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Diminished Alternative Reinforcement as a Mechanism Linking Conduct Problems and Substance Use in Adolescence: A Longitudinal Examination

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Abstract

Aims—To determine whether diminished alternative reinforcement (i.e., engagement and enjoyment from substance-free activities) mediated the longitudinal association of conduct problems with substance use in early-mid adolescence.

Design—Structural equation modeling tested whether the association between Wave 1 (baseline) conduct problems and Wave 3 (24-month follow-up) substance use outcomes was mediated by diminished alternative reinforcement at Wave 2 (12-month follow-up). Additional analyses tested whether sex and socioeconomic status moderated this association.

Setting—Ten high schools in Los Angeles, CA, USA, 2013–2015.

Participants—Students (N=3,396, 53.5% female, Mean[SD] age at Wave 1 baseline = 14.1[0.42] years).

Measurements—Self-reported conduct problems (11-item questionnaire), alternative reinforcement (44-item questionnaire), and use of alcohol, marijuana, and combustible cigarettes over the past 6-months (yes/no) and the past 30-days (9-level ordinal response based on days used in past 30 days).

Results—Significant associations of Wave 1 conduct problems with Wave 3 marijuana use over the past six months (β=.25) and past 30 days (β=.26) were mediated by Wave 2 diminished alternative reinforcement ($\beta_{\text{indirect effect}}$: 6 months=.013, 30 days=.017, *p*s<.001). Associations of conduct problems with alcohol or combustible cigarette use were not mediated by alternative reinforcement. All associations did not differ by sex and socioeconomic status.

Conclusions—Diminished alternative reinforcement may be a modifiable mechanism linking early adolescent conduct problems and subsequent marijuana use that could be targeted in prevention programs to offset the adverse health and social sequelae associated with comorbid conduct problems and marijuana use in early-mid adolescence.

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Keywords

Conduct Problems; Alternative Reinforcers; Behavioral Economics; Adolescents; Substance Use; Alcohol; Cigarette; Marijuana

Introduction

The motivation to pursue positive reinforcement through activities that provide pleasure is potentiated during the developmental window of adolescence when neural circuits underpinning reward-seeking behavior [1–2] mature much more rapidly than the circuits that underlie impulse control and effective decision-making [2]. For these reasons and others, adolescence is a vulnerable period for use of licit and illicit substances, which are powerful mood-elevating reinforcers. According to behavioral economic theory and extant data, the engagement in drug-free activities that are pleasurable (i.e., alternative reinforcers) may satisfy the drive for reinforcement and thus reduce risk of resorting to use of drugs as a means of reinforcement [3–10]. In adolescence, alternative reinforcers can include drug-free hobbies, such as, reading, academic interests, school organizations/clubs, volunteering, spending time with non-drug using family/friends, and other activities [5,11]. A higher density (i.e. frequency engagement×pleasure derived) of alternative reinforcement predicts reduced risk of adolescent substance use initiation and progression of various drugs of abuse [11]. However, research is fairly limited in its understanding of how alternative reinforcers may act as a mediator between early substance use risk factors and substance use itself in adolescence.

One particularly salient substance use risk factor is conduct problems (CPs; e.g. lying, stealing, getting into fights). CPs reflect a range of behaviors that occur in varying degrees of frequency depending on the severity. For example, approximately 19% of 9th grade boys and 12% of 9th grade girls reported stealing something greater than a $5 value compared to only 8% of boys and 5% of girls reported attacking someone [12]. A number of studies have established a strong relation between adolescent CPs and substance use [12–20]. Among adolescents who engage in both CPs and substance use, CPs typically precede initiation into substance use [21–23]. This relationship has been shown to be robust even when co-occurring with other psychopathologies, such as depression and anxiety [18–20].

Examining mechanisms (i.e. alternative reinforcers) linking CPs and substance use will inform etiological models of addiction comorbidity and perhaps provide new pathways to intervene on externalizing risk factors that emerge early in life. We speculate that adolescents with CPs find healthy alternative non-drug reinforcers as less stimulating based on research demonstrating that adolescents high in CPs report lower autonomic physiological response to picture slides regardless of their emotional valence compared to those without CPs [28]. Thus, adolescents high in CPs may not find healthy pro-social activities as reinforcing as the rush experienced from breaking rules and these teens may turn towards substance use as a means of deriving high levels of reinforcement. Other explanations (e.g. peer substance use, socioeconomic status) may also explain the

association between alternative reinforcement, CPs, and substance use; thus, it is critical to examine potential confounding variables that might explain the association.

Mediational models using the same sample as the current study have shown that alternative reinforcers link CPs with substance use using cross-sectional data [4]. Results supported the hypothesized temporal model with adolescents who reported higher levels of CPs engaging in fewer alternatively reinforcing activities and these, in turn, being associated with higher levels of reported substance use. However, this study was limited in its ability to examine the longitudinal nature of the association between these important variables and thus directionality of the association remains unclear.

The current study is the first study to test the role of alternative reinforcers longitudinally as a critical risk factor linking CPs and adolescent substance use across adolescence. Here we advance extant literature by studying alternative reinforcement as a mediator of CPs and substance use comorbidity: (1) longitudinally during the transition to high school (2) while also simultaneously examining a variety of substance use outcomes (i.e. alcohol, marijuana, and cigarettes use). We hypothesize that teens who report more CPs at Wave 1 will report fewer alternatively reinforcing activities at Wave 2 (i.e. 12-month follow-up) and these will, in turn, be associated with greater reports of combustible cigarette, alcohol, or marijuana use at Wave 3 (i.e. 24-month follow-up).

Methods

Participants and Procedures

Data from the Happiness and Health study, a longitudinal survey of substance use and mental health among students from 10 public high schools in the Los Angeles area, was utilized [29]. Schools were selected based on their representation of demographic characteristics; the percent of students eligible for free lunch (i.e., student's parental income < 185% of the national poverty level) across the participating schools was 31.1% (*SD*=19.7, range 8.0% – 68.2%). Students who were not enrolled in special education or English as a Second Language Programs (*N*=4,100) were eligible. Of the 4,100 eligible students, 3,874 (94.5%) assented to participate in the study, of which 3,396 (82.8%) provided active written parental consent. Data collection involved 3 annual assessments: Wave 1 (baseline; 9th grade, fall 2013, N = 3,383), Wave 2 (12-month follow-up; 10th grade, fall 2014, number of students surveyed = 3,277), and Wave 3 (24-month follow-up; 11th grade, fall 2015, number of students surveyed = 3,235). The study had a 95.6% retention rate across the three waves. Paper-and-pencil surveys were administered at each wave in the students' classrooms. Students who were absent the day of data collection completed telephone, postal mail, or online surveys. The University of Southern California Institutional Review Board approved this study.

Measures

Conduct problems—An 11-item conduct problem (CP) measure that has been used with other longitudinal adolescent samples was used to assess past six-month behavior at Wave 1 (e.g., stealing, destroying property, lying, physically fighting)[30–32]. The Cronbach α was .

79. The frequency of each behavior was assessed using six ordinal response options varying from 1 (*never*) to 6 (*10 or more times in the past six-months*) and a weighted sum score was computed across the 11 items. Approximately 2% (N = 76) were missing data on all CP items. The weighted sum score was then log transformed to account for the skewed distribution (Kurtosis = 15.77).

Past Six-Month and Past 30 Day Substance Use—Wave 1 and Wave 3 substance use variables were assessed using standard validated items used in epidemiologic surveys of adolescents [33]. We examined three substance use outcomes: alcohol, marijuana, and cigarette use. For each substance use outcome, we examined past six-month use as well as past 30-day use. Each substance use outcome was entered as an observed categorical variable.

For past six-month use, a binary variable (yes/no) for each outcome was created. The cigarette use variable was coded as 1 (yes) for those who smoked just a few puffs of a cigarette and those who smoked a whole cigarette. The alcohol use variable was coded 1 (yes) for those who reported consuming one full drink of alcohol. The combined marijuana use category variable was coded 1 (yes) those who used marijuana or blunts.

For past 30-day use, adolescents reported days used in past 30 days (forced choice with 9 options ranging 0–30 days) of the three substance use outcomes (i.e. alcohol, cigarettes, marijuana). The responses were ordinal: 0 (0 days), 1 (1–2 days), 2 (3–5 days), 3 (6–9 days), 4 (10–14 days), 5 (15–19 days), 6 (20–24 days), 7 (25–29 days), and 8 (All 30 days).

Alternative Reinforcement—At Waves 1 and 2, we utilized a modified version of the Pleasant Events Schedule (PES) [34] for youths as in prior work [6]. Participants rated 44 different typically pleasant activities (e.g., going out to eat, playing musical instruments, visiting friends, participating in clubs/organizations) for both frequency of engagement (0=Never; 1=1–6 times; 2=7 or more times) and pleasure experienced (0=not pleasurable; 1=somewhat pleasurable; 2=very pleasurable) in the past 30 days. Consistent with prior methods of measuring alternative reinforcement, the primary outcome is the sum of each item's product (engagement frequency × pleasure) only for activities participants marked as not associated with substance use [11]. A weighted sum score using the product of alternative was used in the analyses. Approximately 10.1 % (N = 343) of participants did not have any data on levels of alternative reinforcement. Once the weighted sum score was calculated, the number was log transformed (Kurtosis = −.12).

Covariates—Demographic factors (i.e. sex, highest parental education, ethnicity, living situation, school-level variable indicating percent of students eligible for free lunch), positive urgency using the UPPS-P Impulsive Behavior Scale [35], peer substance use, and internalizing symptoms were included as covariates. Specifically, the Major Depressive Disorder, Generalized Anxiety Disorder, and Panic Disorder scales of the Revised Children's Anxiety and Depression Scale (RCADS) were used as covariates, as these measures have been shown to overlap with CPs [8, 36]. Additionally, peer substance use was calculated from a question asking how many of the participants closest friends have used

each substance. The mean was used in the model. In addition to the above covariates, baseline levels of substance use and alternative reinforcers were also included in each model.

Analysis Plan

The hypothesized conceptual model (see Figure 1) was tested using structural equation modeling (SEM) in Mplus [37]. This model, with alternative reinforcement as the mediator, was developed based on the extant literature showing the mechanisms by which CPs, AR, and substance use predict one another [6,8]. Because respondents were clustered within schools, the error terms of regression models were not independent, leading to an underestimation of standard errors. To avoid this problem, the complex analysis as implemented in Mplus was used to adjust parameter standard errors for interdependence in the data. The Mplus dataset included variables that were already standardized (Mean = 0, SD = 1), thus, we report the unstandardized estimates. All paths of the mediation analyses were estimated in a model that included (1) CPs at baseline statistically predicting alternative reinforcers at Wave 2 (A path) and (2) alternative reinforcers at Wave 2 statistically predicting substance use at Wave 3 (B path). All substance use outcomes were specified as ordinal categorical variables in Mplus. Indirect effects linking CPs and substance use were calculated using Monte Carlo integration methods [38]. The covariance between each of these variables was also estimated in the model. Each SEM model adjusted for covariates discussed in the prior section. Missing data were handled with full information maximum likelihood estimation. Significance was set to .05 (two-tailed).

Hypotheses about moderation were also tested by multigroup analyses examining differences in the strength of paths across subsamples stratified by moderator status (e.g., males vs. females, low vs. high socioeconomic status). High socioeconomic status was defined as those whose parents completed at least some college versus low socioeconomic status was coded as those who completed high school or less. For multigroup analyses, chi-squared differences were calculated using loglikelihood values and the number of free parameters contrasting the fit of models with (versus without) equality constraints on the key mediation analyses paths of interest across groups by the moderator variable. The loglikelihoods were compared using the Satorra-Bentler Scaled Chi-Square test [39].

Results

Preliminary Analyses

Table 1 presents descriptive statistics and Table 2 presents correlations among study variables. Of note, internalizing symptomatology (i.e. depressive, anxiety, panic symptomatology) and living situation were the only covariates consistently associated with all key study variables (i.e. CPs, alternative reinforcement, and substance use). See Table S1 in the online supporting information for detailed descriptive statistics on CPs and substance use stratified by ethnicity.

Primary Analyses of Alternative Reinforcers as a Mediator between Conduct Problems and Substance Use

Table 3 presents adjusted analyses predicting a binary past six-month variable and ordinal past 30-day variable.

Marijuana Use—Table 3 indicates that there was a significant total effect of CPs on past six-month (β = .25 [.17, .34], $p < .0001$) and past-30 day marijuana use (β = .26 [.20, .32], $p < .0001$). The A path of CPs to alternative reinforcers as well as the B path (of alternative reinforcers to marijuana use were significant for past six-month and past 30-day marijuana use ($p < .0001$). There were significant indirect effects for past six-month (β = .013 [.006, .021], $p < .001$) and past 30-days (β = .017 [.006, .027], $p < .001$), indicating that alternative reinforcement significantly mediated the relationship between baseline CPs and marijuana use at Wave 3.

Cigarette Use—Although baseline CPs were significantly associated with cigarette use (i.e. total effect) and alternative reinforcement (i.e. A path), alternative reinforcement did not significantly mediate the relationship between CPs and past six-month (β = .005 [−.006, .016], $p = .14$) or past 30-day cigarette use (β = .003 [−.009, .015], $p = .54$).

Alcohol Use—Although baseline CPs were significantly associated with alcohol use (i.e. total effect) and alternative reinforcement (i.e. A path), alternative reinforcement did not significantly mediate the relationship between CPs and past six-month (β = .001 [−.006, .007], $p = .92$) or past-30 day alcohol use (β = .002 [−.004, .008], $p = .17$).

Supplementary Analyses—See Tables S2 and S3 for a detailed presentation of parameter estimates examining the pleasure and frequency subscales of the PES separately as opposed to the product score used in the main analyses. Although the frequency subscale of the PES yielded similar results to the combined PES model results, the pleasure subscale significantly mediated the association between CPs and alcohol use in addition to marijuana use.

Multigroup Analyses

Across each substance use outcome, multigroup analyses were conducted to test for differences between males and females in the mediating processes of alternative reinforcers. Table 4 indicates that no significant group differences were found between males and females as well as those with higher versus lower socioeconomic status.

Sensitivity Analyses

Sensitivity analyses to test for possible bias due to attrition showed that the association between CPs, alternative reinforcement, and substance use across the follow-up: (a) was consistent among the subsample of participants who completed all waves of data collection (N=3,163, 93.1%) and (2) was consistent among the subsample of participants who only completed the first two waves of data (N=3,277, 96.5%). No meaningful differences were found between these results and those presented in the primary analyses. Detailed results are available upon request to the first author.

Discussion

The present study found that teens who engaged in more CPs at baseline tended to derive less enjoyment and engage in fewer alternatively reinforcing activities at Wave 2 and engaging in fewer activities was associated with higher levels of marijuana use at Wave 3. These results persisted after adjusting for potentially confounding covariates, including demographic, psychological, and school-level variables. Given prior results implicating alternative reinforcement as a mechanism in substance use prevention [3,5–8], intervention development to identify a multitude of strategies to provide greater access to and engagement in alternative reinforcers as well as enhancing means of obtaining greater pleasure from such substance-free activities may slow the progression of substance use. Interventions have shown to be effective in reducing substance use by encouraging increased participation in healthy activities [40–44]. Our results raise the possibility that interventions targeting the span of adolescence studied here – a salient developmental period (i.e. 9th grade) when adolescents are exposed to greater numbers of organizations and clubs that may serve as alternative reinforcers [45,46] – warrant study in efforts to disrupt the comorbidity between early adolescent CP and the subsequent escalation of marijuana use.

Consistent with an extensive prior literature implicating CPs as a risk factor for use of various substances [12–20], results indicated that there was a significant positive total effect for the association of CPs with alcohol and combustible cigarette (in addition to marijuana use). However, different from marijuana use, alternative reinforcement did not significantly mediate the association of CPs with alcohol and combustible cigarette use. There are many theories accounting for the mechanisms of the relationship between CPs and substance use outcomes, including a common genetic vulnerability [24–27]. There are also psychosocial explanations for the overlap between CPs and substance use. For example, it may be that adolescents engaging in higher levels of CPs may encourage substance use involvement or use substances as another manifestation of an underlying propensity toward impulsive decision making or rebellious acts or affective dysregulation [47,48]. Also, sociodemographic (e.g., SES) and other socioenvironmental factors (e.g., peer use, parental involvement) may explain the association. As we adjusted for many of these factors in the analysis, it may be that they simply account for the majority of the elevated risk of alcohol and cigarette use conferred by CPs, and alternative reinforcement does not channel alcohol and cigarette risk over and above such factors.

There are many possible reasons why results did not consistently generalize across each set of substances. It may be that we lacked statistical power in this study and with more variance in substance use involvement, which typically emerges later in adolescence, alternative reinforcers may emerge as a mediator. It is also plausible that certain alternative reinforcers are more protective against use of certain substances but not others. Future research examining differences in the reward mechanisms of different substances and different types of alternative reinforcement may help further illuminate substance-specific differences. It is important to note that Table S3 in the online supplementary material indicates that the indirect effects examining alcohol use were significant when examining the pleasure subscale of the PES separately as opposed to the product of pleasure and frequency presented in the main analyses. This suggests that the pleasure one derives from healthy,

pro-social activities may be a more generalizable protective factor across multiple substances. Thus, creating prevention programs aimed at helping adolescents savor and extend the pleasure derived healthy activities, such as those derived from mindfulness or positive psychological interventions [49], may be a useful intervention target for preventing risk of use of numerous substances conferred by CPs.

Why might diminished alternative reinforcement channel the risk of marijuana use (and perhaps alcohol to some degree) conferred by CPs? Adolescents high in CPs may inherently find healthy alternative non-drug reinforcers less stimulating due to their neurophysiological phenotype. There is some research to support this hypothesis, as adolescents high in CPs report lower autonomic physiological response to picture slides regardless of their emotional valence compared to those without CPs [28]. Also, it may be that adolescents high in CPs are more immune to the punishing aspects of deviant behaviors. Thus, these adolescents may only be experiencing the physiological arousal associated with deviant behaviors and drug use rather than the associated social consequences. Finally, perhaps adolescents high in CPs socially isolate themselves from peers involved in alternative drug-free activities, and thus, self-select into problem behavior trajectories. However, by adjusting for peer substance use in this study and still finding this association, this explanation is less likely.

Multigroup analyses indicated that the mediational process of alternative reinforcement was similar across sex and socioeconomic status. With regards to the lack of sex differences, results are largely similar to our cross-sectional analysis showing few sex differences [8]. Although some studies have noted sex differences in the association between CPs and substance use [50,51], the present study did not find any evidence. With regards to the lack of differences by socioeconomic status, it may be that using other measures of socioeconomic status that are either objective (e.g. income) or subjective (e.g. MacArthur Scale of Subjective School Status) [52] may prove to be more robust when testing hypotheses about moderational effects.

The current study is not without its limitations. First, the PES did not ask students to report which specific activities were associated with which specific substance. Future research examining these differences may allow researchers to better understand the differential association between certain types of activities and certain substances. Second, the CP measure was not a diagnostic tool and does not allow us to assess whether individuals meet criteria for Conduct Disorder, rather it assesses variability across a continuum of functioning. Third, only standardized results were presented, which may be problematic given the varying distributions of the variables. However, this was done to ensure that parameter estimates with CPs and alternative reinforcers could be interpreted on the same metric. Fourth, the nature of our model precludes the ability to estimate reciprocal effects, such that substance use might be a predictor of CPs or participation in alternative reinforcers. Although the literature consistently shows the temporal ordering we have specified [6,8] it is nonetheless possible that these variables exert reciprocal action. Lastly, this study sampled participants from a relatively restricted geographic region that included a relatively high proportion of Hispanic adolescents, raising issues of generalizability. Future research that uses data from a more representative sample would be able to examine whether the findings presented generalize to other regions and populations.

This is the first study to longitudinally examine how diminished alternative reinforcement is a critical mechanism underlying why adolescents with higher behavioral problems may use substances. Results provide important implications for creating prevention and intervention programs that aim to increase access to alternative reinforcers (e.g. extracurricular activities) as well as means of obtaining pleasure. It is possible that providing a range of activities that reflect the interests of adolescents may be able to move adolescents into these activities that are pro-social in nature, rather than activities that facilitate delinquent behaviors and peer groups that use substances. Tailoring interventions like Substance-Free Activity Sessions [43,44] and others aiming to increase engagement in alternative activities [7,40–42] may prove to be fruitful in decreasing substance use in adolescents with CPs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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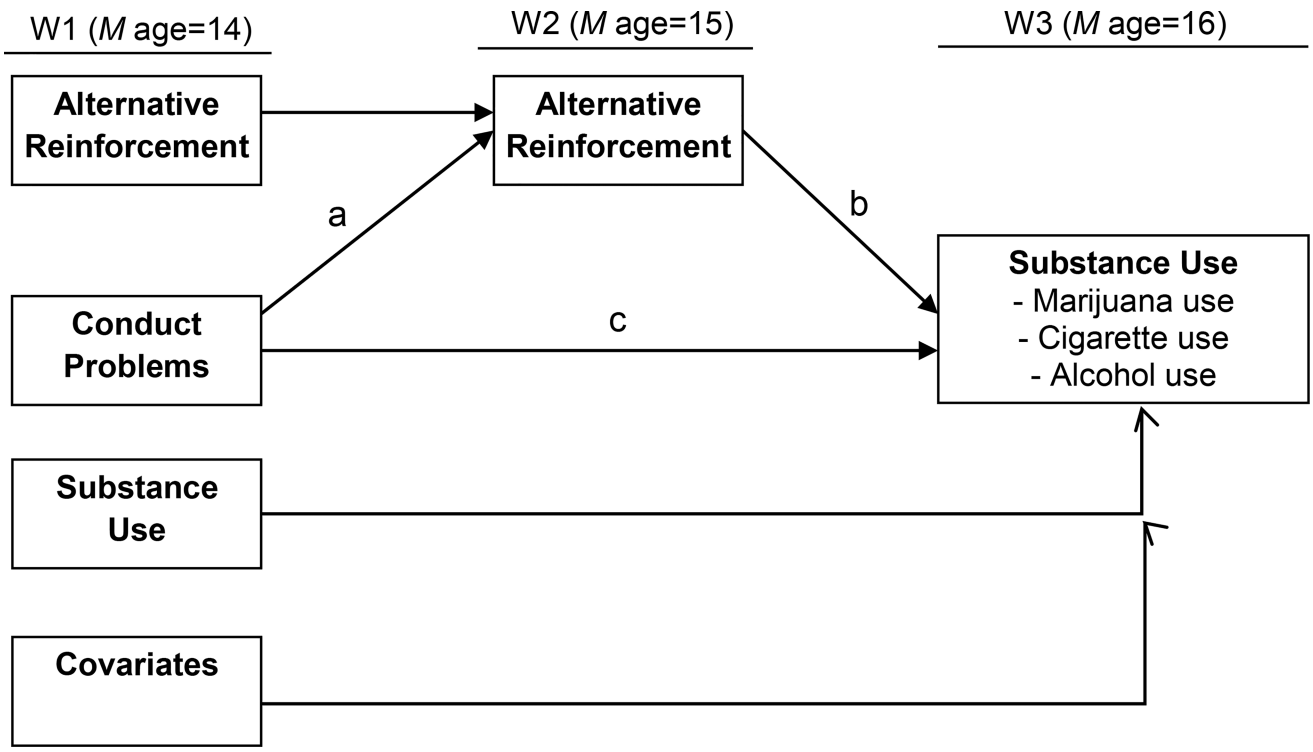

Figure 1. The conceptual framework of alternative reinforcement mediation between conduct problems and substance use

Note. *M* age = Mean age (year). Substance use outcomes of marijuana, cigarette, and alcohol were tested using each observed variable of past 6-month and past 30-day use. Covariates include highest parental education, percent of students eligible for free lunch (school-level), ethnicity, sex, peer substance use, positive urgency, depression, anxiety, panic symptoms, and living situation.

Table 1

Sample Characteristics among the overall sample.

	Overall Sample (*N* = 3,396)
Age (N = 3,360), *M* (*SD*)	14.1 (0.42)
Sex, N=3,369 (%)	
Female	53.5%
Male	46.2%
Ethnicity (N = 3,311)	
American Indian / Alaska Native	0.9%
Asian	16.2%
Black / African American	5.0%
Hispanic or Latino	47.0%
Native Hawaiian / Pacific Islander	3.4%
White	15.7%
Other	5.7%
Multiracial	6.0%
Highest parental education, N=2,931 (%)	
8th grade or less	4.0%
Some high school	9.1%
High school graduate	16.8%
Some college	19.6%
College graduate	31.6%
Advanced graduate	18.9%
Living Situation (N = 3,360)	
Both Parents	36.5%
Other	63.5%
RCADS- MDD, *M* (*SD*), α	6.2 (6.2), .93
RCADS- GAD Symptoms, *M* (*SD*), α	7.1 (4.5), .89
RCADS- PD Symptoms, *M* (*SD*), α	3.4 (4.6), .92
UPPS-P- Positive Urgency, *M* (*SD*), α	3.4 (0.6), .95
Peer Substance Use, *M* (SD)	14.4 (117.5)
CPs, *M* (*SD*)	15.8 (5.5)
Alternative Reinforcers at Baseline /12-month follow-up, *M* (*SD*)	72.3 (28.0) / 69.3 (30.4)
Substance Use, Past six-month use (yes/no) at Baseline / 12-Month Follow-Up / 24-Month Follow-Up (%)	
Alcohol	17.6% / 27.3% / 27.6%
Marijuana	10.5% / 16.3% / 17.5%
Cigarette	4.3% / 7.7% / 7.3%
Substance Use, Past 30-day use at Baseline / 12-Month Follow-Up / 24-Month Follow-Up, *M* (SD)	
Alcohol	0.23 (.80) / .38 (.98) / .39 (.98)
Marijuana	0.25 (1.05) / .37 (1.28) / .40 (1.34)
Cigarette	0.06 (.45) / .09 (.59) / .11 (.70)

Note. Data from ninth grade students in Los Angeles, California, USA collected in 2013–2015. CPs = Conduct Problems. RCADS = Revised Children's Anxiety And Depression Scale; MDD = Major Depressive Disorder; GAD = Generalized Anxiety Disorder; PD = Panic Disorder; UPPS-P = Urgency, Premeditation, Perseverance, Sensation Seeking, and Positive Urgency

Table 2

Correlation matrix of key study variables.

	Data on Variable Collected at Baseline																	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1. CPs (baseline)	**1.00**	−.14	.38	.43	.30	.39	.43	.24										
2. Alternative Reinforcers (Wave 2)	−.19	**1.00**	−.14	−.19	−.12	−.15	−.24	−.13	.01	−.02	.14	−.05	−.01	−.11	.00	−.03	.09	−.13
3. Past 6-mo Alcohol Use (Wave 3)	.25	−.07	**1.00**	.47	.31	.63	.38	.22	.07	.18	−.13	.19	.02	.16	.14	.15	−.11	.11
4. Past 6-mo Marijuana (Wave 3)	.30	−.13	.47	**1.00**	.39	.45	.68	.27	.01	.25	−.14	.15	−.03	.12	.08	.11	−.11	.09
5. Past 6-mo Cigarette Use (Wave 3)	.21	−.09	.31	.37	**1.00**	.35	.36	.58	.02	.28	−.05	.12	.00	.13	.07	.11	−.06	.05
6. Past 30-day Alcohol Use (Wave 3)	.23	−.08	.62	.40	.33	**1.00**	.53	.43	−.01	.15	−.10	.16	.00	.16	.09	.12	−.10	.08
7. Past 30-day Marijuana (Wave 3)	.28	−.17	.33	.63	.36	.47	**1.00**	.37	−.01	.15	−.11	.12	−.02	.09	.05	.06	−.11	.08
8. Past 30-day Cigarette Use (Wave 3)	.15	−.04	.21	.28	.56	.45	.43	**1.00**	−.01	.17	−.05	.13	−.01	.14	.07	.13	−.06	.07
9. Sex	−.02	−.01	.08	.02	.03	.04	.04	.06	**1.00**									
10. Ethnicity	.14	.12	.10	.14	.06	.08	.07	.05	.34	**1.00**								
11. Parental Education	−.15	.13	−.07	−.05	−.05	−.04	−.02	−.02	−.01	.01	**1.00**							
12. Peer Substance Use	.00	−.00	.15	.15	.10	.12	.09	.06	.00	.01	−.03	**1.00**						
13. Impulsivity	.33	−.00	.03	.01	.00	.01	.02	.04	.44	.25	.11	.00	**1.00**					
14. MDD	.28	−.13	.12	.14	.11	.07	.07	.09	.00	.00	−.01	.44	−.01	**1.00**				
15. GAD	.21	−.06	.13	.12	.07	.08	.05	.06	−.02	−.02	−.03	.40	−.01	.61	**1.00**			
16. PD	.23	−.08	10	.11	.10	.07	.06	.07	.01	.00	−.03	.42	−.02	.63	.52	**1.00**		
17. Living Situation	−.12	.07	−.08	−.10	−.07	−.08	−.10	−.07	.05	.03	.07	−.00	−.08	−.08	−.04	−.05	**1.00**	
18. School-level Free Lunch	.11	−.10	.01	.05	.01	.01	.03	−.01	−.01	.01	−.40	−.03	−.00	.02	.01	.03	−.08	**1.00**

Note. CPs = Conduct Problems. Wave 2 refers to 12-month follow-up. Wave 3 refers to 24-month follow-up. All correlations reported above the diagonal use baseline data that were used as covariates. Shaded cells note correlations that were *not* statistically significant at $p < .05$. All coefficients are Pearson correlations except the following: The association between binary variables (e.g. Sex and Past 6-month drug use) were calculated using the Phi Coefficient; The association between Ethnicity and substance use variables were calculated using Cramer's V. The association between ethnicity and CPs as well as ethnicity and alternative reinforcers was tested using an ANOVA and the square-root of R-squared was taken and reported in the table. Ethnicity was coded as a nominal variable. Empty cells signify duplicate correlations from those below the diagonal. MDD = Major Depressive Disorder; GAD = Generalized Anxiety Disorder; PD = Panic Disorder.

Table 3

Association of Conduct Problems to Substance Use-Related Outcomes and Mediation by Alternative Reinforcement

Outcome	Component Paths				Mediation
	Total Effect CP → Outcome	**CP → Mediator [95% CI]**	**Mediator → Outcome [95% CI]**	**Direct Effect CP → Outcome Adjusting for Mediator[a] [95% CI]**	**Indirect Effect [95% CI]**
			Outcome: Marijuana Use		
Past 6-month (yes/no)	0.25 (0.17, 0.34)†	−0.14 (−0.18, −0.10)†	−0.10 (−0.14, −0.06)†	0.24 (0.20, 0.27)†	0.013 (0.006, 0.021)***
Past-30 Day Frequency	0.26 (0.20, 0.32)†	−0.15 (−0.19, −0.11)†	−0.11 (−0.16, −0.06)†	0.25 (0.18, 0.31)†	0.017 (0.006, 0.027)***
			Outcome: Cigarette Use		
Past 6-month (yes/no)	0.24 (0.16, 0.32)†	−0.13 (−0.17, −0.09)†	−0.04 (−0.12, 0.04)	0.24 (0.15, 0.32)†	0.005 (−0.006, 0.016)
Past-30 Day Frequency	0.23 (0.15, 0.31)†	−0.11 (−0.15, −0.06)†	−0.03 (−0.14, 0.08)	0.23 (0.14, 0.31)†	0.003 (−0.009, 0.015)
			Outcome: Alcohol Use		
Past 6-month (yes/no)	0.21 (0.05, 0.35)†	−0.14 (−0.17, −0.10)†	−0.01 (−0.05, 0.05)	0.21 (0.06, 0.35)†	0.001 (−0.006, 0.007)
Past-30 Day Frequency	0.17 (0.12, 0.22)†	−0.13 (−0.17, −0.09)†	−0.01 (−0.06, 0.04)	0.17 (0.12, 0.22)†	0.002 (−0.004, 0.008)

Note. β (95%*CI*) = Standardized parameter estimates for predictor with 95% confidence interval. CP = Conduct Problem. The model is adjusted for highest parental education, percent of students eligible for free lunch (school-level), ethnicity, sex, peer substance use, positive urgency, depression, anxiety, panic symptoms, and living situation.

[a]This model also represents the Direct Effect in traditional path analysis.

*$p < .05$,

**$p < .01$,

***$p < .001$,

†$p < .0001$.

Table 4

Moderation test of sex and socioeconomic status (SES) using multigroup analyses: Robust nested chi-square test statistics

Sex Moderation			
Substance	**Outcome**	**Model fit comparison**	**p-value**
Marijuana Use	Past 6-month (yes/no)	$\Delta\chi 2/3df = 4.57$	.20
	Past-30 Day Frequency	$\Delta\chi 2/3df = 4.30$	.23
Cigarette Use	Past 6-month (yes/no)	$\Delta\chi 2/3df = 1.98$	.58
	Past-30 Day Frequency	$\Delta\chi 2/3df = 1.38$	.71
Alcohol Use	Past 6-month (yes/no)	$\Delta\chi 2/3df = 3.07$	.38
	Past-30 Day Frequency	$\Delta\chi 2/3df = 2.09$	.55
SES Moderation			
Marijuana Use	Past 6-month (yes/no)	$\Delta\chi 2/3df = 1.36$	.71
	Past-30 Day Frequency	$\Delta\chi 2/3df = 0.45$	.93
Cigarette Use	Past 6-month (yes/no)	$\Delta\chi 2/3df = 3.31$	.35
	Past-30 Day Frequency	$\Delta\chi 2/3df = 0.03$	.99
Alcohol Use	Past 6-month (yes/no)	$\Delta\chi 2/3df = 2.43$	.49
	Past-30 Day Frequency	$\Delta\chi 2/3df = 0.08$	.99

Note: The model fit comparison represents the difference of model fits from multigroup analyses on the hypothesized key paths (A, B, and C path in Figure 1) across moderators (i.e. Sex, Socioeconomic Status). High socioeconomic status was defined as those whose parents completed at least some college versus low socioeconomic status was coded as those who completed high school or less.