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Interaction matters: Quantifying conduct problem by depressive symptoms interaction and its association with adolescent alcohol, cigarette, and marijuana use in a national sample

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Abstract

Substance use is a major contributor to morbidity and mortality among American adolescents. Conduct problems and depressive symptoms have each been associated with adolescent substance use. Although they are highly comorbid, the relation of the interaction of conduct problems and depressive symptoms to substance use in not clear. In a national sample of 8th, 10th, and 12th grade students from Monitoring the Future surveys, latent moderated structural equation modeling was used to estimate the association of conduct problems, depressive symptoms, and their interaction to alcohol, cigarette, and marijuana use. Moderation by age and sex was tested. The interaction of conduct problems with depressive symptoms was a strong predictor of substance use, particularly among younger adolescents. With few exceptions, adolescents with high levels of both conduct problems and depressive symptoms used substances most frequently. Conduct problems were a strong predictor of substance use, with larger effects in males; depressive symptoms were a weak predictor, with larger effects in females. Whereas conduct problems are often thought to be a primary predictor of substance use, this study revealed that depressive symptoms potentiate the relation of conduct problems to substance use. Therefore, substance use prevention efforts should target both depressive symptoms and conduct problems.

Keywords

Depressive symptoms; conduct problems; adolescence; substance use

Substance use is one of the leading causes of preventable morbidity and mortality in the United States and worldwide (Mokdad, Marks, Stroup, & Gerberding, 2004; World Health Organization, 2008; World Health Organization, 2011a). Alcohol alone is responsible for 9% of all deaths among 15–24-year-olds, over 320,000 worldwide deaths per year (World Health Organization, 2011b). Substance use typically begins in adolescence; marijuana, cigarette, and alcohol use are all most likely to onset and escalate during this period (Johnston, O'Malley, Bachman, & Schulenberg, 2011). Initiating substance use early in adolescence, before age 14, is one of the strongest predictors of developing a substance use disorder as an adult (DeWit, Adlaf, Offord, & Ogborne, 2000; Grant & Dawson, 1997; Wagner & Anthony, 2002). Nonetheless, early initiation is common; in 2010, 36% of American 8th graders reported that they had used alcohol in their lifetime, 20% had used cigarettes, and 17% had used marijuana. Excessive substance use is also relatively common among 8th graders, with nearly half of the lifetime alcohol users reporting being drunk at

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least once and nearly half of the lifetime marijuana users reporting use in the past 30 days (Johnston et al, 2011).

The serious health effects of substance use across the lifespan necessitate an understanding of its early predictors in order to formulate strategies for delaying its onset and reducing risk of future morbidity and mortality. To that end, the current paper aims to build on existing knowledge regarding the relation between internalizing and externalizing difficulties and substance use during adolescence by adding critical information regarding the effect of the interaction of these two symptom types. Namely, we quantify the individual and interactive associations of internalizing difficulties in the form of depressive symptoms (DS), and externalizing difficulties in the form of conduct problems (CP), to use of alcohol, cigarettes, and marijuana among a national sample of adolescents. We incorporate principles of both epidemiology and developmental psychopathology to provide both breadth and depth in our investigation. While CP and DS have been previously studied as predictors of substance use, no known study has quantified their association with alcohol, cigarette, and marijuana use in a national non-clinical sample; most studies use community based, clinical, or convenience samples, and many focus on a single substance. This study uses a national sample of adolescents in order to provide a broad epidemiological perspective on the relations of CP and DS to substance use.

Importantly, this study also incorporates several core principles of developmental psychopathology, including the importance of understanding comorbidity and attending to subgroup differences, such as age and gender differences, that are essential to understanding the etiology of psychopathology (Sroufe, 1997; Cicchetti & Rogosch, 1999). Despite evidence that CP and DS together are more strongly associated with substance use than either one alone (Lansford et al., 2008; Marmorstein & Iacono, 2001) most studies consider only their main effects. Studying each symptom individually is not sufficient for understanding their relation to substance use, as co-occurring mental health symptoms are known to potentiate each other in relation to a range of poor developmental outcomes (Capaldi, 1991; Capaldi, 1992; Ingoldsby, Kohl, McMahon, & Lengua, 2006). As Sroufe (1997, p. 257) has written, with respect to manifestation of psychopathology, “Comorbidity is the rule, not the exception.” Describing the role of the interaction of CP and DS is therefore an essential task for achieving a more complete understanding of the relations among mental health symptoms and substance use in adolescence.

Conduct problems and depressive symptoms predicting substance use

For the purposes of the current study, continuous measures of CP and DS symptoms, rather than measures of clinical diagnoses, are employed in order to capture relations between mental health symptoms and substance use as they vary at all levels of severity within a national sample of adolescents. CP refers to behaviors that violate social or legal norms, such as theft, property destruction, and aggression (Hinshaw, 1987). The links between CP and substance use are robust, with the adolescent CP consistently found to have a strong, positive relation with alcohol, cigarette, and marijuana use during adolescence (Brook, Zhang, & Brook, 2011; Ellickson, Tucker, Klein, & McGuigan, 2001; McMahon, 1999; Pardini, White, & Stouthamer-Loeber, 2007; Reboussin, Hubbard, & Ialongo, 2007).

Depressive symptoms (DS) refer to feelings of sadness, hopelessness, and loss of pleasure in normal activities. Unlike CP, empirical evidence regarding the relation of DS to substance use by adolescents is inconsistent. Various studies have found negative, positive, and null relations between DS and substance use during adolescence (Dodge et al., 2009; Fite, Colder, & O’Connor, 2006; Goodman & Capitman, 2000; McCaffery, Papandonatos, Stanton, Lloyd-Richardson, & Niaura, 2008). When it is detected, the relation of DS to

substance use is generally small. There are a number of possible reasons for this. It may be that the main effect of DS on substance use is indeed small, and some studies are underpowered to detect it. Alternatively, DS may relate to substance use only among certain subgroups, implying moderation by sociodemographic or risk profile characteristics. Finally, DS may relate differentially to specific substances during adolescence. The current paper tests the relation of DS to use of three substances, alcohol, marijuana, and cigarettes, among a national sample of adolescents and within age and sex subgroups. In doing so, it tests whether DS is related to substance use, and whether this relation is universal or present only in relation to certain substances or within particular subgroups.

Moderation by age and sex

The prevalence of substance use, CP, and DS vary by age and sex during adolescence. The prevalence of each increases with age across adolescence (Cohen et al., 1993; Johnston et al., 2011; Zoccolillo, 1992). Alcohol, marijuana, and cigarette use are generally more common among males than females during adolescence, though in recent years these sex gaps have begun to close or even reverse (Johnston et al., 2011). Rates of CP are higher among males than females (Keenan, Wroblewski, Hipwell, Loeber, & Stouthamer-Loeber, 2010), while DS are generally more common among females (Rushton, Forcier, & Schectman, 2002).

Few studies have examined whether these sex differences in prevalence of CP, DS, and substance use translate to sex differences in the relations between them, and those that have show mixed results. Maslowsky et al. (under review) found that the interaction of CPxDS was more strongly related to polysubstance use by female than male adolescents, while a recent longitudinal study found no sex differences in the relation of adolescent depression to young adult substance use disorders (Marmorstein, 2010).

No known study has tested age as a moderator of the relation of CP and DS to substance use. Thus, while age and sex differences in prevalence of mental health symptoms and substance use may beg the conclusion that the relations between these constructs will vary as their prevalence varies across subgroups, this question remains largely untested. A repeated truism in developmental research is that between-group differences in variables' means do not always translate to between-group differences in the relations between those variables (Miller, Malone, & Dodge, 2010). Thus, this study empirically tests whether the relations between mental health symptoms and substance use vary by age or sex during adolescence.

Interaction of conduct problems and depressive symptoms

CP and DS are two of the most commonly co-occurring symptoms of mental health problems in adolescence (Chen & Simons-Morton, 2009; Kovacs, Paulauskas, Gatsonis, & Richards, 1988; Wolff & Ollendick, 2006; Zoccolillo, 1992). Co-occurring symptoms of multiple mental health problems, compared to a single problem, are related to heightened negative outcomes in a range of domains (Aseltine, Gore, & Colten, 1998). Co-occurring CP and DS are no exception, predicting higher levels of educational failure, adult psychiatric morbidity, and, in the studies that have examined them together, adolescent substance use (Lansford et al., 2008; Marmorstein & Iacono, 2001, 2003; Pardini et al., 2007).

Despite the common co-occurrence of CP and DS during adolescence, few studies have examined the relation of their interaction to substance use. Most studies examining the interaction of CPxDS have found a significant effect, such that having high levels of both CP and DS is related to higher levels of substance use than DS or CP individually (Marmorstein & Iacono, 2001; Miller-Johnson, Lochman, Coie, Terry, & Hyman, 1998; Pardini et al., 2007). However, not all studies examining this interaction have reported the

same direction of effect. Notably, one study found an interaction such that adolescents with low CP and high DS had the highest rates of substance use (Mason, Hitchings, & Spoth, 2008); another found no significant association of CPxDS with substance use (Capaldi & Stoolmiller, 1999). The current study sought to clarify the role of CPxDS in predicting substance use by testing the interaction in a large national sample.

Aims

Using nationally representative samples of adolescent respondents to Monitoring the Future surveys, this study had two aims: 1) to quantify the association of CP, DS, and the CPxDS interaction with alcohol, marijuana, and cigarette use during adolescence and, 2) to examine whether these relations differ by age and/or sex. Accomplishing these aims will allow for the identification of specific patterns of risk incurred by mental health symptoms for individual substances moderated by age and sex. Three hypotheses were tested: 1) CPxDS would significantly predict use of each of the three substances, such that those adolescents with high levels of both CP and DS would have the highest rates of substance use; 2) the strength of the relations of DS, CP, and CPxDS would be strongest in 8th grade versus 10th and 12th grade adolescents; and 3) DS would relate more strongly to substance use among females, and CP would relate more strongly to substance use among males.

Method

Participants were from annual cross-sectional Monitoring the Future (MTF) surveys (Johnston et al., 2011). MTF tracks changes in behaviors and attitudes of American youth, with a primary focus on substance use and its predictors. Each year nationally representative samples of 8th, 10th, and 12th grade students are surveyed[1]. Approximately 16,000 students per grade are sampled from 400 public and private schools. The survey is administered at school during normal class periods (Bachman, Johnston, O'Malley, & Schulenberg, 2011). Each student is randomly assigned to complete one of six survey forms, with item composition varying somewhat by form. The current study included data from students who completed items regarding both their mental health symptoms and their substance use. Due to item availability on randomly distributed questionnaire forms, this included a random one-third of 8th and 10th graders and a random one-sixth of 12th graders surveyed (total N = 257,273). The characteristics of the sample are described in Table 1. Data for 8th and 10th grade students were from 1991–2009; data for 12th grade students were from 1991–1996 due to item availability[2].

[1]The composition of the 12th grade sample differs from that of the 8th and 10th grade samples because it does not contain students who drop out of school before spring of their senior year. To test whether differences in the composition of the 8th and 10th versus 12th grade sample contribute to relation differences among the variables, a supplementary analysis was run in which low-achieving students (GPA lower than 'C' average), those most likely to drop out before 12th grade, were excluded from the 8th and 10th grade samples. The pattern of results did not vary in this analysis versus the primary analyses.

[2]From 1997 onward, CP and DS were not measured on the same survey form in the 12th grade survey, meaning no 12th grade students provided data on both CP and DS in these years. Analyses for all 12th grade students were thus restricted to years 1991–1996, in which data for both CP and DS were available. To test for potential cohort differences, multiple group models were estimated in the 8th and 10th grade samples in which the sample was divided into three cohorts based on the year of data collection (1991–1996–1997–2002–2003–2009). Multiple group structural equation models were used to test whether there were significant differences in the relationships between DS, CP, CPxDS, and the substance use outcomes. These relationships did not vary systematically by cohort in either 8th or 10th grade. Additionally correlations of the mental health and substance use variables in 12th grade on those survey forms on which any combinations of those variables did co-occur did not differ systematically by cohort. Together, these analyses provide reasonable assurance that including only six years of data from 12th grade participants did not bias the subsequent analyses.

Measures

Conduct problems (CP) were measured via the mean of seven items on a scale of 1 = "Never" to 5 = "5 or more times", α = .76. A sample item is: "In the past twelve months, how often have you taken something not belonging to you?"

Depressive symptoms (DS) were measured via the mean of four items on a scale of 1 = "Disagree" to 5 = "Agree", α = .72. Participants were asked "How much do you agree or disagree with each of the following statements?" A sample item is: "Life often seems meaningless."[3]

Alcohol use was measured via a single standard item, "On how many occasions have you drank alcohol, more than just a few sips, in the past 30 days?" on a scale of 1 = "0" to 7 = "40+". MTF substance use items have been well-validated (Johnston et al., 2011).

Marijuana use was measured via a single standard item, "On how many occasions have you used marijuana in the past 30 days?" using the same scale as alcohol use.

Cigarette use was measured via a single standard item, "How frequently have you smoked cigarettes during the past 30 days?" on a scale of 1 = "Not at all" to 7 = "2 packs or more per day".

Analytic Strategy

Mental health symptoms, like many constructs of interest in psychological research, are best represented by latent variables. Likewise, interactions among independent variables are central to many psychological research questions. Until recently, no method was available to test interactions among latent variables. The latent structural equations (LMS) approach by Klein & Moosbrugger (2000) allows latent interactions to be estimated and tested as predictors within a structural equation modeling framework. Although other methods for estimating latent interactions have been proposed (e.g. Kenny & Judd, 1984; Marsh et al., 2007), LMS is the most rigorous and efficient approach to date (Mooijaart & Bentler, 2010).

Along with many advantages, the estimation of LMS models presents two challenges. First, traditional SEM fit indices such as RMSEA, CFI, and TLI have not yet been developed for these models. Second, these models produce only unstandardized regression coefficients, whose effect sizes are not easily interpretable. As described in further detail below, the current paper overcomes these challenges by incorporating standardization procedures not yet implemented in desktop software to standardize the effects and assess the relative contribution of the latent interaction term in explaining variance in the dependent variable.

All analyses were performed via structural equation modeling implemented in Mplus (Muthén & Muthén, 1998–2010). LMS models were estimated using full information maximum likelihood with robust standard errors.Stratum and cluster variables accounted for the nested structure of the data collection (students within schools within sampling area); sampling weights adjusted for differential sampling probability. Because of the large sample size, significance was tested using α = .001 to be conservative regarding significant findings. Moderation by age and sex was tested using the multiple group option.

CP, DS, and each of the substance use outcomes were represented as latent variables, each created using a single indicator. For CP and DS, this indicator was the mean of the items on

[3]This measure, although a brief assessment of depressive symptoms, is valid for our purposes here. The items are similar to those on the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977). In addition, it has been used successfully in other Monitoring the Future analyses (Merline, Jager, & Schulenberg, 2008; Schulenberg & Zarrett, 2006).

that scale; for substance use, it was the single item measure of use of each substance. Indicators were corrected for reliability by specifying 15% measurement error in each construct (Figure 1). Single indicators, although not ideal, were necessary because the model including the latent interaction of CPxDS could not converge with multiple indicators for the mental health constructs (L. Muthen, personal communication, September 5, 2010). The amount of measurement error to be specified was determined using sensitivity analysis (Kline, 2004; Schulenberg, Bachman, O'Malley, & Johnston, 1994). The models were estimated specifying 10%, 15%, and 20% measurement error on each construct. 15% measurement error was selected for two reasons: 1) it led to the best rates of model convergence, and 2) it represents a conservative estimate of the amount of error in the measures and avoids false inflation of the estimated relations between the variables that can result from specifying too much measurement error (Schulenberg et al., 1994).

Model estimation

Models were estimated in the following sequence: 1) measurement model, 2) structural model not including the latent interaction term, 3) structural model including the latent interaction term. Alcohol, cigarette, and marijuana use were modeled separately as dependent variables. This sequence was performed first in the models containing the total sample and then in the multiple group models testing for moderation by age and sex. All models controlled for secular trends in mean rates of substance use across the years in which the data were collected, linear trends in alcohol and cigarette use and quadratic trends in marijuana use (Johnston et al., 2011). Zero-order correlations of the study variables are contained in Table 2.

First, the measurement model (Figure 1) was estimated to ensure its fit. Model fit was assessed using Hu & Bentler's (1999) guidelines, which specify that CFI and TLI values greater than .95 and RMSEA values below .05 constitute an excellent fit. A separate measurement model was fit for each substance, and each had an excellent fit. Next, the structural model was estimated, omitting the latent interaction term (henceforth referred to as Model 1, Figure 2a). Finally, the structural model with the latent interaction was fit (henceforth referred to as Model 2, Figure 2b).

Loglikelihood comparison was used to determine whether the addition of the latent interaction term significantly improved the fit of Model 2 in comparison to Model 1 (Satorra & Bentler, 2010). A significant difference in -2*loglikelihood values between two nested models indicated an improvement in model fit versus the previous model. Significant interaction terms were probed by graphing (Aiken & West, 1991). This sequence was repeated for each of the three substance use outcomes in the total sample. Table 3 depicts the results of the nested model comparisons.

The same analytic sequence was repeated in multiple group models for each substance by sex (male, female) and age (grade 8, 10, 12). The measurement model was estimated and its fit was assessed in the same manner as in the total sample. Because each construct was created with a single indicator, the measurement model was invariant across groups by default. In Models 1 and 2, equivalence of structural parameters (factor means and variances, regression coefficients, and correlations of residual variances) across groups was tested by comparing nested models with these parameters fixed versus freed. Equivalence of structural parameters across groups was tested using the robust X^2 comparison (Satorra & Bentler, 2010). Loglikelihood comparisons tested whether allowing the relation of the interaction term to the outcome to vary across groups in multiple group comparisons improved the fit of the model. Table 4 summarizes the estimates of latent variable means and variances; Table 5 summarizes regression coefficients and factor correlations.

Model fit indices such as CFI, TLI, RMSEA, and X^2 have not yet been developed for LMS models. Therefore, the overall fit of each model was assessed in two steps. First, CFI, TLI, RMSEA, and X^2 values were obtained from Model 1, which produced these fit indices because it was estimated using maximum likelihood without numeric integration. Second, the loglikelihood ratios of Model 1 and Model 2 were compared[4]. Although the absolute fit of Model 2 could not be determined, its relative fit versus Model 1 was indicated by the results of this loglikelihood ratio test.

Standardized regression coefficients are not provided by Mplus for LMS models. The standardized beta coefficients presented here were obtained via a two-step process. The standardized estimates of main effects of DS and CP were obtained from Mplus output for Model 1. The effect of the interaction was obtained by standardizing the unstandardized estimate from Model 2 (Mooijaart & Satorra, 2009)[5]. Importantly, main effects and interactions are independent in LMS models (Klein & Moosbrugger, 2000), allowing their estimates to be obtained from separate models. The total percentage of variance explained was computed by summing the percentage of variance explained by the main effects of CP and DS in Model 1 and the percentage of variance explained by the interaction term in Model 2.

Results

Results of all analyses are summarized in Table 5. The first set of analyses pertained to the total sample of 8th, 10th, and 12th grade students combined. Analyses were conducted separately for alcohol, marijuana, and cigarette use. In the model predicting alcohol use, CP was a strong positive predictor (i.e., higher CP predicted higher alcohol use), DS was a weak negative predictor (i.e., higher DS predicted lower alcohol use), and CPxDS was not significant. Similarly, in the models predicting marijuana and cigarette use; CP was a strong positive predictor, and DS was a weak negative predictor. In contrast to the results for alcohol use, CPxDS was a significant positive predictor of both marijuana and cigarette use (Figure 3). As shown in Figure 3, it is only when both CP and DS are especially high that levels of cigarette and marijuana are high.

Moderation by sex

Two group (male and female) multiple group models were estimated to test for sex differences in the relations of DS, CP, and CPxDS to each of the substances. With regards to alcohol, CP was a significantly larger predictor of alcohol use for males than for females. DS was a significantly larger predictor for females than for males. CPxDS was not a significant predictor of alcohol use for either males or females.

With regards to marijuana, CP was a significantly larger predictor of alcohol use for males than for females. DS was a significantly larger predictor for females than for males. The relation of CPxDS to marijuana use, though significant for both sexes, did not vary for males versus females.

Finally, with regards to cigarette use, CP was again a larger predictor of cigarette use for males than females, and DS was again a larger predictor for females than males. CPxDS was a significant predictor for both males and females but did not differ between them.

[4]Model 1 was first re-estimated using the integration algorithm in order to obtain a -2* loglikelihood value comparable to that of Model 2.

[5]Mooijaart & Satorra present a formula for determining the percentage of variance in the dependent variable explained by the interaction term. The standardized beta coefficient presented here is the square root of the percentage of variance explained. The sign of the coefficient is obtained from the unstandardized output of Mplus.

In summary, there was no moderation of the relation of CPxDS to substance use by sex. CPxDS was not a significant predictor of alcohol use for either sex. CPxDS did predict use of marijuana and cigarettes among both males and females, but there were no sex differences in these effects. The main effects of CP and DS were moderated by sex, however: CP was a larger predictor of use of each of the three substances among males than females, while DS was a larger predictor for females than males.

Moderation by age

Three group (8^{th}, 10^{th}, and 12^{th} grade) multiple group models were estimated to test for differences by age group in the relations of DS, CP, and CPxDS to each of the substances. The relation of DS to alcohol use did not vary significantly by grade. The relation of CP to alcohol use was comparable among the three grades, though it was significantly smaller among 10^{th} graders than 8^{th} and 12^{th} graders. CPxDS showed a larger age difference in regards to alcohol (Figure 4a). Among 8^{th} graders, this effect was positive (B = .24, $p < .001$). Among 10^{th} graders, it was not significant. Among 12^{th} graders, it was negative (B = −.08, $p < .001$), though smaller in magnitude than the positive effect among 8^{th} graders. That is, among 8th graders, highest alcohol use was found for those highest on CP and DS, whereas for 12th graders, highest alcohol use was found for those highest on CP and lowest on DS.

For marijuana use, the multiple group model was estimated only for 10^{th} and 12^{th} grade students. The model was unable to converge in the 8^{th} grade sample due to low variance in marijuana use among this age group. DS was a stronger predictor for 10^{th} than 12^{th} graders. CP was a stronger predictor for 12^{th} versus 10^{th} graders. CPxDS did not differ in its relation to marijuana use among 10^{th} versus 12^{th} grade students, though it was a positive predictor in each grade (B = .10, $p < .001$ and B = .08, $p < .001$, respectively).

In regards to cigarette use, DS had a fairly consistent positive association across grades 8–12, though it grew slightly stronger in higher grades. The positive associations of CP and CPxDS to cigarette showed the opposite pattern by age, with effects decreasing in higher grades. Among 8^{th} graders, the positive interaction was quite strong (B = .43, $p < .001$) translating to levels of cigarette use that were 1.5 SD higher among those adolescents who had high levels of both CP and DS versus those with high levels of CP and low levels of DS (Figure 4b). Among 12^{th} graders, the effect was smaller (B = .07, $p < .001$), but it still translated to a .5 SD increase in use among those with high CP and DS versus those with high CP and low DS.

In summary, while the relations of DS, CP, and CPxDS clearly differ by age, these results suggest that the age differences are both substance- and symptom-specific. The effects of CP and DS were fairly consistent across the three grades, with CP having a stronger relation to substance use than DS. The largest age differences were seen with regards to the interaction, whose effects were strongest in 8^{th} graders and decreased among older students.

Discussion

This study examined the relations of depressive symptoms (DS), conduct problems (CP), and their interaction (CPxDS) to alcohol, cigarette, and marijuana use among a national samples of 8^{th}, 10^{th}, and 12^{th} grade American adolescents over the past two decades. It aimed to add to the substantial existing literature examining CP and DS individually as predictors of substance use by testing the interaction of CPxDS, clarifying the role of DS, for which there are contradictory findings, and examining differences in the relations of DS, CP, and CPxDS to substance use by age, sex, and substance.

Interaction of conduct problems and depressive symptoms

The primary aim of this paper was to test the relation of the interaction of CPxDS to alcohol, marijuana, and cigarette use. As hypothesized, this interaction was significant in most models, such that those adolescents who had high levels of both CP and DS had the highest levels of substance use, particularly marijuana and cigarette use. Also as hypothesized, the largest associations of the interaction with substance use were seen among 8th grade students. For example, 8th grade students who had high levels of both CP and DS had levels of cigarette use 1.5 SD higher than those who had equivalent levels of CP but low levels of DS (Figure 4b). Both cigarette and marijuana use become more normative with age; use among 10th and especially 12th graders is less associated with internalizing and externalizing difficulties. In contrast, in 8th grade when use is less normative, high use is thus a more extreme behavior that is more associated with emotional and behavioral difficulties.

With regards to alcohol use, the interaction also had its largest effect in 8th graders, where it explained 6% of the variance in alcohol use. In 12th grade students, the interaction was negative, such that, among those with high levels of CP, those who had higher DS used less alcohol than those with low DS, but among those with low CP, those with high DS used more alcohol. The shifting direction of the effect of CPxDS from positive in 8th grade, to non-significant in 10th grade, to negative in 12th grade, particularly in terms of the DS component of the interaction, underscores the sometimes paradoxical nature of alcohol use during late adolescence (and early adulthood) whereby it gains some pro-social associations (Maggs & Schulenberg, 2005; Patrick & Schulenberg, 2011) and is thus less a function of low mood than it appears to be in earlier adolescence (Crosnoe, 2011).

Finally, although CPxDS was a significant predictor of substance use among both male and female adolescents, this relation was not moderated by sex. In other words, the relation of CPxDS to alcohol, marijuana, and cigarette use was similar for male and female adolescents.

Overall, these results are consistent with the few other studies that have examined the interaction of CP and DS as a predictor of substance use, and they also speak to some gaps not yet addressed by previous studies. Using data from the Pittsburgh Youth Study, Pardini et al. (2007) found that high levels of both CP and DS related to the highest levels of alcohol use among this all-male adolescent sample. In a sample of 340 African-American adolescents, Miller-Johnson et al. (1998) found a significant CPxDS interaction: adolescents with heightened CP and DS in 6th grade had higher levels of alcohol and marijuana use in 8th grade than those with high levels of just one symptom in 6th grade. Mason et al. (2008) also noted a significant CPxDS interaction in a sample of 429 rural adolescents, though the interaction was negative, such that adolescents with high CP and low DS used the most substances (a combined measure of alcohol, cigarette, and marijuana use).

The current study builds on this previous work examining the relation of CPxDS to substance use in fairly homogeneous samples by testing the interaction in a large national sample, allowing for population-level generalization of the results. It also individually characterizes the relation of CPxDS to alcohol, cigarettes, and marijuana use. These substance-specific analyses revealed that the effect of CPxDS is particularly strong for marijuana and cigarette use, though it also has a strong relation to alcohol use among 8th grade students. Furthermore, for alcohol, we find that for 12th graders, it is the combination of high CP and low DS (i.e., negative CPxDS interaction) that is associated with higher use, showing the developmental and substance-specific limits of the positive CPxDS interaction.

Role of depressive symptoms in substance use

The second aim of this study was to clarify the relation of DS to substance use among adolescents. Whereas CP has consistently been associated with substance use in past

research, and was in the current study as well, previous studies have produced conflicting results regarding whether DS relates to substance use, and if so, whether the association is negative or positive. The results suggest that DS generally has a small but positive relation to use of alcohol, marijuana, and cigarettes. Exceptions were that DS had a small negative relation to alcohol and marijuana use in the models including the total sample. In multiple group comparisons, the effect of DS was stronger for female than male adolescents for use of all three substances, though the effect was small in both sexes. DS related most strongly to cigarette use, and it showed increasingly strong associations with cigarette use in older adolescents.

While these results indicate that DS alone is not a strong risk factor for contemporaneous substance use, the role of DS in adolescents' substance use should not be disregarded. In fact, as seen in Figures 3 and 4, DS potentiates the relation of CP to substance use. With the exception of alcohol use in 12th grade, high levels of DS in addition to high levels of CP were associated with significantly higher rates of substance use than high rates of CP alone. This result provides some insight into some previous studies' conclusions that DS is not related to substance use during adolescence. Such studies tested the main effect of DS, which we have shown to be small, but may have overlooked the significant interactive effect it has with CP.

Estimating latent variable interactions

The use of latent moderated structural equations (LMS) models to estimate the latent variable interaction of CP and DS was an important element of this study, in which we aimed to demonstrate the utility of these models in testing research questions involving interactions between latent variables. The current paper provides a needed substantive demonstration of latent interaction methodology. Symptoms of mental health problems are complex constructs best represented as latent variables, and testing the interaction effect of two sets of symptoms thus requires estimation of a latent variable interaction. Although computationally intensive, LMS models are well suited for this task. The two primary limitations of LMS models, lack of fit indices and lack of standardized regression coefficients, can be overcome using the methods described here. Namely, relative fit of the LMS model can be judged by comparing to a well-fitting nested model estimated without the latent interaction term, and standardized regression coefficients can be computed by hand using the method described by Mooijaart & Satorra (2009). With the addition of these two steps in the analytic process, LMS models are a useful and accessible method for investigating research questions that imply interactions among latent variables.

Strengths, limitations and implications

Important strengths of this study include the use of nationally representative data on 8th, 10th, and 12th graders from cohorts spanning the past two decades (providing strong basis for generalizability), the substantively important emphasis on how depressive symptoms and conduct problems interact to predict different forms of substance use, and the methodologically important emphasis of how to model the interaction as a latent term. Of course, there are limitations. The data are cross-sectional, meaning that apparent age differences must be interpreted with caution as the sample compositions vary by grade. The data are also self-report and may be subject to method covariance as both the mental health symptoms and substance use are reported by the participant. The measures of mental health are brief (four items for DS, seven for CP), and represent symptoms, not clinical disorders. However, the aim of the study was not to capture clinical disorders but rather to measure symptom-level fluctuations in the general population and model their relation to substance use. Therefore, the study's aims were not unduly impeded by brief measurement. Further, limitations of the brief measures of mental health are mitigated by the strengths of the large

national sample, particularly its diversity and the generalizability of conclusions that it affords. Finally, testing moderating effects of race/ethnicity and socioeconomic status on the relation of DS, CP, and CPxDS was beyond the scope of the current study. These important questions will be addressed in future studies.

Despite some limitations, this study offers several new insights into the relations among mental health and substance use in adolescence. It builds upon work in the area of mental health and substance use epidemiology by moving beyond establishing national prevalence of individual behaviors to quantifying the relations that exist between them during adolescence on a population level and within age and sex subgroups. For the first time in a national sample, it quantifies the association of the interaction of CPxDS to use of each of three substances, alcohol, marijuana, and cigarettes, revealing that the interaction contributes significantly to the prediction of use of these three substances. It also speaks to questions fundamental to developmental psychopathologists, including age and sex differences and the interactive effects of co-occurring mental health symptoms. In particular, it demonstrates that the effect of the interaction is strongest among younger adolescents and that it does not vary by sex, arguing for early identification and intervention into co-occurring mental health problems in both male and female adolescents as a strategy for preventing substance use initiation. Furthermore, it demonstrates that the interaction shifts direction for 12th graders regarding alcohol use, highlighting the paradoxical prosocial aspects of alcohol use during late adolescence.

Most importantly, the results of this study reveal that DS, despite its small main effect relation with substance use, plays an important role in predicting substance use through its interactive relation with CP. CP is often thought to be a primary driving factor of adolescent substance use, but the current study suggests that this relation is highly dependent on concurrent levels of DS. Thus, the role of DS in adolescent substance use should not be overlooked. DS remains an important predictor to be measured in studies of adolescent substance use. Future studies focused on the development of substance use among adolescents should include DS and CPxDS as predictors. Additionally, preventive interventions should be specifically tailored to those youth who evidence multiple, co-occurring mental health problems in early adolescence. Interventions that delay onset of substance use in adolescence have been shown to reduce rates of problematic substance use in young adulthood (Spoth, Trudeau, Guyll, Shin, & Redmond, 2009). The results of the current study provide clear evidence that targeting young adolescents who display multiple mental health symptoms for early intervention is a promising strategy for reducing early adolescent substance use and its associated morbidity and mortality implications in adolescence and beyond.

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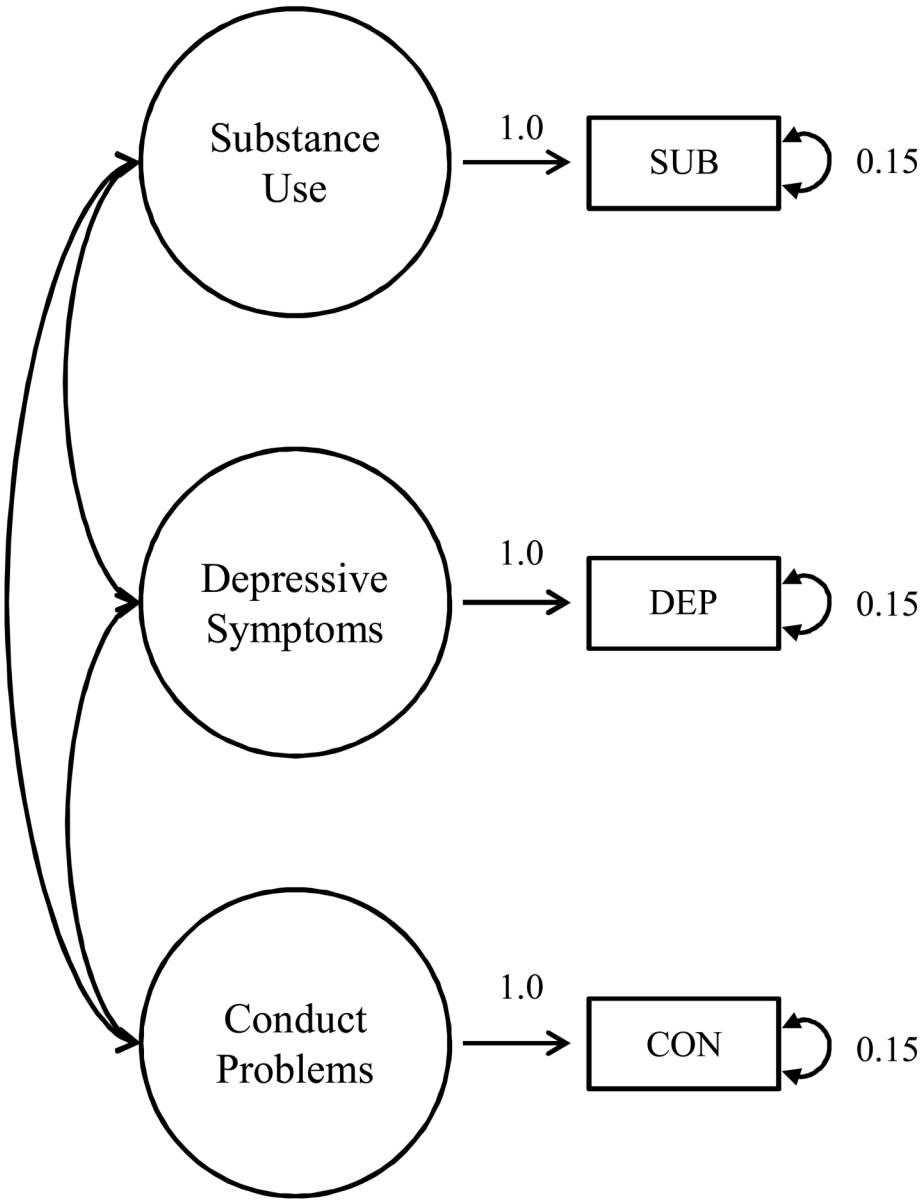

Figure 1.
Measurement model. Each latent variable was created using a single indicator of that construct. Single, rather than multiple, indicators were necessary in order for models to converge. Unique variance for each single indicator was fixed at 15%. A separate measurement model was estimated for each substance: alcohol, marijuana, and cigarettes.

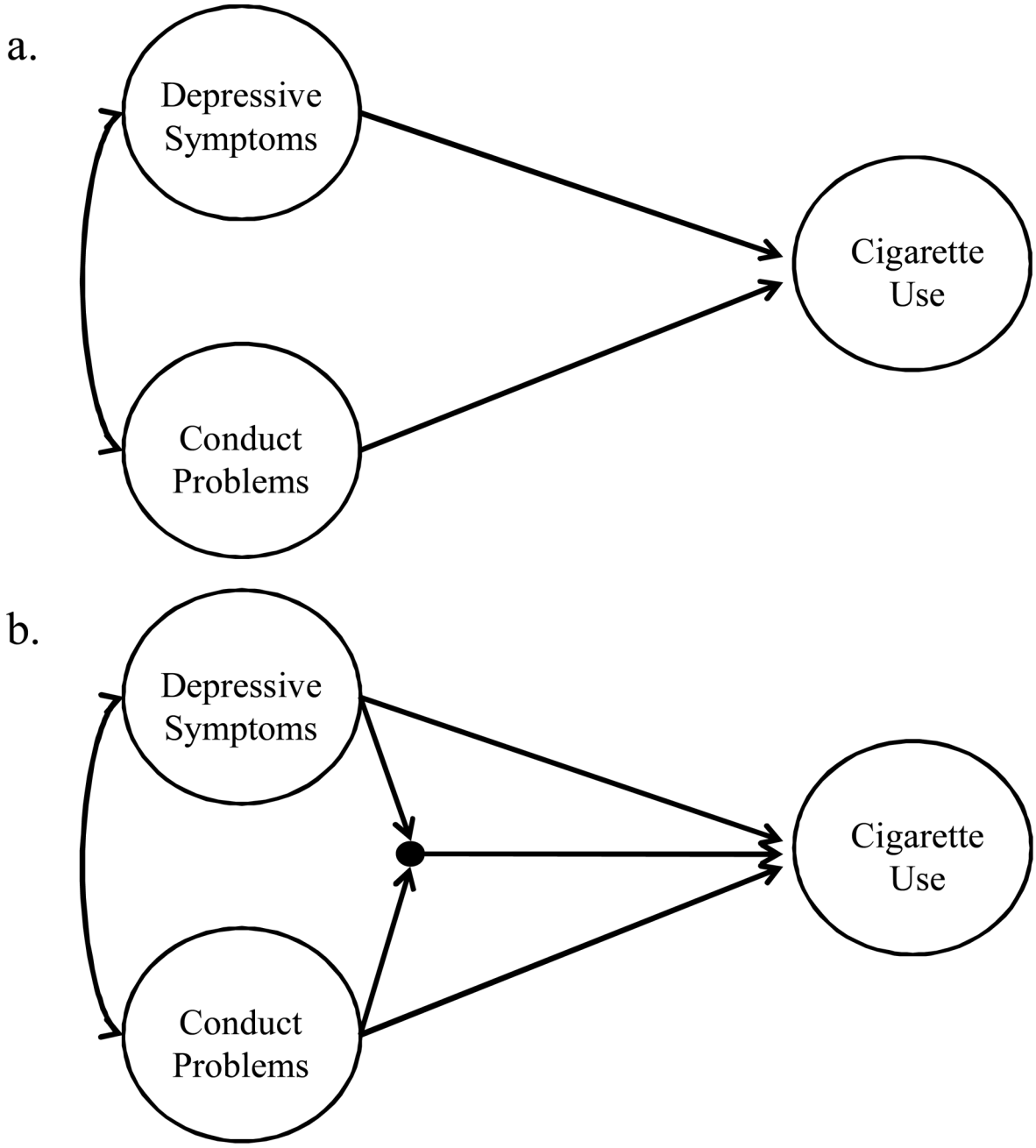

Figure 2.
a. Model 1: Model with main effects of depressive symptoms and conduct problems predicting substance use. Each substance (alcohol, marijuana, cigarettes) was modeled separately as the dependent variable. b. Model 2: Model including the latent interaction of depressive symptoms x conduct problems, depicted as a filled circle per Mplus standard notation. A third model was included in multiple group comparisons. In this model, the effect of the latent interaction was allowed to vary freely across groups, whereas it was constrained to be equal across groups in Model 2. Each substance (alcohol, marijuana, cigarettes) was modeled separately as the dependent variable.

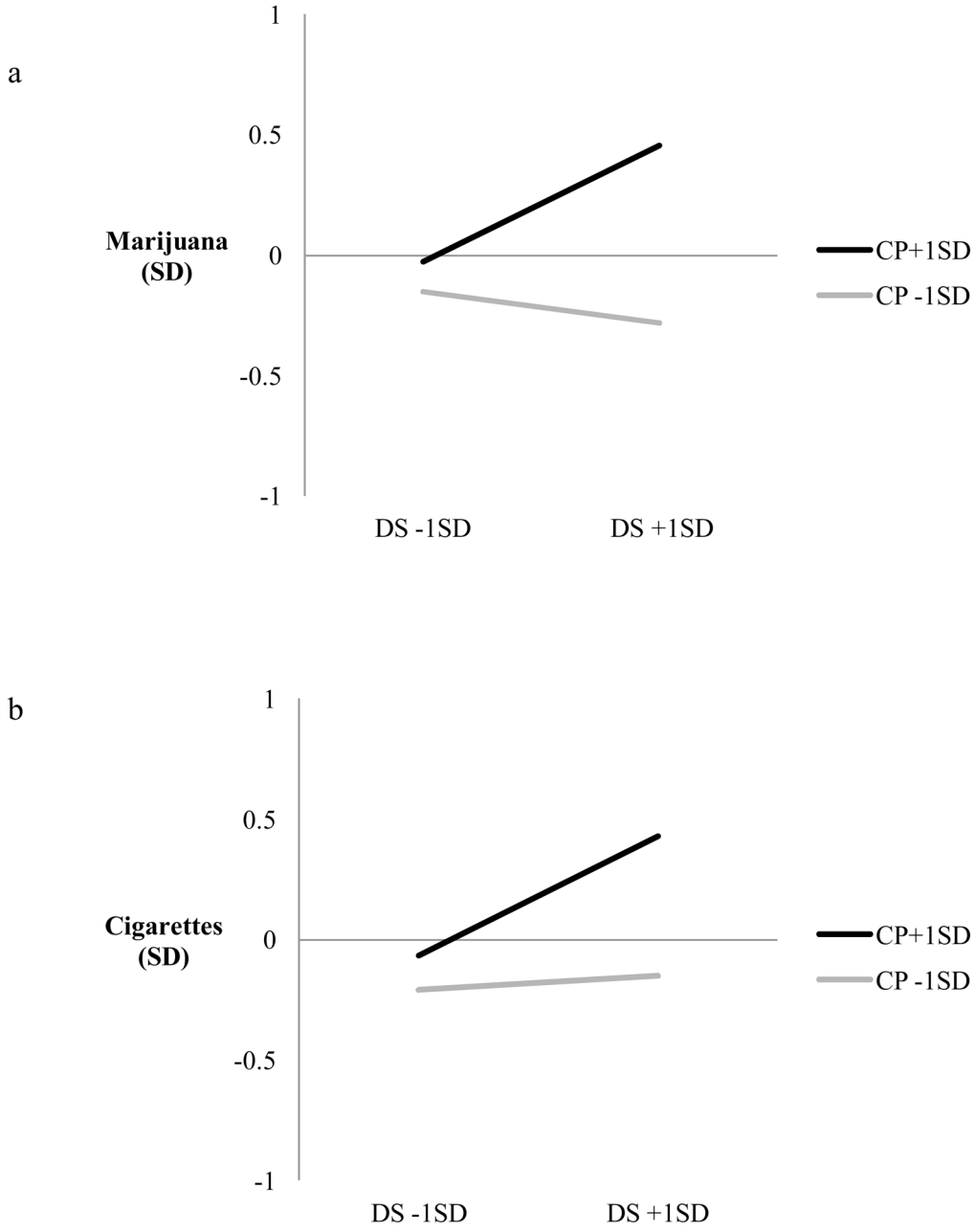

Figure 3.

Interaction of depressive symptoms (DS) and conduct problems (CP) predicting a) marijuana (B = .25, $p < .001$), and b) cigarette use (B = .18, $p < .001$) during the past 30 days in the full sample of 8th, 10th, and 12th grade students combined. The effect of the interaction was not significant in relation to alcohol use.

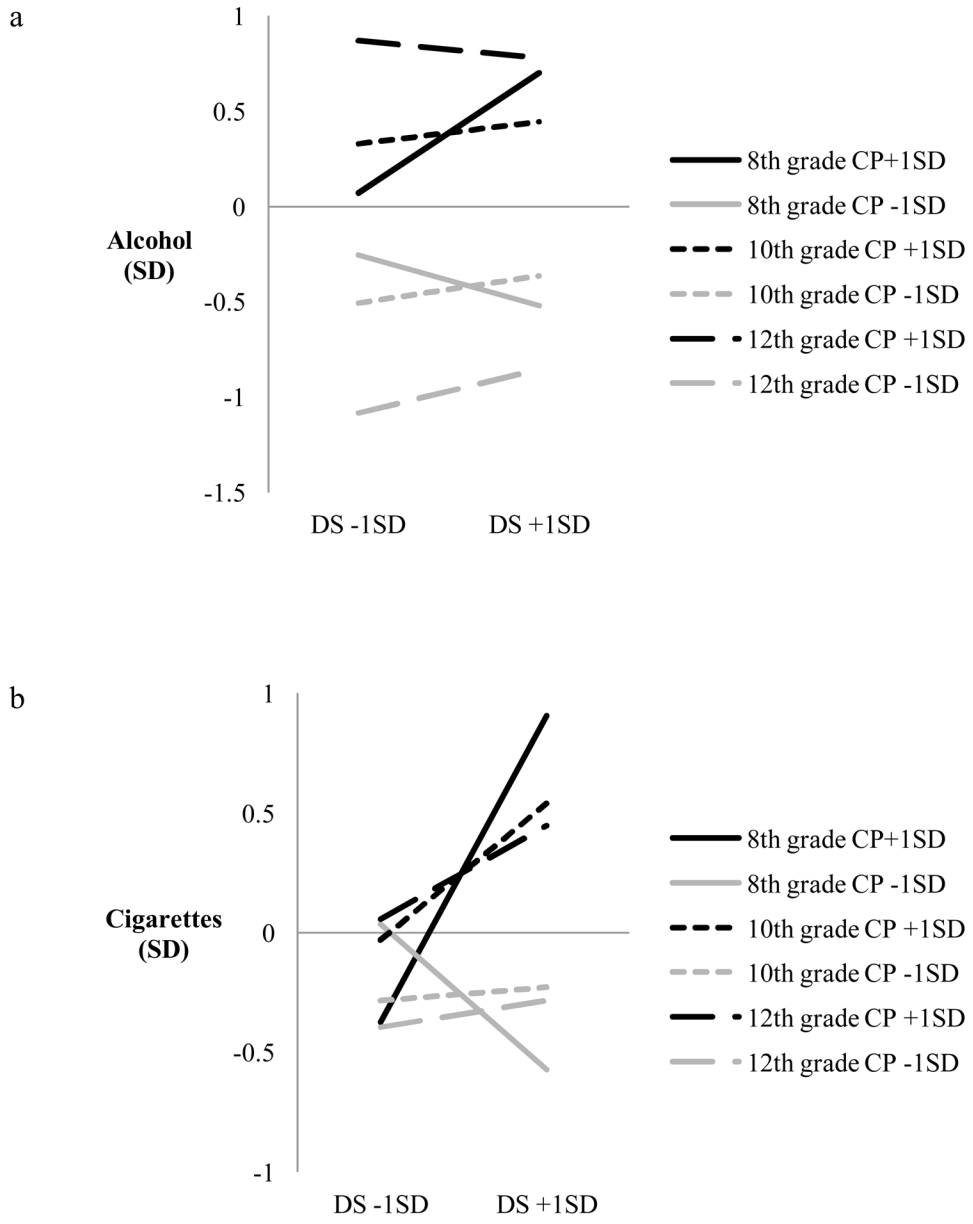

Figure 4.

Interaction of depressive symptoms (DS) and conduct problems (CP) by grade. Models predicting (a) alcohol (8^{th} grade: B = .24, $p < .001$; 10^{th} grade: B = −.01, ns; 12^{th} grade: B = −.08, $p < .001$) and (b) cigarette use (8^{th} grade: B = .43, $p < .001$; 10^{th} grade: B = .16, $p < .001$; 12^{th} grade: B = .13, $p < .001$) during the past 30 days in multiple group models by grade. The effect of the interaction in relation to marijuana use did not differ significantly by grade.

Table 1

Sample characteristics by grade

	8th grade (*N* = 127,272)	10th grade (*N* = 114,251)	12th grade (*N* = 15,750)
Sex (%)			
Male	48.7	48.8	47.6
Female	51.3	51.3	52.4
Race (%)			
White	59.6	67.5	68.3
Black	14.9	12.7	13.9
Hispanic	11.6	10.3	9.2
Other	13.8	9.5	8.7
		M (SD)	
Depressive Symptoms	1.96 (0.97)	1.97 (0.94)	1.94 (0.88)
Conduct Problems	1.39 (0.64)	1.36 (0.61)	1.32 (0.53)
Cigarette Use	1.26 (0.77)	1.43 (0.99)	1.71 (1.27)
Alcohol Use	1.38 (0.90)	1.70 (1.18)	2.15 (1.48)
Marijuana Use	1.17 (0.74)	1.40 (1.16)	1.47 (1.23)

Table 2

Zero-order correlations of study variables

	1	2	3	4	5
1. Conduct problems	--				
2. Depressive symptoms	.23	--			
3. Alcohol use	.36	.14	--		
4. Marijuana use	.30	.12	.45	--	
5. Cigarette use	.30	.19	.44	.45	--

Note. All correlations are significant, $p < .001$.

Table 3

Nested model comparisons

Substance	Sample	Model	Free parameters	Δ-2* loglikelihood
Alcohol	Full sample	1.0	10	
		2.0	11	5.0
	Multiple group by gender	1.0	20	
		2.0	21	4.1
		3.0	22	4.4
	Multiple group by grade	1.0	26	
		2.0	27	84.7*
		3.0	29	355.6*
Marijuana	Full sample	1.0	10	
		2.0	11	174.1*
	Multiple group by gender	1.0	21	
		2.0	22	118.9*
		3.0	23	13.4
	Multiple group by grade (grades 10/12 only)	1.0	20	
		2.0	21	12.4
		3.0	22	0.0
Cigarettes	Full sample	1.0	10	
		2.0	11	241.9*
	Multiple group by gender	1.0	21	
		2.0	22	190.0*
		3.0	23	1.3
	Multiple group by grade	1.0	28	
		2.0	29	276.0*
		3.0	32	58.5*

Note. Δ-2*loglikelihood is distributed as X^2. Degrees of freedom are the difference in the number of free parameters in the two models being compared. Model 1: main effects only with no interaction term. Model 2: main effects and interaction term (in multiple group models, effect of interaction is held equal across groups). Model 3: allows effect of interaction to vary across multiple groups.

*$p < .001$

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Table 4

Estimates and equivalence of latent variable means and variances in single and multiple group structural equation models

				Depressive Symptoms (DS)		Conduct Problems (CP)		Substance Use (Alcohol, Marijuana, or Cigarettes)	
Substance	**Model**	**Group**	**N**	**Mean**	**Variance**	**Mean**	**Variance**	**Mean**	**Variance**
Alcohol	Full Sample		254,587	0.00	0.60	0.00	0.17	0.00	0.96
	Gender	Male	120,479	0.00 [a]	0.72 [a]	0.00 [a]	0.43 [a]	0.00 [a]	1.21 [a]
		Female	127,568	0.04 [a]	0.82 [a]	−0.20 [a]	0.19 [a]	−0.13 [a]	0.82 [a]
	Grade	8	125,328	0.00	0.76	0.00 [a]	0.34 [a]	0.00 [a]	0.68 [a]
		10	113,515	0.00	0.76	−0.03 [a]	0.31 [a]	0.32 [a]	1.18 [a]
		12	15,744	0.00	0.76	−0.07 [a]	0.24 [a]	0.77 [a]	1.87 [a]
Marijuana	Full Sample		256,273	0.00	0.60	0.00	0.17	−0.06	0.77
	Gender	Male	121,347	0.00 [a]	0.72 [a]	0.00 [a]	0.43 [a]	0.00	1.03 [a]
		Female	128,340	0.04 [a]	0.78 [a]	−0.20 [a]	0.19 [a]	0.00	0.59 [a]
	Grade	8							
		10	114,251	0.00	0.73	0.00 [a]	0.30	−0.08 [a]	1.13 [a]
		12	15,748	0.00	0.73	−0.04 [a]	0.30	−0.01 [a]	1.34 [a]
Cigarettes	Full Sample		256,421	0.00	0.60	0.00	0.17	0.00	0.64
	Gender	Male	121,892	0.00 [a]	0.72 [a]	0.00 [a]	0.43 [a]	0.00 [a]	0.77 [a]
		Female	128,714	0.04 [a]	0.79 [a]	−0.20 [a]	0.19 [a]	−0.02 [a]	0.66 [a]
	Grade	8	126,656	0.00	0.76	0.00 [a]	0.34 [a]	0.00 [a]	0.50 [a]
		10	114,018	0.00	0.76	−0.03 [a]	0.31 [a]	0.17 [a]	0.83 [a]
		12	15,747	0.00	0.76	−0.07 [a]	0.24 [a]	0.46 [a]	1.38 [a]

Note. Estimates of means and variances are from Model 1, model estimated without latent interaction.

[a]Estimates were significantly different across groups, $p < .001$

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Table 5

Results of single and multiple group structural equation models

				Depressive Symptoms (DS)	Conduct Problems (CP)	DSxCP						
Substance	**Model**	**Group**	**N**	**B**	**B**	**B**	**R^2 total**	**CFI**	**TLI**	**RMSEA**	**X^2**	**DF**
Alcohol	Full Sample		254,587	−0.07	0.62	0.02 n/s	0.36	1.00	0.99	0.01	69.54	2
	Gender	Male	120,479	0.04 [a]	0.41 [a]	0.01[b]	0.19	0.99	0.96	0.02	212.78	4
		Female	127,568	0.08 [a]	0.38 [a]	0.01[b]	0.18					
	Grade	8	125,328	0.07	0.46 [a]	0.24[a]	0.29	0.99	0.98	0.02	212.08	10
		10	113,515	0.06	0.41 [a]	−0.01[a] n/s	0.19					
		12	15,744	0.04	0.45 [a]	−0.08[a]	0.26					
Marijuana	Full Sample		256,273	−0.07	0.57	0.25	0.21	1.00	0.99	0.01	39.92	2
	Gender	Male	121,347	0.03 [a]	0.37 [a]	0.23	0.21	1.00	0.99	0.01	59.92	4
		Female	128,340	0.06 [a]	0.35 [a]	0.22	0.19					
	Grade	8										
		10	114,251	0.05 [a]	0.38 [a]	0.10[b]	0.17	0.97	0.95	0.02	274.75	7
		12	15,748	0.04 [a] n/s	0.47 [a]	0.08[b]	0.24					
Cigarettes	Full Sample		256,421	0.06	0.47	0.18	0.30	0.99	0.98	0.01	74.31	2
	Gender	Male	121,892	0.11 [a]	0.32 [a]	0.19	0.17	0.99	0.96	0.02	222.02	4
		Female	128,714	0.15 [a]	0.31 [a]	0.14	0.18					
	Grade	8	126,656	0.13 [a]	0.37 [a]	0.49[a]	0.43	0.99	0.97	0.02	207.75	8
		10	114,018	0.15 [a]	0.30 [a]	0.13[a]	0.16					
		12	15,747	0.16 [a]	0.27 [a]	0.07[a]	0.13					

Note. All beta coefficients are standardized.

[a] coefficients were significantly different across groups, $p < .001$.

[b] adding interaction did not improve fit of model versus main effects only model.