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Childhood ADHD Symptoms and Risk for Cigarette Smoking during Adolescence: School Adjustment as a Potential Mediator

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Abstract

Although a large body of research suggests that children with ADHD are at increased risk of cigarette smoking during adolescence compared to their non-ADHD peers, much less research has examined *why*. The current study addressed this gap in the literature by examining middle school adjustment, broadly defined, as a possible mediator of the relation between childhood ADHD symptoms and cigarette smoking during middle adolescence (10th grade). Longitudinal data were collected from a community sample of 754 youth using self- and parent-report along with school records, and a novel statistical technique was used in the process of testing for mediation. Consistent with hypotheses, school adjustment was found to mediate the relation between childhood ADHD symptoms and later cigarette smoking, even after controlling for early externalizing problems. Results have implications for etiological theories of adolescent deviant behavior and suggest that successful smoking prevention programs targeting youth with ADHD should include a school adjustment component.

Keywords

ADHD; School adjustment; Cigarette smoking; Mediation

It has been well-documented that children with Attention-Deficit/Hyperactivity Disorder (ADHD) are at increased risk for cigarette smoking as they reach adolescence and adulthood (e.g., Lambert & Hartsough, 1998; McMahon, 1999; Milberger, Biederman, Faraone, Chen, & Jones, 1997). However, little research has examined *why* children with ADHD are more at-risk than their peers without the disorder. An understanding of *why* is crucial for informing etiological theories and preventive interventions. Thus, the current study will examine middle school adjustment as a potential mediator of the relation between childhood ADHD symptoms and middle adolescent (10th grade) cigarette smoking (see Figure 1).

ADHD and Cigarette Smoking

Multiple studies (e.g., Barkley, Fischer, Edelbrock, & Smallish, 1990; Burke, Loeber, & Lahey, 2001; Busch et al., 2002; Disney, Elkins, McGue, & Iacona, 1999; Hartsough & Lambert, 1987; Lambert, 1988; Lambert & Hartsough, 1998; Milberger et al., 1997; Molina

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& Pelham, 2003; Riggs, Mikulich, Whitmore, & Crowley, 1999; Tercyak, Lerman, & Audrain, 2002), conducted with both community and clinical samples, have provided robust evidence that youth with ADHD are at increased risk for cigarette smoking. For instance, in a study that followed a community sample of children with and without clinically-significant ADHD symptoms into adulthood, Lambert and Hartsough (1998) found that the ADHD group began smoking regularly at an earlier age than the non-ADHD group (15.7 vs. 17.1), and by age 17, 50% of all participants with ADHD, as contrasted with 27% of non-ADHD controls, smoked cigarettes daily. Similar results have been found using referred populations. In a 4-year follow-up of clinically-referred youth with and without ADHD (Milberger et al., 1997), 19% of adolescents (M age = 15.0) with ADHD were smokers compared to only 10% of non-ADHD controls. Adolescents with ADHD also had an earlier age of smoking onset than those without the disorder (15.5 vs. 17.4). Of note, the association between ADHD and cigarette smoking remains even after controlling for the overlap of ADHD with conduct problems, which is a robust predictor of substance use and abuse (see Flory & Lynam, 2003 for a review).

These statistics are particularly disturbing in light of evidence indicating that most adult smokers begin to smoke during adolescence, that most attempts to quit are unsuccessful (SAMHSA, 2004), and that smoking is the number one cause of preventable disease and death among U.S. adults (USDHHS, 2000). Combined, these findings point to a crucial need for researchers to focus on understanding *why* youth with ADHD are at greater risk for smoking. An understanding of *why* will inform etiological theories and the development of effective smoking prevention programs for this high-risk population.

Why are Youth with ADHD at Greater Risk for Smoking?

Only a handful of studies have examined why youth with ADHD are at greater risk for cigarette smoking than their peers without the disorder. Although a number of factors likely contribute to smoking behavior among adolescents with ADHD, the self-medication hypothesis has received the most attention. This theory points to the similarities in the neurobiological and psychological effects of nicotine and psychostimulant medications (e.g., Ritalin), and suggests that individuals with ADHD may self-medicate with nicotine to manage their symptoms. Using a double-blind procedure, several studies (e.g., Connors et al., 1996; Levin, Connors, Silva, Canu, & March, 2001; Levin et al., 1996; Potter & Newhouse, 2008) have administered nicotine via transdermal patch to adolescent and adult smokers and nonsmokers with ADHD. Results from these studies consistently demonstrate that, compared with placebo, nicotine improves attention, cognitive/behavioral inhibition, and mood. However, these studies do not address the issue of self-administration, which is also a critical component of the self-medication hypothesis. The self-medication hypothesis (including the self-administration component) has received some support from studies that directly ask individuals with ADHD whether or not they use cigarettes to self-medicate (e.g., Wilens et al., 2007).

Although the self-medication hypothesis may explain why some adolescents with ADHD become regular smokers, it has not yet been adequately tested, and it is likely that many other psychosocial factors also contribute to smoking *initiation* and even regular smoking among these youth. However, the research examining factors other than the self-medication hypothesis is sparse. The few studies that have examined other factors have suggested that deviant peer affiliation, peer and parental substance use, lower levels of perceived parental support, and poorer adaptive coping skills might play important roles (Burke, Loeber, White, Stouthamer-Loeber, & Pardini, 2007; Marshal, Molina, & Pelham, 2003; Molina, Marshal, Pelham, & Wirth, 2005). Studies (e.g., Burke et al., 2001; Fuemmeler, Kollins, & McClernon, 2007; Kollins, McClernon, & Fuemmeler, 2005; Tercyak et al., 2002) which have investigated differential influences of the ADHD symptom dimensions (i.e., inattention

vs. hyperactivity/impulsivity) on cigarette use also contribute to understanding why adolescents with ADHD smoke. Although this work does begin to address the gap in the literature, there is still much important work to be done in this area. The current study further advances this knowledge base by examining a longitudinal model of middle school adjustment as a potential mediator of the relation between early childhood ADHD symptoms and cigarette smoking during adolescence.

School Adjustment as a Potential Mediator

There are several reasons why we chose to examine school adjustment, broadly conceptualized, as a potential mediator of the ADHD-smoking relation. Our construct includes both academic success (i.e., grades), as well as child- and parent-reported relationships with other students, academic and behavior problems, and other general aspects about the child's experience at school. One reason that we chose this conceptualization is because it is clear that a diagnosis of ADHD impacts not only academic success (see Barkley, 2006 for a review), but also the social relationships of children with the disorder (e.g., Hoza, 2007), which has implications for how these youth relate to teachers and classmates and for how connected they generally feel towards school. Research suggests that both academic success *and* school connectedness are important for general academic outcomes, such as achievement and graduation (e.g., Bond et al., 2007; Klem & Connell, 2004).

Another reason that we chose to examine broad school adjustment as a mediator is because academic success and school connectedness have received considerable attention in the general literature on risk for smoking during adolescence. For instance, Bergen, Martin, Roeger, and Allison (2005) found that persistent or increasing perceptions of academic failure between the ages of 13 and 15 predicted weekly cigarette use at age 15. In a slightly older sample, Schulenberg, Bachman, O'Malley, and Johnston (1994) found that high school grade point average was predictive of substance use, including cigarette smoking, both during and post high school. With regards to school connectedness, Wang, Matthew, Bellamy, and James (2005) demonstrated that as minority adolescents ages 11–16 are more connected to school, there is a decreased chance for substance use, including the use of cigarettes. Similarly, Catalano, Haggerty, Oesterle, Fleming, and Hawkins (2004) found that students who were more connected to school in the 5th and 6th grades were less likely to start smoking during 7th grade and to ever smoke during adolescence.

We also chose to examine school adjustment as a potential mediator because of theoretical implications. Our model (Figure 1) is consistent with several theories that have relevance for the relation between school adjustment problems and substance use. For instance, in Hirschi's (1969) social control theory, school success reflects a commitment to a conventional way of life that inhibits substance use and other expressions of delinquency. Dishion and colleagues (e.g., Dishion, Patterson, Stoolmiller, & Skinner, 1991) have suggested a similar theory that is specific to children with ADHD and other disruptive behavior problems. In this theory, children's behavior problems in school (e.g., the impulsivity and inattention associated with ADHD) result in school failure and rejection by conventional peers. These children then seek out deviant peer groups, which promote engagement in deviant behaviors, such as substance use. Although we do not examine the peer rejection or deviant peer involvement components of this theory in the current study, the model we do examine is consistent with both Dishion's theory and social control theory and our results may have important implications for both.

A final reason that we chose to examine school adjustment as a potential mediator of the relation between ADHD symptoms and cigarette smoking is that, to our knowledge, this is the first study to examine school adjustment in this role. The literature in this area is sparse

and thus it is important for researchers to identify empirically- and theoretically-supported constructs, as we did, to examine as possible mechanisms to explain the high rates of cigarette smoking among youth with ADHD.

The Current Study

Using data from a large, multi-site longitudinal study (the Fast Track Project; CPPRG, 1992) and a novel statistical technique, we examined middle school adjustment problems as a potential mediator of the relation between childhood ADHD symptoms and cigarette smoking during middle adolescence (10th grade). Consistent with existing literature and theory, we hypothesized that: (1) childhood ADHD symptoms would significantly predict middle school adjustment problems, controlling for childhood academic success (a component of school adjustment); (2) middle school adjustment problems would significantly predict cigarette smoking during middle adolescence, controlling for smoking during middle school; and (3) middle school adjustment problems would mediate the relation between childhood ADHD symptoms and cigarette smoking during middle adolescence.

We utilized a measure of continuous ADHD symptoms rather than discrete diagnoses because of the non-clinical nature of our sample. In all analyses, we controlled for early childhood externalizing/conduct problems given the strong predictive relation between these behaviors and later substance use (see Flory & Lynam, 2003 for a review). It is important to note that researchers often disagree on whether pre-existing or concurrent conduct problems should be controlled for in prospective studies linking ADHD to outcomes. We elected to control for pre-existing conduct problems in this study because of concerns that concurrent conduct problems could mediate the relation between ADHD symptoms and our other constructs. Including a potential mediator as a confound might have spuriously reduced the link between ADHD symptoms and smoking (MacKinnon, Krull, & Lockwood, 2000). Finally, although we did not expect our mediation model to differ by gender, we did examine this possibility given the strong gender differences in rates of ADHD, with boys outnumbering girls at a rate of 3:1 to 9:1 depending on the population examined (Barkley, 2006).

It is important to consider our research questions in light of the two other studies which examined ADHD using Fast Track data. Miller-Johnson and colleagues (Miller-Johnson, Coie, Maumary-Gremaud, Bierman, & the CPPRG, 2002) examined the relations among peer rejection, conduct problems, aggression, and ADHD among elementary-aged Fast Track participants. Results suggested that peer rejection partially mediated the relation between early ADHD symptoms and later conduct problems (Miller-Johnson et al., 2002). More relevant to the current study, Hillemeier and colleagues (Hillemeier, Foster, Heinrichs, Heier, & the CPPRG, 2007) examined differences in the measurement of ADHD between African-American and European-American children participating in Fast Track. Results indicated that parents of European-American children were more likely to endorse 18% of items assessing ADHD hyperactivity/impulsivity symptoms than were parents of African-American children, despite similar levels of hyperactivity/impulsivity in the youth (Hillemeier et al., 2007).

Method

Participants

Participants came from the control schools of a longitudinal, multi-site investigation of the development and prevention of conduct problems in children, the Fast Track Project (CPPRG, 1992). At each of four sites (Durham, NC; Nashville, TN; Seattle, WA; and rural,

central Pennsylvania), high-risk schools were selected and randomly assigned to intervention or control conditions. “High-risk” schools were drawn from high-risk areas of the communities based on poverty, low parental education levels, and high rates of crime (Lochman & CPPRG, 1995). From among the control schools ($n = 27$), teachers completed ratings of child disruptive behavior in order to identify a within-site stratified sample of about 10 children within each decile of behavior problems. Across the four sites, 387 children were selected to represent the normative population of these schools. In addition, high-risk children were over-sampled in order to measure finer gradations of high risk. A multistage, multi-informant screening process identified three annual cohorts of kindergartners with the highest disruptive behavior scores, yielding an n of 446 high-risk students and bringing the total number of participants to 754 (79 students were included in both the high-risk sample and the normative sample, as they represented the highest-risk deciles in their [control] schools; see Lochman & CPPRG, 1995 for further details). Weighting was used in all analyses to reflect the over-sampling of high-risk children. Weighted proportions of the analysis sample (normative and high-risk control) are 54% female and 51% European-American, 43% African-American, 2% Latino/a, <1% Asian-American, <1% Native American, and 2% “Other”. Sixty-three percent lived in two-adult households at study start (i.e., kindergarten); 36% lived in female-headed one-adult households; and 1% lived in male-headed one-adult households. Less than 1% lived in any other situation. Students receiving Fast Track interventions were not included in the sample for the current study.

Procedure

Beginning in kindergarten, annual measurements were collected from the teacher, the peer group, administrative school records, the mother, the child, and interviewer ratings. Teacher, peer, and administrative-record measures were collected in the Spring, and mother, child, and interviewer measures were collected in the following Summer. Of the original sample of 754 non-intervention youth, 701 (93%) provided data in grade 3, 642 (85%) in grade 7, and 564 (75%) in grade 10 (the last year from which data were used in the current analysis). Some respondents still in this study did not provide data for all variables; missing data rates on variables specific to this study appear in Table 3. We examined differential attrition in a discrete-time survival analysis, predicting attrition by grades 3, 7, and 10 from site, cohort, race/ethnicity, sex, and kindergarten externalizing problems. Only site was a significant predictor of attrition, $p < .05$, with the greatest hazard of loss in Nashville and the least in Durham.

Measures

The following measures used in the current study are described in detail at www.fasttrackproject.org. The principal constructs included childhood ADHD symptoms, measures of middle school adjustment, and adolescent cigarette use. Chronologically earlier versions of each of these variables were included as covariates, along with a measure of early childhood externalizing behaviors.

Childhood ADHD symptoms—In the summer after the child's third-grade year (i.e., three years after kindergarten recruitment), a parent (usually the mother) completed the computerized version of the National Institute of Mental Health (NIMH)'s Diagnostic Interview Schedule for Children (C-DISC; Shaffer & Fisher, 1997), a structured interview designed to assess DSM-III-R (American Psychiatric Association, 1987) psychiatric disorders in youth. For each diagnosis module included, the parent responded “yes” or “no” to the presence of each symptom. Each parent respondent was asked all questions; no skip patterns were used. A symptom count variable was created to indicate the number of diagnostic criteria (i.e., symptoms of inattention, hyperactivity, and impulsivity) a subject

met for a given disorder. The current study used counts of criteria for ADHD-Inattentive subtype and ADHD-Hyperactive/Impulsive subtype as they had been noted in the child in the 6 months prior to measure administration. We initially intended to model hyperactive/impulsive and inattentive symptoms separately, but the symptom counts were so highly correlated ($r = .58$, unadjusted for skewed, discrete measurement) that we concluded there was no useful distinction in this dataset and modeled the combined symptom count in order to improve stability of the measure. This symptom count was modeled as a Poisson variable. The weighted frequency distributions of total ADHD symptom counts are presented in Table 1. Though we did not use diagnostic status in analyses, we note for descriptive purposes that 2.9% of the weighted sample met criteria for a diagnosis of ADHD.

Middle school adjustment problems—The youth's adjustment to school was assessed by eight measures from three sources in the seventh grade. First, course grades in four core subjects (language arts, math, science, and social studies) were obtained from school records at the end of the seventh-grade year. Grades in each subject were noted on a 5-point scale, from 0 (failing) to 4 (A). Second, school adjustment difficulties were measured by total scale scores from Fast Track's School Adjustment (Child report) scale (CPPRG, 1997a; e.g., “My school friends and I got along well this year” [reversed], “Most teachers at my school do not care about kids, especially me”; 20 items, $\alpha = .82$). The parent completed a parallel measure of the child's school adjustment difficulties (CPPRG, 1997b; 18 items, 12 of them parallel, $\alpha = .89$). The two questionnaires used 5-point response scales (“Never true” to “Always true”) and were administered in the summer after seventh grade. These measures have been used successfully in prior studies (e.g., Ingoldsby, Kohl, McMahon, & Lengua, 2006; Schofield, Bierman, Heinrichs, & Nix, 2008).

Earlier measures of academic success were collected from fourth-grade records, including a dichotomous indicator of a failing grade in either math or language arts and an indicator of whether the student had been retained in a grade by that point. A third measure was derived from performance on the Fast Track-administered Woodcock-Johnson Revised (Woodcock & Johnson, 1989)—an indicator of whether the student had scored at least one standard deviation below the normative-sample mean on any of three key subtests (passage comprehension, calculation, and letter-word identification). The broader school adjustment measures were not collected in elementary school.

Adolescent cigarette use—Cigarette use in the summer after tenth grade was assessed by a single item asking adolescents on how many of the past 30 days the youth had smoked cigarettes, recoded as none (0 days), some (1–29 days), and daily (30 days). This variable was modeled as ordinal except as noted. An identical measure was used to assess seventh-grade cigarette use; however, the “some” and “daily” categories were collapsed due to a low frequency of daily smokers. Smoking rates for seventh and tenth grade are presented in Table 5.

Early externalizing behavior problems—A parent of each child in the study completed the Child Behavior Checklist (CBCL; Achenbach, 1991) in the summer following the child's kindergarten year. This instrument comprises 112 items that each significantly differentiates clinically-referred from non-referred children. Parents rated each item of the CBCL with a 0 for “not true,” a 1 for “somewhat or sometimes true,” or a 2 for “very true or often true.” Responses were summed to create each subscale. The Externalizing Behavior broad-band scale encompasses the 13 Delinquent Behavior and 20 Aggressive Behavior items (excluding those items which reflect ADHD symptoms).

Socioeconomic status—During the post-kindergarten interview, the parent reported the education level and occupation of the child's biological father and biological mother.

Following Hollingshead (1975), these four responses were scored and combined to form a single score for family socioeconomic status (SES) ranging from 4.5–66.0.

Modeling Strategy

We developed a two-stage modeling process to accommodate the distinctive characteristics of our measurement model and to evaluate the structural model. First, we applied partial least squares (PLS; Chin, 1995) modeling to develop the measurement model for the school factors construct (both the middle school mediator and the earlier covariate). PLS modeling as applied here is superficially similar to confirmatory factor analysis (CFA) but uses an alternative estimation technique (versus maximum likelihood) that has its own advantages and disadvantages. In PLS, summary variables are modeled with formative indicators, versus the reflective indicators usual for latent variables in CFA. Reflective approaches are appropriate when component variables are presumed to be indicators of a single latent construct (such as a trait), whereas formative approaches make no such assumption (such as indicators of a life events index). The formative indicator approach involves each summary variable being modeled as a linear composite of its components, as in a principal components analysis, rather than being a source of common variance among a factor's indicators. The key difference between a PLS analysis and a principal components analysis is that in the latter the composites are constructed to maximize the variance of the indicators accounted for by the component, whereas in PLS the indicators for each composite are weighted to maximize the strength of the relations among the PLS variates (similar to a canonical correlation), resulting in the best possible prediction of the downstream variates. Rather than assume equal weights for all indicators of a scale, the PLS algorithm allows each indicator to vary in how much it contributes to the composite score. Thus, indicators with weaker relations to other indicators and the construct are given lower weightings. In this sense, PLS is preferable to techniques, such as regression, which assume error-free measurement (Lohmoller, 1989; Wold, 1982, 1985, 1989). The primary drawback to PLS is that the indicator weights are calculated with respect to the specific predictive model, rather than (as in the ideal CFA case) characteristic only of the construct being measured. That is, the PLS calculation process is model-specific.

Once the PLS weights for the school variables were estimated, we tested our hypotheses about the relations among the constructs of interest in a path modeling (i.e., structural equation modeling or SEM) framework, using standardized scores for the PLS variates to ease interpretation of results. Given our intent in predicting the smoking outcome, we estimated two separate PLS models, creating measurement models for grade 4 academic success and grade 7 school adjustment problems independently (an alternative strategy would have been to estimate weights for both variates in a single PLS model with ADHD measures and smoking; however, the PLS algorithm would have then also worked to maximize prediction among the entire sequence, at the cost of maximal prediction of cigarette smoking). We then retained the individual scores. Weights for the scores are shown in Table 2.

Descriptive Statistics and Treatment of Missing Data

Descriptive statistics (means, standard deviations, missing data rates) for the manifest variables used in the analyses, incorporating the sample weights reflecting the over-sampling of higher-risk students, are shown in Table 3. We conducted our PLS modeling in SAS v.9.1.3 (SAS Institute, 2004), which includes the option to accommodate missing data by estimating values for the scores through the Expectation-Maximization (EM) algorithm. One important component of this modeling is estimation of the standard error in the context of missing data estimation, which we completed in Mplus v.5.0 (Muthén & Muthén, 2007), accommodating the sample weights. These methods assume data are missing at random

(MAR; Little & Rubin, 1987). The MAR assumption is not logically testable and not informed by retention analyses; however, we believe it is likely to be approximately true in this analysis given the inclusion of demographic and problem behavior covariates. We estimated the correlations among the model variables in Mplus. Correlations appear in Table 4. Of note, the initial correlation between grade 3 ADHD symptoms and grade 10 smoking was significant ($p < .01$) at .16.

We then tested the mediating relations among the key study variables. We hypothesized that grade 3 ADHD symptoms would predict grade 7 school adjustment problems, controlling for grade 4 academic success (a component of school adjustment), and that the grade 7 school adjustment problems variable would predict grade 10 smoking, controlling for grade 7 smoking. Mediation was tested by deriving the asymmetric confidence interval for the product of the two relevant coefficients using the software PRODCLIN (MacKinnon, Fritz, Williams, & Lockwood, 2007), per the recommendation of MacKinnon et al. (2007). All models included kindergarten externalizing behavior along with child race, sex, SES, site, and cohort as exogenous covariates, predicting all model variables.

Results

The mediating relations were tested in a single model (Figure 1). Because we did not incorporate a measurement model at the hypothesis testing stage, the structural coefficients represent a saturated model, which necessarily fit the data perfectly. The first hypothesis was that third-grade ADHD symptoms would predict seventh-grade school adjustment problems, controlling for fourth-grade academic success. This hypothesized relation was significant in the expected positive direction, $b = 0.070$, $SE = 0.027$, $Est./SE = 2.58$, $p = .001$. The second hypothesis was that seventh-grade school adjustment problems would predict tenth-grade cigarette use, controlling for seventh-grade cigarette use. School adjustment problems significantly predicted cigarette use in the expected positive direction, logistic $b = 0.330$, $SE = 0.090$, $Est./SE = 3.68$, $p < .001$, $OR = 1.39$ per standard deviation. Finally, the indirect effect (the product of these two paths) was tested in PRODCLIN, resulting in a logistic coefficient estimate of 0.023, 95% CI: 0.005, 0.047. The residual (direct) effect of ADHD symptoms on grade 10 smoking was not statistically significant, $b = 0.028$, $SE = 0.039$, $Est./SE < 1$, ns . The null residual effect suggests a result consistent with full mediation; however, a test in a separate model of the total effect of third-grade ADHD symptoms on tenth-grade cigarette use, without the seventh-grade variables in the model, showed no significant total effect when including the third-grade and earlier covariates, $b = 0.393$, $SE = 0.032$, $Est./SE = 1.25$, $p = .212$ (this is in contrast to the significant Pearson's correlation in Table 4; the discrepancy might be due to the shift from continuous data-modeling in the bivariate correlations to the more appropriate logistic regression here, or due to the inclusion of the covariates as correlated predictors; Cohen, Cohen, West, & Aiken, 2003). The question of full mediation is impossible to resolve in the absence of a significant total effect; however, the indirect effect can be interpreted in itself nonetheless (see Shrout & Bolger, 2002, for a discussion of this phenomenon in longitudinal studies).

We repeated the above analysis adjusting for clustered sampling by school of recruitment. We considered this to be a secondary analysis due to missing data for school membership for 46 youth in the Fast Track dataset, which reduced our sample size in a listwise fashion. These changes had the expected effect of increasing standard errors, but the key finding of a significant indirect effect was still present, with a logistic coefficient of 0.024, 95% CI: 0.000, 0.058.

Moderators

As a final step, we tested the equivalence of the model parameter estimates across student gender and ethnicity, in separate models. Weighted seventh and tenth-grade smoking rates for the moderator groups are presented in Table 5. To test moderation by gender, we repeated the prior model of mediating relations in a multiple-group structural equation model, in which all estimates were initially free to vary by gender. We then tested the reduction in fit associated with constraining all path estimates to be equal across groups. The 53 constraints taken together showed significant differences, $\chi^2(53, N = 748) = 72.9, p = .036$. In order to localize the difference as being in the covariate portion of the model versus the theoretical part of the model, we then tested the 45 constraints linking the covariates to the study variables. These constraints did not yield a significant difference in fit, $\chi^2(45, N = 748) = 57.1, p = .107$. Finally, retaining the constraints on covariate paths, we examined singly the eight specific paths among the study variables (ADHD, school adjustment problems, and smoking) by freeing one constraint at a time from the fully constrained model. Only one of the eight paths – grade 10 cigarette use regressed on grade 7 cigarette use – showed a significant difference, $p < .05$. As this path was not central to our hypotheses, and given the needed caution in interpreting unexpected interactions, we do not discuss this interaction further.

Finally, in light of the Hillemeier et al. (2007) finding of differential item functioning for the C-DISC Hyperactivity/Impulsivity scale in this dataset, we tested moderation by ethnicity. Again, we used a fully-constrained multiple-group structural equation model: one group for European-American youth and one group for African-American youth. Thirty (30) students were of other ethnic backgrounds and were excluded from this analysis, as no other group was large enough to yield stable estimates. We did find significant differences, $\chi^2(48, N = 724) = 80.0, p = .003$. Following the same strategy as for gender, we then tested the 40 constraints linking the covariates to the study variables. These constraints did not yield a significant difference in fit, $\chi^2(40, N = 724) = 43.8, p = .315$. Finally, among the single paths linking the study variables, five of the eight paths showed significant differences, $ps < .05$. In all five cases – grade 7 school adjustment problems regressed on ADHD and grade 3 academic success; grade 7 cigarette use regressed on ADHD and grade 3 academic success; and grade 10 cigarette use regressed on grade 7 school adjustment problems – the significant differences were such that the path coefficients were significant in the expected direction for European-American students, but not significant for African-American students. This suggests that the effects of interest may only be present for European-American youth; we return to this point in the Discussion.

Discussion

A large body of research (e.g., Lambert & Hartsough, 1998; Milberger et al., 1997) suggests that children with ADHD are at an increased risk of cigarette smoking as they reach adolescence and adulthood; however, much less work has been done investigating *why*. The results of the current study address this gap in the literature by demonstrating a significant indirect effect via poor middle school adjustment between childhood ADHD symptoms and adolescent cigarette smoking. Further, we demonstrated that our mediation model is similar for boys and girls, and holds even after controlling for early childhood externalizing problems, which have been linked to both ADHD symptomatology and later involvement in substance use (see Flory & Lynam, 2003).

Of note, our post-hoc analysis examining ethnicity (African-American versus European-American) as a moderator suggests that the mediation results may only be present for European-American youth. Among African-American children, childhood ADHD symptoms may not be significantly related to middle school adjustment. This unexpected

finding may be due to the underreporting of ADHD symptoms by parents of African-American children. Hillemeier and colleagues (2007) found, using the same dataset and measure of ADHD, that parents of European-American children were more likely to endorse items assessing ADHD hyperactivity/impulsivity symptoms than were parents of African-American children. We also found that middle school adjustment was not related to grade 10 cigarette smoking among African-American participants. This suggests that there may be other psychosocial or cultural factors that may be more important predictors of substance use among these youth. It is important to note that rates of cigarette smoking for European-American and African-American participants in this sample were very similar, which is in contrast to national prevalence data which suggests that African-American youth generally smoke less than European-Americans (Johnson, O'Malley, Bachman, & Schulenberg, 2009). This may also be an explanation for why we did not find significant results for African-American participants. Clearly, more research is needed to further examine whether and how ethnicity influences the relation between ADHD and cigarette smoking.

To our knowledge, this study is the first to examine middle school adjustment as a mediator of the relation between childhood ADHD symptoms and adolescent cigarette smoking. As discussed earlier, we utilized a broad conceptualization of school adjustment problems including both academic failure *and* poor school connectedness. Our findings suggest that *both* aspects of school adjustment are important in explaining the relation between early ADHD symptoms and adolescent cigarette smoking. This is not surprising in light of prior findings (e.g., Catalano et al., 2005; Schulenberg et al., 1994) suggesting that both academic failure and poor school connectedness are related to cigarette smoking among the general population of adolescents *and* strong evidence (e.g., Barkley, 2006; Hoza, 2007) that many children with ADHD suffer not only from academic difficulties, but also from social and behavioral problems which likely affect relationships with classmates and teachers as well as their general experiences in school.

Our results are consistent with several theories addressing the relation between school adjustment problems and substance use, both for adolescents in general (e.g., Hirschi, 1969) and for those with disruptive behavior disorders (e.g., Dishion et al., 1991). Together, these similar theories suggest that children who have behavioral problems in the classroom, such as those with ADHD, often experience school adjustment problems and rejection by conventional peers as a result. Many of these children then begin to identify with unconventional or deviant peer groups and become involved in deviant activities, including substance use and other delinquent behaviors. Although our model did not include the peer rejection or the deviant peer involvement components of these theories, our results provide important empirical support for both theories. Future research can help to further clarify the mechanisms by which school adjustment problems impact later cigarette use for adolescents with ADHD.

Future research should also explore other psychosocial factors that may help to explain the link between ADHD and risk for cigarette smoking. In the general adolescent/young adult smoking literature, much emphasis has been placed on the stages of smoking model (e.g., contemplation, initiation, established smoking), and it has been suggested that different mechanisms may be related to smoking at different stages (Leventhal & Cleary, 1980). Unfortunately, very little research on ADHD and smoking has utilized the stage framework. We encourage researchers in this field to more explicitly measure stages of smoking and to discuss how their findings fit within this framework. We also encourage researchers to explore how trajectories of ADHD symptoms over time might influence the relations between psychosocial mechanisms and later substance use.

Our findings may also have important implications for prevention. Both academic interventions (with the goal of improving grades) *and* broader school-based interventions (with goals of improving students' school-related relationships, increasing involvement in school-based activities, and decreasing disciplinary problems) may contribute to a decreased risk for cigarette smoking among youth with ADHD. Such academic and psychosocial interventions may be especially important for *adolescents* with ADHD as stimulant medications are effective for only about 50% of these youth and have limited impact on academic performance (Evans et al., 2001; Findling, Short, & Manos, 2001; Smith, Pelham, Gnagy, Molina, & Evans, 2000; Wilens et al, 2006). There are also problems with medication compliance as children's desire for autonomy from authority figures and acceptance by peers increases (Robin, 2006; Smith et al., 2000), and their tendency to take medication decreases (Barkley, Fischer, Smallish, & Fletcher, 2003; Molina et al., 2009), with age. As a field, we are beginning to understand more about why adolescents with ADHD are at greater risk for cigarette smoking than their non-ADHD peers. We believe that it is time to take this knowledge and begin to develop smoking prevention programs that are specifically designed for this high-risk population. Research, including results from the current study, suggests that addressing academic success and broader school adjustment, as well as perhaps peer and parent factors, will need to be critical components of such programs.

In addition to being the first to examine school adjustment problems as a mediator of the relation between childhood ADHD symptoms and adolescent cigarette use, the current study has a number of other strengths. Foremost, as discussed, our research question was grounded in theory and our results have important implications for both theory and practice. Other strengths include the large, diverse community sample recruited from multiple sites across the U.S. and the use of a novel statistical technique in the measurement model. The PLS approach allowed us to construct a mediating variable comprising a broad array of school adjustment issues that did not necessarily reflect a single source of common variance. Indeed, the more frequently-used common factor model would have been less appropriate for these data due to the (expected) modest correlations among the indicators. A factor would have been so dilute from the lack of common variance that much useful measure-specific variance would have been discarded. The PLS modeling allowed us to create an *index* (i.e., an additive composite that retains this variance) rather than a *factor*.

Despite these strengths, our study has several limitations that must be considered. First, as implied previously, there may be additional mediating steps that account for the relation between school adjustment problems and later cigarette use among youth with ADHD. Possibilities include peer rejection or association with deviant peers, as well as cognitive or emotional factors which might encourage self-medication, such as poor self-efficacy, low self-worth, or even symptoms of depression or anxiety. It is important to note that by not including these other possible intervening variables in our analysis, we do not know the relative role of school adjustment in the context of other potential contributors to the ADHD-smoking relation. Although a model with two successive mediators may be difficult to test statistically, researchers could examine a series of simpler models looking at various possible mediators of the relation between school adjustment problems and cigarette smoking among adolescents with ADHD. It would also be informative to examine the ADHD symptom dimensions (i.e., inattention, hyperactivity/impulsivity) separately in these models.

Another possible limitation is our reliance on only parent report for assessing ADHD symptoms. However, there is some debate in the literature whether symptom pervasiveness across two or more settings is necessary for an accurate diagnosis of ADHD, particularly as parents and teachers often do not agree on current symptomatology (see Barkley, 2006).

Nonetheless, by not requiring teacher corroboration of symptoms, the current study might have over or underestimated ADHD symptomatology among participants. This is less of a concern, however, as we used a continuous measure of ADHD symptoms versus assigning a dichotomous diagnosis. Of note, because so few of our participants (2.9%) met diagnostic criteria for ADHD, our results using continuous ADHD symptoms may not generalize to all youth with a clinical diagnosis of ADHD.

It is also possible that the over-representation of high-risk children in the Fast Track sample may pose a limitation to the generalizability of results. For example, the similar rates of cigarette smoking among African-American and European-American youth in this study likely stems from the sampling strategy. However, the sample composition can also be considered a strength as it implies potentially greater variability in high-risk behaviors and associated power to detect effects when testing relations between variables as informed by theory and prior research. The use of only one item to assess cigarette smoking might also be considered a limitation. However, because smoking is an observed (rather than latent) variable, we can be fairly confident that the one item is a good measure of this behavior. Many studies (e.g., Molina & Pelham, 2003) examining substance use rely on single items (e.g., ever used cigarettes, age at first use) as outcomes. Finally, the Fast Track Project did not assess whether participants were currently taking medication for ADHD, so we were unable to include this as a covariate. ADHD medications can positively impact academic and social functioning, and may even reduce the risk of substance use (see Barkley, 2006); thus, future studies in this area should certainly assess and control for current ADHD medication usage.

In sum, this study addressed one possible reason why children with high levels of ADHD symptoms are at increased risk for cigarette smoking as they reach adolescence—school adjustment problems. Although advancing etiological theories is important, we believe that the ultimate goal of this line of research should be to directly improve the lives of youth with ADHD. These youth are already at risk for a number of detrimental outcomes as they mature into adulthood. Thus, we hope that the results from this study and others will be used to inform prevention and intervention programs that serve to decrease cigarette smoking among these individuals.

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Note: ADHD = Attention Deficit Hyperactivity Disorder. Ext Beh = Externalizing Behaviors.

Figure 1. Conceptual model relating Attention Deficit Hyperactivity Disorder symptoms, school adjustment, and adolescent cigarette smoking.

Note: ADHD = Attention Deficit Hyperactivity Disorder. Ext Beh = Externalizing Behaviors.

Figure 2. Model with unstandardized regression coefficients relating Attention Deficit Hyperactivity Disorder symptoms, school adjustment, and adolescent cigarette smoking.

Table 1

Attention Deficit Hyperactivity Disorder Symptom Count Distributions

Symptom Count (of 18)	Grade 3
0	31.5
1	10.4
2	9.6
3	6.2
4–5	9.8
6–7	8.8
8–9	6.8
10–12	7.2
13–15	5.2
16–18	4.4
Mean (weighted)	2.71
SD (weighted)	12.50
% Missing	12.8

Note: $N = 754$. Tabled values in the first 10 rows are proportions of participants with each symptom count. SD = Standard Deviation.

Table 2

Partial Least Squares Weights for School Variates

Grade 4 Academic Success ^a	
Grade Retention	0.079
Core Subject Failure	−0.053
Poor Woodcock-Johnson Performance	0.031
Grade 7 School Adjustment ^b	
Math Grade	−0.029
Language Arts Grade	−0.025
Social Studies Grade	−0.029
Science Grade	−0.030
School Adjustment Difficulties (youth report)	0.040
School Adjustment Difficulties (parent report)	0.042

Note: $N = 754$. Tabled values are coefficients for the linear combination of observed variables to create the partial least squares variates.

^aProportion of smoking variance accounted for = .008.

^bProportion of smoking variance accounted for = .053.

Table 3

Descriptive Statistics for Study Variables

	Percent Missing	M	SD	Range
Grade 4 Academic Success				
Grades Retained to Date	0%	.168	1.26	0–2
Core Subjects Failed	0%	.078	1.10	0–2
Poor Woodcock-Johnson Performance (number of subtests)	15%	0.42	2.73	0–3
Grade 7 School Adjustment				
Math Grade	20%	2.30	3.72	0–4
Language Arts Grade	20%	2.42	3.89	0–4
Social Studies Grade	21%	2.43	3.91	0–4
Science Grade	23%	2.34	4.06	0–4
School Difficulties (youth report) ^a	19%	4.55	1.91	2.08–5.83
School Difficulties (parent report) ^a	19%	3.62	2.32	1.19–5.00
Grade 7 Smoking	19%	0.11	1.11	0–1
Grade 10 Smoking	27%	0.27	1.95	0–2
Kindergarten Socioeconomic Status	0%	28.34	42.79	4.5–66

Note: $N = 754$. Results for weighted sample. Smoking scored as 2-point (grade 7) or 3-point (grade 10) ordinal scale, treated as continuous.

^aReversed. M = Mean. SD = Standard Deviation.

Table 4

Correlations among Study Variables

Variable	1	2	3	4	5	6	7
1. Male	--						
2. Externalizing T-score	.20**	--					
3. Childhood ADHD Symptoms	.24**	.44**	--				
4. Grade 4 Academic Success	.07	.18**	.08	--			
5. Grade 7 School Adjustment	.27**	.27**	.28**	.25**	--		
6. Grade 7 Smoking	.12	.15**	.10*	.12*	.22**	--	
7. Grade 10 Smoking	.08†	.18**	.16**	.07	.26**	.41**	--

Note: $N = 754$.

ADHD = Attention Deficit Hyperactivity Disorder.

† $p < .10$

* $p < .05$

** $p < .01$.

Table 5

Smoking Rates (Weighted) by Moderator Group

	Grade 7			Grade 10		
	None	Some/Daily	None	Some	Daily	
Total	90%	10%	81%	12%	8%	
Females	93%	7%	84%	11%	5%	
Males	85%	15%	78%	12%	10%	
African Americans	89%	11%	82%	12%	6%	
European Americans	91%	9%	80%	11%	9%	

Note: Percentages may not add to 100 due to rounding.