Following this idea, neuroimaging studies are beginning to shed light on the neurobiological development of reward function during adolescence (Bjork et al., 2004; Ernst et al., 2005; May et al., 2004; van Leijenhorst, Crone, & Bunge, 2006). These studies may benefit greatly from knowledge about the natural course of early development of reward-related disorders such as substance abuse disorders.

Conclusions from this exploratory work should be drawn with caution. Our ability to generalize the findings is constrained to adolescents who are nicotine dependent and have requested smoking cessation treatment. Although this sample selection prevents us from examining the smoking trajectory in nicotine-dependent adolescents who are not interested in treatment and who might not experience negative effects of smoking, it provides a relatively homogeneous sample, which moderates the reduced statistical power of a small sample.

The generalizability of the present findings also may be limited because externalizing disorders are more frequent among males, and nearly three quarters of both groups were female. Although a large majority of the sample was female, these data are unique in providing important information about an underserved group. Future studies should examine gender differences with regard to reward function and the interaction of reward function with externalizing behaviors and their influence on risk for substance abuse. Such a consideration would help to develop a more comprehensive understanding of the various patterns of smoking behavior across adolescents.

Another limitation is the cross-sectional study design that relied on retrospective self-report of smoking behavior. Although retrospective data are subject to bias or false recall, findings from these studies seem to indicate fairly good recall on specific smoking measures, such as the number of cigarettes smoked per day (e.g., timeline followback; Moolchan et al., 2000). Because of the limited sample size, we could not address the contributions of sex differences and differences among externalizing diagnoses. In addition, we did not examine environmental and familial factors, including smoking behavior. Large longitudinal studies are warranted to address these complex questions adequately. Finally, access and age might have influenced the present findings, insofar as they can constrain how

rapidly some adolescents move on to higher stages of addiction (i.e., they may not have unlimited free access to cigarettes and can smoke only when cigarettes are available).

Taken together, the present findings provide preliminary data that may be useful for informing a priori hypotheses across several areas. First, the function of reward systems in externalizing disorders can be tested further in neuroscience-based studies. Another promising area is the study of the developmental course of nicotine dependence as a function of psychiatric symptoms that can be evaluated longitudinally. Finally, clinical researchers can consider similar studies to better improve the timing for prevention and smoking cessation treatment.

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Declaration of Interests

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