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Identifying and predicting adolescent smokers' developmental trajectories

Warren R. Stanton, Brian R. Flay, Craig R. Colder, Paras Mehta

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Very few studies have defined trajectories of smoking. In the present study, we modeled growth in adolescent smoking and empirically identified prototypical trajectories. We conceptualized escalation of smoking as a growth process and modeled rates of change and heterogeneity of these patterns using latent growth mixture modeling. The analysis identified six trajectories with low ambiguity about group membership (early rapid escalators, late rapid escalators, late moderate escalators, late slow escalators–smokers, stable puffers, and late slow escalators–puffers). A trajectory of quitters was not identified. We also examined predictors of the smoking trajectories. The predictors were assessed across the adolescent years and included variables related to smoking and other substance use, as well as a range of variables related to sociodemographic factors and mental health. Observed change in the pattern of predictors across age has implications for the mechanism of effect of these variables in relation to smoking trajectories, including predictors that differentiated among daily smokers, variables that may determine the trajectory (e.g., friends smoking), and variables that may result from the trajectory (e.g., marijuana use, less attachment to friends).

Introduction

Epidemiological data suggest that smoking is typically initiated and escalates into heavy regular smoking during adolescence (Kandel & Logan, 1984; Stanton, Silva, & Oei, 1991). Most etiological research on adolescent smoking has focused on psychosocial variables that predict initiation or that distinguish smokers from nonsmokers (Mayhew, Flay, & Mott, 2000). These outcomes confound the process of onset and escalation. This is problematic because the predictors of onset and escalation of smoking may be different, which has important implications for intervention, particularly preventive interventions (Maggs, Schulenberg, & Hurrelmann, 1997). For example, results of a few studies that have examined antecedents of different stages of smoking indicate that different predictor variables are associated with trial, experimental, and regular smoking (Chassin, Presson, Sherman, & Edwards, 1992; Flay, Hu, & Richardson, 1998).

A small number of studies have used latent growth mixture modeling to identify trajectories of adolescent smoking. Growth mixture modeling (Muthén & Muthén, 2000; Muthén & Shedden, 1999) is an extension of finite mixture modeling (Duncan & Duncan, 1996; Willett & Sayer, 1994). It allows one to model heterogeneity in growth by identifying homogeneous subgroups based on common growth trajectories. Once the subgroups have been identified, their relationships to other variables (e.g., psychosocial predictor variables) can be examined. That is, latent growth modeling with discrete groups allows one to model developmental processes and to identify multiple etiological pathways to diverse outcomes. Growth mixture modeling was used by Chassin, Presson, Sherman, and Pitts (2000), who identified four trajectories characterized by different combinations of age at onset and rate of escalation between ages 11 and 31 years. These pathways were labeled early-onset stable smoking (i.e., escalation after age 11, maximum level of smoking by age 15), late-onset stable smoking (i.e., escalation after age 14, maximum level by age 24), experimental smokers (i.e., early age

Warren R. Stanton, Ph.D., Centre for Health Promotion and Cancer Prevention Research, and Department of Physiotherapy, University of Queensland, Australia; Brian R. Flay, Ph.D., Health Research & Policy Centers, University of Illinois at Chicago; Craig R. Colder, Ph.D., Psychology Department, State University of New York at Buffalo; Paras Mehta, Ph.D., Psychology Department, University of Houston, TX.

Correspondence: Associate Professor Warren R. Stanton, Centre for Health Promotion and Cancer Prevention Research, School of Population Health, University of Queensland, Herston Road, Herston, Queensland 4006, Australia. Tel.: +(0061) 7-33654557; Fax: +(0061) 7-33652775; E-mail: w.stanton@mailbox.uq.edu.au

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at onset, little escalation), and quitters (i.e., escalation from 14 to 20 years, then a decline). Colder et al. (2001) examined early to middle adolescence (ages 11–16 years) and identified five trajectories based on level of smoking at first assessment, rate of change, and age at inflection (shift in rate of change). These trajectories were labeled early rapid escalators (i.e., escalation occurred relatively early, and rate of escalation was rapid), late moderate escalators (i.e., low level of smoking to age 14, then a moderate rate of escalation), late slow escalators (i.e., puffers until age 15, then a slow escalation), stable light smokers (i.e., one or two cigarettes per month and no escalation), and stable puffers (i.e., a few puffs per month and no escalation). On the basis of the Bayesian information criteria (BICs) and probabilities of class membership, a good fit of the model for the five classes (trajectories) was obtained, and little ambiguity existed about the classes to which smokers belonged.

The goals of the present study were (a) to identify growth trajectories of adolescent smoking or subgroups of smokers based on common patterns of change in smoking, (b) to examine whether psychosocial variables assessed in adolescence discriminate these different developmental patterns of smoking, and (c) to determine whether a quitter group (e.g., nonpersistent smokers) would be apparent in adolescence. Chassin, Presson, Rose, and Sherman (1996) identified quitters based on their young adult data, but whether this pattern would emerge prior to young adulthood is unclear.

Method

Sample

The present sample was selected from the Dunedin Multidisciplinary Health and Development Study, a longitudinal study of a New Zealand birth cohort (Silva & Stanton, 1996). The sample members were born in Dunedin's only obstetric hospital, Queen Mary, between April 1972 and March 1973. Among the 1037 individuals assessed at age 3 years, 96% of the sample were White and 4% were Maori or Polynesian.

Procedures

Confidential interviews about smoking were conducted with participants starting at age 9 years. The present study included data from five assessments of smoking at ages 9, 11, 13, 15, and 18 years. Details of the procedures are found elsewhere (Silva & Stanton, 1996; Stanton, McClelland, Elwood, Ferry, & Silva, 1996; Stanton et al., 1991).

Following the procedure of Colder et al. (2001), we included in the analysis only those smokers for whom we had complete data (306 of the 498 eligible smokers in the study). Chi-square analysis and analysis of variance were used to compare subjects with missing data to those with complete data. Among those who smoked in the past month, no significant differences were found overall between those with or without missing data for the variables used in the multivariate analyses, except at age 15 years those without missing data had lower depression scores ($p < .05$) and fewer changes of address in the past 2 years ($p < .05$). In the total sample, we found no significant differences between those with missing data and those with complete data ($p > .05$) in terms of smoking status. However, participants with missing data reported that their peers were more involved with cigarettes, compared with participants with complete data ($p < .05$). This finding suggests that participants with missing data were at increased risk for smoking, and some caution is warranted when generalizing the current findings.

Measures

Smoking. The number of cigarettes adolescents smoked in the past month was calculated using self-report data, which have been shown to be valid and reliable in this sample (Stanton et al., 1996). Participants were asked to report the number of cigarettes they usually smoked each day or week or month. (Smoking part of a cigarette was coded as "1"). Skewness and kurtosis statistics for the data suggested that the monthly smoking variables were non-normally distributed, particularly in the earlier assessment, and they were transformed using the log transformation as suggested by Neter, Wasserman, and Kuntner (1985) and B. Muthén (personal communication, October 28, 1999).

Predictors. Predictor variables were chosen based on past research with this sample of smokers (Stanton, Silva, & Oei, 1989). Gender and socioeconomic status (Elley & Irving, 1972) were included in all analyses as predictor variables. Participants' reports of the number of days since their last alcoholic drink were dichotomized (yes–no) to reflect drinking in the past 7 days (Casswell, Stewart, Connolly, & Silva, 1991). Mental health variables included the Rutter behavior problem scores (Rutter, Tizard, & Whitmore, 1970), Revised Behavior Problem Checklist (Quay & Peterson, 1987), Family Relations Index (Moos & Moos, 1981), social competence (McGee & Williams, 1991), Diagnostic Interview Schedule for Children (Costello, Edelbrock, Kalas, Kessler, & Klaric, 1982), Life Satisfaction Scale (Williams & McGee, 1996), Attachment Scale (Armsden & Greenberg, 1987), and mother's psychological symptoms, all of which are described in detail

by McGee and colleagues (Feehan, McGee & Stanton, 1993; Feehan, McGee, Williams, & Nada-Raja, 1995; McGee, Feehan, Williams, & Anderson, 1992; McGee et al., 1990; McGee, Kashani, Silva, & Williams, 1983; Nada Raja, McGee, & Stanton, 1992).

Analysis

Only smokers' data were considered for our latent growth mixture models, estimated in Mplus Version 1.04 (Muthén & Muthén, 1998). Several different forms of growth trajectories (i.e., linear, quadratic, and piecewise growth) were fit to the data to model different times and rates of escalation across subgroups of smokers. The piecewise models provided the best fit to the data and the best description of classes. Accordingly, the final mixture models were based on piecewise growth. Piecewise growth models are useful because they describe discontinuity in growth, such as nonlinear growth processes in which the rate of change in the outcome accelerates rapidly at a given time. Our modeling started with one class and added other classes based on different starting points (e.g., early, middle, and late adolescence) and rates of escalation (e.g., slow or rapid escalation). We followed procedures described by Colder et al. (2001) for estimating residuals and constraining parameters. That is, residual variances were estimated to be a function of the mean levels of smoking both within and across classes. We also started with the simple hypothesis that initial levels of smoking and rates of escalation, regardless of when the escalation began, would be the same across classes.

BICs (Schwarz, 1978) were used to evaluate improvement in model fit when additional classes were added. Nagin (1999) demonstrated the usefulness of the BIC in identifying the optimal number of classes in finite mixture models. If addition of a class resulted in a reduction in the model BIC relative to a previous model, then the adjustment was considered an improvement to the model and was retained.

We also present here average probabilities of class membership from our final model. These probabilities provide descriptive information about the uncertainty of classification. For example, in a six-class solution, six probabilities are estimated for each individual in the sample, where each estimates the probability that an individual is a member of one of the classes. For each individual, these probabilities sum to 1.0. Ideally one of these probabilities would be very high (around 1.0) and the others very low (close to 0), indicating little ambiguity about class membership. Poor classification would be indicated by average probabilities in the moderate range (around .5), whereas good classification would be indicated by average probabilities that are close to 0 and one that is close to 1.

For each class, a two-piece growth model was used to describe change in the level of smoking in log scale over the entire study period for all classes. Increases in smoking are described by two line segments, each representing different rates of change for a two-piece growth model. The parameters of interest in a two-piece growth model are (a) level of smoking at the first assessment, (b) rate of change during the first change-segment, (c) age at inflection, or the age at which a shift in the rate of change occurs, and (d) rate of change during the second change-segment. The age at inflection, therefore, demarcates change in the rate of increase for smoking. Change in smoking in one class was described using a three-piece growth model, which included an additional age at inflection and growth segment. The current findings are presented in terms of both the model parameters in log scale and the original metric (i.e., number of cigarettes smoked per month). Additional discussion about the assumptions and technicalities of fitting the models are provided in Colder et al. (2001).

We also were interested in whether prototypical classes (trajectories) of adolescent smokers could be distinguished based on psychosocial risk factors. Accordingly, class membership based on results from our latent growth mixture models was regressed on psychosocial risk factors at each age in separate multinomial logistic regressions. At each respectively later age, variables from the earlier assessments were included as covariates. Variables used as predictors in these multivariate analyses were checked for co-linearity effects.

Results

Model BICs suggested that the six-class model provided the best fit to the data (Table 1). Presented in Table 2 are the average class probabilities by class. Probabilities within each row represent the average probabilities for individuals most likely to be classified in that class. For example, the first row suggests that the probability of being in class 1 for those actually classified in class 1 is high (.889), whereas the probability of being in one of the other classes for these individuals is quite low (ranging from 0 to .097).

Table 1. Bayesian information criteria for mixture models.

Model[a]	Bayesian information criterion
One class	4050.76
Two classes	3076.82
Three classes	3065.56
Four classes	2768.50
Five classes	2634.93
Six classes	2611.07

[a]The seven-class solution did not converge.

Table 2. Average class probabilities for final six-class model.

	Average class probability					
	1	2	3	4	5	6
Class 1	.889	.097	.014	.000	.000	.000
Class 2	.008	.926	.066	.000	.000	.000
Class 3	.003	.110	.867	.020	.000	.000
Class 4	.000	.000	.026	.872	.000	.102
Class 5	.000	.000	.000	.000	.981	.019
Class 6	.000	.000	.007	.016	.044	.933

This pattern is true for each of the classes (for each row), which suggests the six-class solution provided good classification of individuals.

Parameter estimates in log scale from the six-class solution are presented in Table 3. The means suggested slow escalation during the first three assessments and rapid escalation between assessments 3 and 5 (ages 15 and 18 years). Five of the six identified trajectories (classes) were modeled using a two-piece growth model. These classes had a single age at inflection and two separate rates of change. For a single class (late moderate escalators), rate of change was allowed to change twice—once at age 13 and again at age 15. The age at inflection was 13 years for three classes. Of these, the rate of change in the second segment for the late rapid escalators was very high. The rate of change for the late moderate escalators was relatively lower, with an additional escalation occurring at age 15. The rate of change for the late slow escalators–puffers was very low. Before the inflection age for each trajectory, mean smoking rates estimated in the model were low owing to the variable number of nonsmokers at respective ages.

Figure 1 shows the expected level of smoking in the original metric scale. As expected, conversion of the scale of the outcome from log scale to original scale resulted in nonlinear trajectories, particularly for the escalating classes. (Note that the scale of the *y*-axis does not enable depiction of the relative slopes of the trajectories.) Findings suggested two rapid escalating classes of smokers: An early rapid escalator class, which on average exhibited escalation after age 11 that accelerated at age 13 and again at age 15, and a late rapid escalator class, which on average exhibited some escalation after age 13 that accelerated after age 15. Both of these groups typically smoked more than 335

Table 3. Growth factor means (in log-transformed metric) for each smoking group.

	Rate of change				
Smoking group	Intercept	First piece	Second piece	Third piece[b]	Age at inflection (years)[a]
Early rapid escalators	.03*	.18	.78*	NE	11
Late rapid escalators	.03*	−.01	1.17*	NE	13
Late moderate escalators	.03*	.01	.67*	.29	13 and 15
Late slow escalators (smokers)	.03*	−.01	.72*	NE	15
Stable puffers	.17	−.01*	−.01*	NE	NA
Late slow escalators (puffers)	.03*	−.01	.08*	NE	13

[a]NA, not applicable (there is no age at inflection for stable puffers, the class with relatively flat rates of change).
[b]NE, not estimated (for the five classes that had a single age at inflection and two-piece growth).
*$p < .05$.

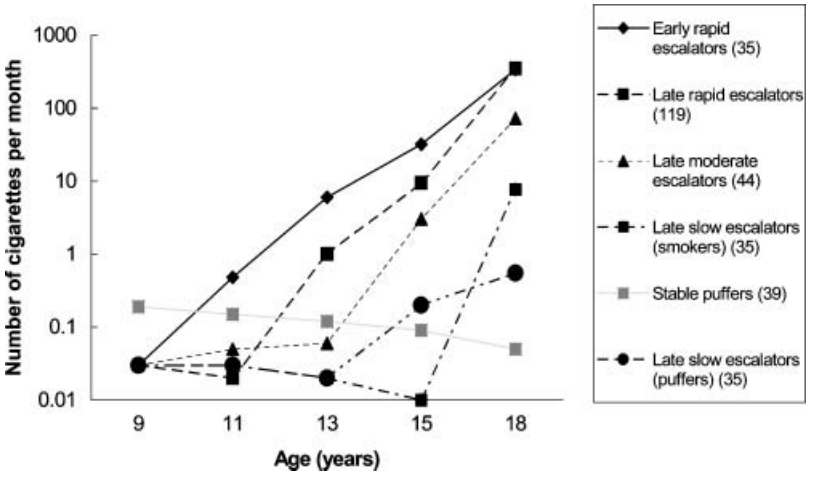

Figure 1. Average monthly smoking levels across age for six classes of smoking trajectories. Group sizes are indicated in parentheses in the legend.

cigarettes per month by age 18. A late moderate escalator group also was identified. Smoking in this class was typified by low initial levels (a couple of puffs per month) and moderate escalation after age 15 to smoking approximately 73 cigarettes per month by age 18. Two late slow escalating classes were evident. The typical pattern of smoking for the late slow escalating–smokers class was very light smoking (a couple of puffs per month) until age 15, when smoking escalated to 7.74 cigarettes per month at age 18. The typical pattern for the late slow escalators–puffers group was characterized by slow escalation in puffing that did not escalate beyond .55 cigarettes per month. The final class, stable puffers, was characterized by occasional puffing across the study period. This group was characterized by variation across age in terms of whether individuals had smoked in the past month and, hence, had low average levels of smoking. The predicted frequencies showed that, among adolescent smokers, late rapid escalators represented the largest group (Figure 1).

Predictors of smoking trajectories

The predictors of the smoking trajectories are shown in Tables 4 and 6. The risk category nominated in these tables is the expected direction of the effects based on the literature. Among the smoking and substance use variables (Table 4), intention to smoke was a predictor at an early age. By age 13, friends smoking was a predictor of adolescents' trajectories. Later marijuana use and conforming to parental smoking status by age 18 also were related to the smoking trajectories. Notably, alcohol use did not predict the patterns of smoking and smoking did not conform to patterns of later alcohol use. The pattern of odds ratios shown in Table 5 indicates which trajectories are distinguished by these predictors. Whether the odds ratio is greater or less than 1 indicates the direction of the effect: Those greater than 1 indicate that higher levels of the predictor variable are associated with the nominated risk category shown in the tables. The variable of intention to smoke relates differently across age, identifying the light smokers at age 9 (early rapid escalators less likely than late slow escalators–puffers to intend to smoke; $OR = .24$) and the heavy smokers at age 13 (early rapid escalators 7.28 times more likely than late rapid escalators but late rapid escalators .18 times less likely than late slow escalators–smokers to intend to smoke), and separating the majority of the smoking trajectories at age 15. In general, at age 13, friends smoking

Table 4. Smoking and substance use predictors[a] of adolescent smoking trajectories (maximum likelihood multivariate logistic regression).

Variables	Risk category	Percentage in risk category	χ^2
Gender	Male	45.4	4.6
Age 9 years ($n=268$)			
Intention to smoke later in life	Yes	11.1	11.1*
Mother smokes	Yes	48.8	.9
Father smokes	Yes	38.9	7.1
Number of friends who smoke (0–4)[b]	More	23.7[c]	3.3
Drank alcohol in past month	Yes	52.2	4.0
Age 11 years ($n=268$)			
Intention to smoke later in life	Yes	8.2	2.6
Number of friends who smoke (0–5)[b]	More	38.6[c]	9.1
Drank alcohol in past month	Yes	47.1	7.6
Intention to get drunk later in life	Yes	22.9	10.5
Age 13 years ($n=268$)			
Intention to smoke later in life	Yes	14.4	12.1*
Mother smokes	Yes	33.0	6.6
Father smokes	Yes	34.6	5.8
Number of friends who smoke (0–4)[b]	More	48.4[c]	20.5**
Drank alcohol in past month	Yes	53.1	5.4
Intention to get drunk later in life	Yes	12.8	8.1
Age 15 years ($n=292$)			
Intention to smoke later in life	Yes	38.6	27.9**
Drank alcohol in past month	Yes	76.5	4.2
Intention to get drunk later in life	Yes	21.1	4.0
Smoked marijuana in past year	Yes	25.9	12.7*
Age 18 years ($n=279$)			
Mother smokes	Yes	52.2	14.0*
Father smokes	Yes	62.0	2.4
Number of friends who smoke (0–5)[b]	More	89.2[c]	45.0**
Been drunk in past year	Yes	62.3	9.0
Smoked marijuana in past year	Yes	67.0	11.7*

[a]Regression adjustment approach in which respective variables are adjusted for the same variable assessed at an earlier age.
[b]Risk category is "more friends smoke" specified as an ordinal scale in the analysis.
[c]One or more friends smoke.
*$p<.05$; **$p<.01$.

Table 5. Adjusted odds ratios for post hoc comparisons of smoking groups for substance use predictor variables[a].

Risk group	Intention to smoke			Friends smoke[b]		Marijuana use		Mother smokes
Reference group	(Age 9)	(Age 13)	(Age 15)	(Age 13)	(Age 18)	(Age 15)	(Age 18)	(Age 18)
1. Early rapid escalators (ERE)								
2. LRE	.59	7.28*	2.35	4.80*	.66	3.80*	1.75	1.35
3. LME	3.09	5.91	6.33*	9.03*	1.59	1.47	3.66	9.56*
4. LSES	2.69	1.34	3.65*	17.49*	3.75*	4.29*	5.66*	.90
5. SP	1.10	5.78	7.43*	14.52*	3.13*	10.04*	6.42*	.73
6. LSEP	.24*	1.73	34.23*	4.63*	5.95*	2.33	9.75*	1.77
2. Late rapid escalators (LRE)								
3. LME	5.24	.81	2.69*	1.88	2.41*	.39	2.09	7.09*
4. LSES	4.57	.18*	1.55	3.65	5.67*	1.18	3.23*	.67
5. SP	1.87	.79	3.16*	3.03	4.74*	2.64	3.66*	.54
6. LSEP	.41	.24	14.55*	1.04	9.01*	.61	5.56*	1.31
3. Late moderate escalators (LME)								
4. LSES	.87	.23	.58	1.94	2.36*	2.92	1.54	.09*
5. SP	.36	.98	1.18	1.61	1.97	6.83*	1.75	.08*
6. LSEP	.08*	.29	5.41*	.51	3.74*	1.59	2.66	.19
4. Late slow escalators–smokers (LSES)								
5. SP	.41	4.31	2.04	.83	.84	2.34	1.13	.81
6. LSEP	.09*	1.29	9.39*	.26	1.59	.54	1.72	1.97
5. Stable puffers (SP)								
6. LSEP	.22*	.30	4.61	.32	1.90	.23	1.52	2.44
6. Late slow escalators–puffers (LSEP) (see above)								

[a]An odds ratio greater than 1 indicates the risk group is more likely than the reference group to have the characteristic measured by the predictor variable.
[b]Odds ratio for one unit change in predictor variable.
*$p < .05$; significant chi-square related to odds ratio.

discerns the heavy smoker (early rapid escalators) from the remainder, and at age 18 identifies the majority of trajectories except the lightest smokers (late slow escalators–smokers and stable puffers). The rapid escalator groups (early and late) were more likely to smoke marijuana and conform to the patterns of maternal smoking by age 18 (except late moderate escalators).

Among the sociodemographic and mental health variables (Table 6), the trajectories are significantly related to sociodemographic characteristics by age 18. Mother's psychological symptoms scores were an early predictor (by age 9). Mental health variables that predicted the trajectories changed with age, suggesting that an underlying dimension rather than a specific mental health issue was related to smoking. Notably, anxiety scores were not predictive of smoking trajectories. The pattern of odds ratios shown in Table 7 indicates that overall the first group of heavy smokers (early rapid escalators) can be distinguished from the remaining groups, including the second group of heavy smokers (late rapid escalators). Few mental health variables distinguished among the other trajectories. A nonlinear relationship occurred for attention deficit disorder scores at age 11; high scores predicted rapid escalation (early rapid escalators) and predicted those who remained puffers (late slow escalators–puffers), compared with late escalators (rapid and moderate). Among the three groups who became regular smokers, the early rapid escalators were less likely to belong to an organized club.

Discussion

The present study showed two patterns of rapid escalation (early and late), compared with only one pattern of rapid escalation in a similar study that focused on early to middle adolescence in a sample of youths from Kansas City (Colder et al., 2001). Smoking rates were higher in the current rapid escalator groups than in the Kansas City rapid escalator group. Moreover, early rapid escalation represented the dominant pattern in the present sample, whereas stable puffing was the dominant pattern in the Kansas City sample. A late moderate escalating group was found in both samples; this group was typified by an average 34–35 cigarettes per month by the end of the study period in the Kansas City sample, compared with 72–73 cigarettes per month in the present sample. Late slow escalators also were found in both samples. In the present sample, two classes of late slow escalators were identified that were distinguished by levels of smoking at age 18. One class typically smoked 7.7 cigarettes per month (late slow escalators–smokers), and the other typically smoked about .55 cigarettes per month by the end of the study period (late slow escalators–puffers). Finally, a group of stable puffers was identified in

Table 6. Sociodemographic and mental health predictors[a] of adolescent smoking trajectories (results of a maximum likelihood multivariate logistic regression analysis).

Variables	Risk category[b]	χ^2
Socioeconomic status of father (1–6)	Unskilled	3.9
Age 9 years ($n=240$)		
Behavior problems score	Higher	5.9
Family Relations Index	Lower	5.4
Mother's psychological symptoms	Higher	12.6*
Age 11 years ($n=219$)		
Father's occupation	Unskilled	10.2
Behavior problems score	Higher	4.7
Attitude toward school	Poorer	6.9
Number of changes to address in past 2 years	More	3.7
Belongs to organized club	Yes	5.2
Attention deficit disorder score	Higher	15.6**
Depression score	Higher	2.6
Anxiety score	Higher	10.2
Age 13 years ($n=240$)		
Father's occupation	Unskilled	2.5
Behavior problems score[c]	Higher	9.1
Attitude toward school	Poorer	5.9
Number of changes to address in past 2 years	More	5.6
Belongs to organized club	No	3.4
Regular part-time job	Yes	5.6
Depression score	Higher	7.0
Attention deficit disorder score	Higher	.4
Anxiety score	Higher	4.3
Conduct disorder score	Higher	17.9**
Trouble with police in past 2 years	Yes	4.2
Help seeking for emotional or behavioral problem in past 2 years	Yes	3.2
Age 15 years ($n=237$)		
Father's occupation	Unskilled	3.4
Behavior problems score	Higher	12.0*
Social competence score	Lower	1.1
Year level intending to leave school	Lower	6.6
Number of changes to address in past 2 years	More	14.2*
Belongs to organized club	No	3.2
Regular part-time job	Yes	1.9
Depression score	Higher	11.1*
Anxiety score	Higher	6.4
Conduct disorder score	Higher	6.5
Trouble with police in past 2 years	Yes	10.5
Help seeking for emotional or behavioral problem in past 2 years	Yes	9.4
Age 18 years ($n=258$)		
Life satisfaction scale	Lower	5.2
Attachment to family	Lower	2.4
Attachment to friends	Higher	11.2*
School qualification	Lower	11.6*
Belongs to organized club	No	13.2*
Depression score	Higher	2.7
Anxiety score	Higher	2.7
Conduct disorder score	Higher	9.9

[a]Regression adjustment approach in which respective variables are adjusted for the same variable assessed at an earlier age.
[b]Specified as an ordinal scale.
*$p<.05$; **$p<.01$.

both samples. Overall, the patterns of adolescent smoking were remarkably similar across the two datasets.

Levels of smoking were generally higher at the end of the study period for the present sample. Further, the dominant group in the present sample was characterized by late rapid escalation in smoking, whereas the dominant group in the Kansas City sample was characterized by stable puffing. These differences may be the result of the difference in age at last assessment: Age 18 in the present sample vs. a mean age of 16 in the Kansas City sample. Thus, participants in the present sample were older at the end of the study, which may correspond to greater independence (e.g., lower parental monitoring) and easier access to cigarettes (e.g., 18-year-olds can purchase cigarettes legally).

The differences in smoking levels across the samples also may reflect differences in measurement. Adolescents in the Kansas City sample responded to smoking behavior questions using a Likert-type scale, which truncated their level of smoking at the high end of the scale and included several options to assess very low levels of smoking (e.g., "a few puffs" and "part of

Table 7. Adjusted odds ratios for post hoc comparisons of smoking groups on mental health variables.[a]

Risk group / Reference group	Mother's psychological symptoms (Age 9)	Attention deficit disorder score[b] (Age 11)	Conduct disorder score[b] (Age 13)	Behavior problem[b] score (Age 15)	Change to address[b] (Age 15)	Depression score[b] (Age 15)	Low school qualification[b] (Age 18)	No club activities (Age 18)	More attachment to friends (Age 18)
1. Early rapid escalators (ERE)									
2. LRE	2.69	1.20*	1.40*	1.01	9.85*	1.40*	2.27	4.15*	2.08
3. LME	13.35*	1.31*	1.34*	.98	284.70*	1.33	4.35	6.56*	4.35
4. LSES	22.07*	1.06	1.36*	1.03	86.89*	1.43*	11.11*	1.75	6.67
5. SP	13.51*	1.25	1.46*	.99	470.03*	1.52*	9.09*	2.96	11.11*
6. LSEP	4.69	.91	1.40*	1.18*	8.93	1.37*	5.26	1.34	6.25
2. Late rapid escalators (LRE)									
3. LME	4.96	1.09	.99	.98	16.14	.95	1.89	1.56	2.08
4. LSES	8.20	.88	1.01	1.02	4.92	1.03	5.00*	.42	3.23
5. SP	5.02	1.04	1.08	.99	26.64	1.09	4.00*	.71	5.56*
6. LSEP	1.74	.76*	1.03	1.17*	.51	.98	2.27	.32*	3.03
3. Late moderate escalators (LME)									
4. LSES	1.65	.80	1.01	1.05	.31	1.08	2.63	.27*	1.52
5. SP	1.01	.95	1.08	1.02	1.65	1.14	2.13	.45	2.63
6. LSEP	.35	.69*	1.04	1.20*	.03*	1.03	1.22	.21*	1.43
4. Late slow escalators–smokers (LSES)									
5. SP	.61	1.18	1.07	.97	5.41	1.06	.81	1.69	1.72
6. LSEP	.20	.86	1.02	1.15*	.10	.96	.46	.76	.94
5. Stable puffers (SP)									
6. LSEP	.35	.73*	.96	1.18*	.02	.90	.57	.45	.55
6. Late slow escalators–puffers (LSEP) (see above)									

[a]An odds ratio greater than 1 indicates the risk group is more likely than the reference group to have the characteristic measured by the predictor variable.
[b]Odds ratio for one unit change in predictor variable.
*$p < .05$; significant chi-square related to odds ratio.

a cigarette"). Adolescents in the present sample reported the number of cigarettes smoked in the past month, and this question was not structured to assess very low levels of smoking (e.g., puffing). This difference in how smoking was assessed may have resulted in proportionately more light smokers and puffers in the Kansas City sample and generally lower levels of smoking.

Finally, the Kansas City sample was a school-based sample, and the present sample represented a 1-year birth cohort of children recruited from a hospital. These sampling differences may account for differences in smoking levels. A combination of these factors likely resulted in different levels of smoking in the two samples. Thus, some caution is warranted when generalizing these trajectories, particularly with regard to absolute levels of smoking. Rather, it may be best to interpret the relative shape of the trajectories for descriptive purposes because these seemed to replicate across samples. Furthermore, some caution is warranted in generalizing findings from one sample to another, because the etiological processes and patterns of tobacco use may be subject to local norms. Oetting and Beauvais (1990) have argued that adolescents in different geographic locations exhibit different patterns of drug use that may require different types of interventions. Our findings support this position.

The present study went beyond our study of the Kansas City sample and examined a broad range of predictor variables. In relation to smoking and other substance use predictors, intentions to smoke and friends smoking were relatively early predictors of adolescent smoking trajectories, whereas marijuana use and mother's smoking status were late predictors. This change in predictors across age reflects to some extent the nature of the influence. Early predictors can be seen to drive or determine the trajectory, which leads to a drift toward other characteristics or outcomes identified as late predictors (push vs. pull mechanisms of effect). Notably, alcohol use did not predict the smoking trajectories, and intention to smoke at age 9 predicted puffing rather than the trajectory of rapid escalation. Among the mental health and sociodemographic variables, mother's psychological symptoms and attention deficit and conduct disorder scores were early predictors (ages 11–13 years); behavior problems, depression scores, and changes of address were midadolescent predictors (age 15 years); and poor school performance, not belonging to an organized club, and attachment to friends were late predictors or outcomes (age 18 years). A few variables operated in a nonlinear manner, demonstrating the complexity of the relationship to smoking. For example, relatively higher ADD scores at age 11 predicted rapid escalation of smoking

(possibly through the mechanism of rebelliousness), but this same mechanism also may have led some youths to ignore the influence of friends and remain puffers.

Some limitations of the current study should be noted. The data analysis strategy removed subjects without complete data, and it has been found that subjects who drop out of studies are at greater risk for substance use (Beauvais, Chavez, Oetting, & Deffenbacher, 1996; Chassin, 1984). In addition, because the number of smokers in the trajectories is relatively small, this pattern of trajectories needs to be confirmed in further studies. It also may be important for future research to examine a more extensive list of predictor variables. Finally, smoking was assessed during adolescence. Chassin et al. (2000) found that some adolescent smokers quit or decrease their smoking in adulthood. Differences in the analysis method and age at which the group of quitters emerged may account for the present finding that there was not a sufficiently homogenous or large enough group of quitters to be identified as a trajectory. It is important to identify which adolescent smokers quit and which smokers escalate their smoking in adulthood. It also is relevant for future research to examine smoking trajectories beyond adolescence into adulthood.

Despite these limitations, the present study addressed an important omission in the literature. Using a relatively new data analysis technique, latent variable growth mixture modeling, we examined growth trajectories of cigarette use and identified homogenous groups of adolescents based on common patterns of change. We also examined potential predictors of these patterns. Our findings suggest that trajectories of adolescent smoking are quite heterogeneous and provide a useful approach to examination of the patterns of adolescent smoking.

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