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Alternative and Complementary Reinforcers as Mechanisms Linking Adolescent Conduct Problems and Substance Use

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Abstract

The present study tested the hypothesis that teens who engage in conduct problems are more likely to use substances because they engage in fewer alternative reinforcing (i.e., pleasurable) substance-free activities and more complementary reinforcing substance-associated activities. In a cross-sectional, correlational design, ninth grade students (*N*=3,396; mean age=14.6 years) in Los Angeles, California, USA completed surveys in 2013 measuring conduct problems (e.g., stealing, lying, getting in fights), alternative and complementary reinforcement, use of a number of licit, illicit, and prescription drugs, and other co-factors. Conduct problems were positively associated with past six-month use of any substance (yes/no) among the overall sample and past 30-day use frequency on a composite index that included six substances among past six-month users. These associations were statistically mediated by diminished alternative reinforcement and increased complementary reinforcement when adjusting for relevant covariates. Conduct problems were associated with lower engagement in alternative reinforcers and increased engagement in complementary reinforcers, which, in turn, was associated with greater likelihood and frequency of substance use. Most mediational relations persisted adjusting for demographic, environmental, and intrapersonal co-factors and generalized to alcohol, cigarette, and marijuana use; though, complementary reinforcers did not significantly mediate the relation of CPs with alcohol use frequency. These results point to diminished alternative reinforcement and increased complementary reinforcement as mechanisms linking conduct problems and adolescent substance use. Interventions that increase access to and engagement in a diverse set of alternative substance-free activities and deter activities that complement use may prevent substance use in adolescents who engage in conduct problems.

Keywords

Conduct Problems; Alternative Reinforcers; Complementary Reinforcers; Adolescents; Substance Use

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Introduction

Conduct problems (CPs; e.g. stealing, lying, skipping school, fighting) reflect a range of externalizing behaviors that are strongly associated with adolescent substance use (Brown et al. 1996; Connor, Steingard, Cunningham, Anderson, & Melloni, 2004; Couwenbergh et al., 2006; King, Iacono, & McGue, 2004; Maslowsky & Schulenberg, 2013). In addition to more severe behaviors seen only in Conduct Disorder (e.g. mugging, using a weapon), it is important to consider CPs that are relatively common in the general population of adolescents (e.g., skipping school). Studying a range of CPs and the relative frequency of each would help us better understand externalizing comorbidity in substance use, as they may capture subclinical levels of conduct-associated problems worthy of targeting in broad population-based teen prevention programs. Additionally, CPs and substance use in non-clinical populations early in adolescence are risk factors for Substance Use Disorders and adult Antisocial Personality Disorder (Grant & Dawson, 1998; Howard, Finn, Jose, Gallagher, 2012). Thus, it is important to understand mechanisms that underlie the relation between adolescent CP and substance use uptake to inform etiological models of addiction risk and preventive interventions that thwart the development of severe addiction trajectories.

Behavioral economics is a useful framework for understanding adolescent substance use, which recognize that one's preference for substances arises within a broader context that involve the availability or utilization of: (1) alternative competing substance-free reinforcers, such as joining school clubs, volunteering, or other hobbies, which may deter substance use; and (2) complementary reinforcing activities that occur in conjunction with substance use (e.g. stimulants with sports), which may increase substance use engagement (Audrain-McGovern et al., 2004). Alternative reinforcers is defined as any activity (e.g. school clubs, dating, volunteering) that is used as a substitute for substance use (Audrain-McGovern et al., 2004). Prior research has found that engagement in more alternatively reinforcing activities is related to a reduction in substance use in substance using adolescents and young adults (Audrain-McGovern et al., 2004; Correia et al., 2005). Alternative reinforcers has also been implicated as a potential mechanism linking internalizing symptomatology and substance use, whereby, increased depressive symptoms are associated with decreased engagement in alternatively reinforcing activities and decreased alternatively reinforcing activities are associated with increased tobacco use (Audrain-McGovern, Rodriguez, Rodgers, & Cuevas, 2010). However, alternative reinforcers has yet to be examined for its relationship among externalizing behaviors that are more robustly associated with substance use than internalizing symptomatology (King et al., 2004; Maslowsky, Schulenberg, O'Malley, & Kloska, 2013).

Examining alternative reinforcers as a mechanism underlying the link between CPs and substance use is particularly important, as behavioral economic interventions that have young adults engage in healthy prosocial activities are effective in reducing drinking (Correia, Benson, & Carey, 2005; Murphy et al., 2012a; Murphy et al., 2012b). Should alternative reinforcers be shown to be a significant mediator between CPs and substance use, it would warrant further research on applying behavioral economic interventions to at-risk adolescents who have yet to engage in substance using behaviors. To date, these types of interventions have largely been done in college populations and have yet to be applied to

adolescents with high CPs. Similarly, contingency management interventions may be another type of treatment that can be applied to this at-risk group. This intervention regards drug use as a form of operant conditioning and posits that, alternative non-drug reinforcers should decrease substance use if individuals have access to the reinforcer and it is reinforced at a schedule incompatible to drug use and in contexts connected with substance abstinence (Carroll, Lac, & Nygaard, 1989; Higgins, Bickel, & Hughes, 1994; Roll & Higgins, 2000).

Complementary reinforcers, by contrast, has been less well-examined in the adolescent substance use literature, but are important to understand as some activities that are inherently social in nature may enhance substance-using experiences (e.g., dancing, parties, sports) and have been shown to be associated with increased odds of adolescent smoking (Audrain-McGovern et al., 2004). Given teens who endorse higher levels of CPs also endorse higher levels of boredom (Newbury & Duncan, 2001), it may be that teens with high CPs naturally derive less reinforcement from low-risk activities that adolescents commonly engage in for fun (e.g., dancing, hanging out with friends, going to movies), and are thus motivated to enhance their ability to derive reinforcement from such activities. Some substances may act as reward enhancers and have social facilitative properties that strengthen the reinforcing effects of the non-drug related rewards experienced while using substances (Beck & Treiman, 1996; Caggiula et al., 2009; MacLatchy-Gaudent & Stewart, 2001; Phillips & Fibiger, 1990; Robbins, 1977; Wall, Hinson, & McKee, 1998). That is, synergistic reinforcing qualities to the non-drug behaviors could be apparent when combined with substance use, such that drinking or smoking while engaging in activities, such as dancing, may pharmacologically amplify the reinforcing properties of the non-drug related activities. This association may be desirable as it would putatively increase the overall amount of environmental reinforcement for adolescents who engage in CPs. Thus, substances not only act as a primary reward that causes direct psychoactive effects, but they also alter the reinforcing effects of rewarding stimuli that are present in the environment in which substances are used.

When considering the role of these behavioral economic mechanisms to the CP-substance use connection, several important features of the study design should be considered. First, the beginning of high school is a salient developmental period in which adolescents enter a new social atmosphere and are exposed to older teens who may engage in more delinquent behaviors, have new levels of increased access to substances, and have opportunities to begin engaging in activities that compliment substance use (e.g., alcohol use at high school parties). At the same time, adolescents entering ninth grade are also newly exposed to greater numbers of organizations and clubs that are associated with a number of positive outcomes and academic resilience and may serve as alternative reinforcers (Finn & Rock, 1997; Stewart, 2008). Hence, the outset of 9^{th} grade is an important developmental period to study in terms of CPs, behavioral economic factors, and substance use. Second, it is of use to examine associations of CPs and behavioral economic variables across alcohol, tobacco, and marijuana separately as well as a considering influences involving overall risk of use of any substance, as it is possible that these mechanisms may generalize across substances, but also may be more relevant to certain substances versus other (e.g., nicotine has particularly strong reward-enhancing pharmacological properties and therefore may be tightly linked with complimentary reinforcement in youth with higher levels of CPs). Lastly, it is important

to examine possible sex differences in how alternative and complementary reinforcers may operate differently for males and females in terms of their roles in substance use. Some studies have suggested that males endorse more CPs than females (Maughan, Rowe, Messer, Goodman, & Meltzer, 2004) and female CPs tend to be relatively lower risk and limited to adolescence (Fergusson & Horwood, 2002). Thus, how alternative and complementary reinforcers mediate the association with substance use may differ across sexes. Taken together, these features (i.e. focusing on a salient developmental time period, multiple substance use outcomes, and studying sex differences) are important goals for research aimed at advancing a nuanced understanding of how and why youth with CPs are more likely to engage in substance use.

The current cross-sectional study of 14-year-old high school students reflects an initial test of the hypothesis that diminished alternative reinforcement and increased complementary reinforcement are mechanisms underlying the association between CPs and substance use. To this end, we examined whether diminished alternative reinforcement mediated the relationship between CPs and markers of two different points on the substance use uptake continuum: (1) substance use status (yes/no in the past 6 months) in the entire sample; and (2) substance use frequency among past six-month users. Given that complimentary reinforcers may be linked with progression from use experimentation to more frequent use patterns, we also examined whether increased complementary reinforcement mediated the relationship between CPs and substance use frequency among past six-month users. Substance-specific analyses were also done on alcohol, cigarette, and marijuana use as separate outcomes given they are the most commonly used drugs in the United States (NSDUH, 2012; Shi, 2014) and may perhaps lend themselves to substance-specific policy interventions. Anxiety and depression are comorbid with CPs (Chan, Dennis, & Funk, 2008; King et al., 2004; Maslowsky & Schulenberg, 2013) and substance use (Audrain-McGovern et al., 2010; Wolitzky-Taylor, Lyuba, Zinbarg, Mineka, & Craske, 2012); these internalizing symptoms may directly diminish the ability to derive reinforcement from substance-free activities (Lloyd-Richardson, Papandonatos, Kazura, Stanton, & Niaura, 2002). Hence, in addition to examining how these relations involving CPs, alternative/complimentary reinforcers, and substance use are incremental to common covariates utilized in adolescent substance use research (e.g., demographics, peer substance use), we also explore whether the hypothesized pathways are incremental to anxiety and depression.

Methods

Participants and Procedures

This paper describes an analysis of a survey of 9th grade students enrolled in ten public high schools in the Greater Los Angeles metropolitan area. Participating schools were selected based on their adequate representation of diverse demographic characteristics; the percent of students eligible for free lunch within each school (i.e., student's parental income < 185% of the national poverty level) on average across the ten schools was 31.1% (*SD*=19.7, range: 8.0% −68.2%). All students who were not enrolled in special education (e.g., severe learning disabilities) or English as a Second Language Programs (*N*=4,100) were eligible. Among those eligible, 3,874 (94.5%) assented to participate in the study, of whom 3,396 (82.8%)

provided active written parental consent and 3,383 (82.5%) completed the first wave of data collection. Paper-and-pencil surveys were administered in the fall of 2013 during two separate in-class 60-minute survey administrations conducted less than two weeks apart. Researchers informed students that their responses would be confidential and not shared with their teachers, parents, or school staff. Students were not individually compensated; each participating school was compensated for their general activity fund. The questionnaires were administered in random order and some students did not complete the entire survey within the time allotted or were absent on one of assessment days. Thus, participants who did not complete measures used in this report were not included in the final sample used (N = 3,202). The study was approved by the University of Southern California Institutional Review Board.

Measures

Conduct problems—CPs were measured via an 11-item measure of past six-month behavior (e.g., stealing, stealing an item worth more than $50, destroying property, lying to parents, running away, physically fighting, skipping school, being suspended, selling illegal drugs, driving a car without permission, getting in trouble with police); α in current sample = .79 (Lloyd-Richardson et al., 2002; Resnick et al., 1997; Thompson, Ho, & Kingree, 2007). Six of the 11 items assessed are behaviors consistent with a Conduct Disorder diagnosis. The frequency of each behavior is ascertained with 6 ordinal response options varying from never to 10 or more times in the past six-months (scored 1 to 6, respectively) and a sum score is computed across the 11 items.

A weighted sum score of CPs was used in the analyses to most accurately reflect conduct problems endorsed. A weighted score is optimal given both a mean and a sum score would include individuals who had missing data on items and thus not accurately reflect a true endorsement of 11 CP items. Of the total sample, 76 participants did not fill in any of the conduct problem items and an additional seven participants did not fill in at least six of the 11 items. The cutoff used for the number of responses needed to have a weighted sum score was six of the 11 items; otherwise the data was considered missing for that participant due to possible instability of the CP estimate. Among adolescents who responded to at least 6 of the 11-item measure, the weighted score was created by calculating the mean frequency rating (1 to 6) for the number of items answered was calculated and then multiplied by the total number of items, which for this measure, was 11. The possible range for responses was 11 to 66 where a score of 11 indicates that an adolescent never engaged in any CPs. Approximately 12% of the overall population reported never engaging in any CPs.

Past Six-Month and Past 30 Day Substance Use—Substance use was assessed using standard validated items used in epidemiologic surveys of adolescents (Johnson, O'Malley, Miech, Bachman, & Schulenberg, 2014). For past six-month use, students were asked whether they had used any of the substances for recreational purposes or to get "high": few puffs of a cigarette (prevalence of endorsement in overall sample, 3.3%), whole cigarette (1.9%), electronic cigarettes (12.4%), smokeless tobacco (0.7%), big cigars (1.0%), little cigars or cigarillos (1.8%), hookah water pipes (9.2%), other forms of tobacco products (1.4%), marijuana (8.7%), blunts (6.4%), one full drink of alcohol (14.3%), inhalants

(2.7%), cocaine (0.5%), methamphetamines (0.3%), ecstasy (0.8%), LSD/mushrooms/psychedelics (1.0%), salvia (0.5%), heroin (0.3%), prescription pain killers (1.6%), tranquilizers or sedatives (2.0%), diet pills (1.0%), and prescription stimulant pills (0.6%). Adolescents who endorsed use of any substance were coded as past six-month users (26.2% of the sample). For substance specific analyses, a binary past six-month alcohol, cigarette, and marijuana use variables were used. The binary cigarette use variable included those who smoked just a few puffs of a cigarette and those who smoked a whole cigarette (3.5%). The combined marijuana use category variable included those who smoked blunts (9.1%).

Past 30 day frequency of recreational use was assessed for each of six key substances (alcohol, cigarettes, marijuana, stimulants, prescription stimulants, and prescription opioid) with 9 ordinal response options coded 0 to 8 (0, 1–2, 3–5, 6–9, 10–14, 15–19, 20–24, 25–29, 30 days). The substances mentioned were chosen for the survey based on their prevalence in prior work in a demographically-similar sample collected from the region overlapping with the 10 participating schools in this study (Unger, 2014). A mean past 30-day use frequency score that used data across the six substances was used for the current analyses. For alcohol, cigarette, and marijuana use separately, if a participant's frequency response was greater than two, participant's response was changed to two to increase power given that less than 3% of teens reported use in the higher categories.

Alternative and Complementary Reinforcement—We utilized a modified version of the Pleasant Events Schedule (PES; MacPhillamy & Lewinsohn, 1976) for youths as in prior work (Audrain-McGovern et al., 2010). Participants rated 44 different typically pleasant activities (e.g., going out to eat at a restaurant, playing musical instruments, visiting/hanging out with friends, participating in clubs or community organizations, playing sports) 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. Additionally, participants were asked to indicate (yes/no) whether they associated the pleasant activity with alcohol, smoking, or drug use (Madden, 2000). Consistent with prior methods of measuring alternative reinforcement, the primary outcome is the sum of each item's product (engagement frequency × pleasure) for activities marked as not associated with substance use (Murphy, Correia, Colby, & Vunchinch, 2005). The complementary reinforcement outcome is the same product for activities that are marked as being associated with substance use.

A sum score using the product of alternative and complementary reinforcers was used in the analyses. To prevent biased underestimated scores for those with missing responses, individual weighted sum scores were calculated and imputed. This imputation was calculated using a similar method described in the CP measure section above. In instances of missing data when an individual did not answer questions related to a particular activity, a weighted sum score was calculated based on the proportion of complementary and alternative reinforcers in which the adolescents engaged. For instance, if an adolescent only answered 30 questions on the PES out of the 44 possible, the proportion of alternative reinforcers to complementary reinforcers was calculated. If 10 of the 30 questions answered were classified as complementary reinforcers, then we assumed that 33.3% of the total questions that would have been answered would have been classified as complementary

reinforcers as well. The same computation was done for alternative reinforcers, whereby, 66.6% of the total questions on the PES could be assumed to be alternative reinforcers. Subsequently, the average score was multiplied by the number of items that would have been endorsed as alternative and complementary reinforcers based on the proportion score previously calculated, with the exception of cases in which less than 60% of the items were completed (N = 9). In these instances, the sum score was entered as missing. Additionally, if an individual had not endorsed any substance use, the sum score for complementary reinforcers was entered as missing given it was not possible to have activities that complement substance use if they did not use substances. See Table 1 for available N for both alternative and complementary reinforcers after eliminated those considered as missing.

Covariates—Three sets of adjusted models were included in the analyses. The first adjusted model included demographic covariates: sex, parental education (high school diploma or less vs. some college education or greater), and ethnicity (Hispanic vs. Not Hispanic).

The second adjusted model included a measure of positive urgency and peer substance use, in addition to the demographic covariates. We used the 26-item Positive Urgency subscale of the UPPS-P Impulsive Behavior Scale, which measures the tendency towards rash, impulsive action in response to positive affect and has been implicated in the etiology of substance use and externalizing behaviors; α in current sample = .95 (Cyders et al., 2007; Whiteside & Lynam, 2001). A composite peer substance use variable was created for alcohol, cigarettes, marijuana, stimulant, prescription stimulant, and prescription painkillers. For each substance use category, participants answered how many of their five closest friends have used each substance (each scored 0 to 5). The mean across each substance was used in this model.

The third adjusted model included internalizing symptom measures in addition to the covariates tested in the first two adjusted models. The Revised Children's Anxiety and Depression Scale (RCADS) was used to assess Major Depressive Disorder, Generalized Anxiety Disorder and Panic Disorder symptoms (Chorpita, Yim, Moffitt, Umemoto, & Francis, 2000). The Major Depressive scale included 10 items relating to depressive symptoms; α in current sample = .93 (e.g., "I feel sad or empty;" "I worry that something awful will happen;" "I worry that bad things will happen to me;" "I worry about death;" "I worry about what is going to happen;" "I worry that something bad will happen to me). The Generalized Anxiety Disorder scale included six items relating to worry about the future (e.g., "I worry about things"); α in current sample = .89. The Panic Disorder scale on the RCADS has nine items that assess bodily symptoms of a panic attack; α in current sample = .92 (e.g., "When I have a problem, I get a funny feeling in my stomach;" "I suddenly feel as if I can't breathe when there is no reason for this;" "When I have a problem, I feel shaky").

Analytical Approach

Primary analyses utilized generalized estimating equations GEEs (Zeger, Liang, & Albert, 1988) that accounted for clustering of students within schools (Hubbard et al., 2010).

Mediational paths for alternative and complimentary reinforcers were tested in three stages: (1) The relation of CPs on the substance use outcome variable (total effect), (2) The relation of CPs on the mediator (i.e. alternative or complementary reinforcers; A path), and (3) The relation of the mediator on the substance use outcome variable when adjusting for CPs (B path). In this last stage, the association between CPs and the substance use outcome variable when adjusting for the mediator represents the direct effect in the mediational pathway. The product of the coefficients from the A path and B path models indicated the strength of the indirect ("mediated") effect. Using the PRODCLIN approach, we determined significance via asymmetric confidence intervals (*CI*s) around the mediational effect (MacKinnon, Fritz, Williams, & Lockwood, 2007).

Each step of the analyses used participants who were not missing any data on the key study variables (i.e. CPs, alternative or complementary reinforcement, and substance use). Table 1 presents available sample size of each variable. Also, scores were standardized (Mean =0 and Standard Deviation =1) to generate parameter estimates that could be judged on the same metric across variables. Sample sizes for each of these analyses are reported in Tables 3–7.

All three of the GEEs mentioned above were tested in four steps: (Model 1) unadjusted, (Model 2) adjusted for demographic covariates, (Model 3) adjusted for demographic covariates as well as measures of peer substance use and positive urgency, and (Model 4) adjusted for depression, generalized anxiety, and panic symptoms as well as all aforementioned covariates. Analyses were conducted in SAS with PROC GENMOD (SAS Institute, 2003) using an exchangeable correlation matrix and modeling CPs as a continuous variable and past six-month substance use as a binary variable. PROC SURVEYLOGISTIC was used in addition to PROC GENMOD for substance-specific analyses to calculate total effect, direct effect, and the B path beta estimates. In analyses predicting past 30-day frequency of any substance use, the subsample who endorsed any past six-month substance use was utilized and Poisson distribution was specified to account for the skewed count outcome distribution. Complementary reinforcement was not analyzed as a mediator between CPs and past six-month reports of substance use because teens who have never used a substance cannot report any activities associated with substance use, which would have generated criterion contamination between the mediator and outcome. Missing data on covariates were accounted for using dummy variable adjustment (Cohen & Cohen, 1985), which creates a dummy variable to code for missingness for each covariate with missing data, to allow inclusion of the entire sample in analyses. Results are reported as parameter estimates (*B*+95% *CI*s).

Sex Differences—For each step of the analyses previously mentioned, the main effect of sex was tested along with an interaction term with the independent variable in the model. Thus, in the total effect and A path models, an interaction term between sex and CPs was created. In the B path model, an interaction term between sex and alternative or complementary reinforcers was created. If the sex interaction term was significant across all three models tested, simple effect models were run to test the mediational path separately among males and females.

Reverse Mediation—Given the cross-sectional nature of this data, each step of the mediational analyses was run in the reverse direction in a supplementary analysis. Thus, the three models tested for reverse mediation were (1) The relation of substance use on CPs (total effect), (2) The relation of substance use on the mediator (i.e. alternative or complementary reinforcers; A path), and (3) The relation of the mediator on the CPs when adjusting for substance use (B path).

Results

Preliminary Analyses

Descriptive statistics for demographics and study variables within past six-month substance users and the overall sample stratified by males and females are depicted in Table 1. Correlations between study variables are presented in Table 2. Males and females did not significantly differ in frequency levels of CPs, alternative and complementary reinforcers, and substance use, and all other study variables (see non-significant associations between gender and other variables in Table 2).

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

As shown in Table 3, in the first set of unadjusted analyses predicting a binary variable of past six-month any use among the entire sample, there was a significant total effect (β= .96, $p < .0001$), which represents the overall relation of CPs to adolescent substance use (i.e., portion of the association accounted for by the mediator + portion of the association not accounted for by the mediator). The positive direction of this finding indicates that higher levels of CPs were associated with greater reports of substance use. Both the A path (β= −.18, $p < .0001$) and B path (β= −.13, $p < .01$) were also significant in the negative direction, indicating that greater levels of CPs was associated with decreased levels of alternative reinforcers and decreased alternative reinforcers was associated with a greater likelihood of substance use after adjusting for CPs, respectively. Multiplying these two path coefficients together provides the indirect effect (β= .02, $p < .01$). Lastly, there was a significant direct effect (β= .95, $p < .0001$), which represents the association between CPs and substance use after adjusting for the mediator.

For the second set of analyses, we examined the extent to which complementary reinforcers mediated the relationship between CPs and substance use frequency among past six-month users. The positive A path (Unadjusted, β= .41, $p < .0001$) and B path (Unadjusted, β= .18, $p < .001$) coefficients signify that higher levels of CPs was associated with greater levels of engagement in complementary reinforcers and greater levels of engagement in complementary reinforcers was associated with more frequent substance use, respectively. There was significant indirect (Unadjusted, β= .08, $p < .001$) effect, indicating that complementary reinforcers mediated the relationship between CPs and substance use frequency.

For the third set of analyses, we examined the extent to which alternative reinforcers mediated the relationship between CPs and substance use frequency among past six-month

substance users. Higher levels of CPs were associated with decreased levels of alternative reinforcers (Unadjusted, β= −.28, $p < .0001$) and decreased levels of alternative reinforcers was associated with increased substance use frequency after adjusting for CPs (Unadjusted, β= −.46, $p < .0001$). The product of these two paths revealed a significant indirect effect (Unadjusted, β= .13, $p < .0001$), indicating that diminished alternative reinforcers mediated the relationship between CPs and substance use frequency.

Each of the abovementioned results remained statistically significant after various levels of covariate adjustment (see Table 4).

Substance-Specific Analyses

Alcohol—Table 4 presents analyses predicting past six-month alcohol use in the overall sample and alcohol use frequency among past six-month users, revealing a significant total effect for the association of CPs to alcohol use status and frequency. Among the overall sample, alternative reinforcers significantly mediated the relationship between CPs and alcohol use, whereby, greater levels of CPs was associated with decreased likelihood of alternative reinforcers, which was, in turn, associated with greater levels of alcohol use (Unadjusted indirect effect, β = .03, $p < .0001$). This mediational path was also significant when predicting alcohol use frequency among past six-month drinkers in the first two adjusted models (see Table 4), but was reduced to a non-significant trend after adjusting for internalizing symptomatology in the most stringent model including all covariates (Indirect effect, β = .03, $p = .06$). Complementary reinforcers did not significantly mediate the relationship between conduct problems and alcohol use frequency in either the unadjusted or adjusted models.

Cigarettes—Table 5 presents predicting past six-month cigarette use in the overall sample and cigarette use frequency among past six-month users, revealing a significant total effect for the association of CPs to cigarette smoking status and frequency. Among the overall sample, alternative reinforcers significantly mediated the relationship between CPs and past six-month cigarette use prevalence (Unadjusted indirect effect, β= .07, $p < .0001$). Alternative reinforcers also significantly mediated the relationship between CPs and cigarette use frequency among past six-month users (Unadjusted indirect effect, β= .18, $p < .001$). As with other substances, CPs had a significant negative association with alternative reinforcers and alternative reinforcers had a significant negative association with cigarette use frequency. These results remained robust after adjusting for all covariates. Complementary reinforcers mediated the relationship between CPs and cigarette use frequency in the unadjusted model (Indirect effect, β= .12, $p < .05$) and the adjusted model (Indirect effect, β= .12, $p < .05$) that controlled for only demographic covariates. After additionally controlling for peer substance use, impulsivity, and internalizing symptomatology, complementary reinforcers was no longer a significant mediator between CPs and cigarette use frequency in past six-month users.

Marijuana—Table 6 presents predicting past six-month marijuana use in the overall sample and marijuana use frequency among past six-month users, revealing a significant total effect for the association of CPs to marijuana use status and frequency. All marijuana use

outcomes were significant at $p < .05$. Specifically, alternative reinforcers was a significant mediator when predicting past six-month marijuana use (Unadjusted indirect effect, β= .07, $p < .0001$) and marijuana use frequency (Unadjusted indirect effect, β= .18, $p < .0001$) among users. Thus, greater levels of CPs was associated with decreased alternative reinforcers, which was associated with greater levels of marijuana use. Similarly, complementary reinforcers significantly mediated the relationship between CPs and marijuana use frequency (Unadjusted indirect effect, β= .50, $p < .01$). This relationship remained robust across all adjusted models.

Sex Differences

Tests of the interaction term between sex and the independent variable in the total effect model, A path, and B path revealed significant interactions for each of these three associations in predicting past six-month alcohol use status among the overall sample in the unadjusted model and adjusted model for demographic covariates. In the unadjusted model, the interaction terms between the independent variable and sex were significant for the total effect (β = −.42, $p < .0001$), A path (β = .07, $p = .04$), and the B path (β = .29, $p < .001$). Results were maintained across the total effect (β = −.43, $p < .0001$), A path (β = .07, $p = .04$), and B path (β = .27, $p < .01$) even after adjusting for demographic covariates. Given the direction of the interaction terms, and that male was coded 1 and female was 0, results indicated that girls had stronger associations of CPs with both alternative reinforcers and alcohol use and of alternative reinforcers with alcohol use compared to boys. The A path was no longer significant when adjusting for peer substance use and impulsivity in Model 3 as well as internalizing measures in Model 4. No other significant sex differences were found across any other set of analyses for both alternative and complementary reinforcers.

Table 7 presents simple effect analyses to examine the mediational pathway separately for males and females. Among males in the unadjusted model, the total effect (β = .72, $p < .0001$) and A path (β = −.16, $p < .0001$) were significant, but the B path (β = −.08, $p = .21$) and indirect effect (β = .01, $p = .07$) were not, indicating that alternative reinforcers did not significantly mediate the relationship between CPs and alcohol use among males. The B path and indirect effect were also non-significant in the adjusted model. Among females in both the unadjusted and adjusted models, alternative reinforcers significantly mediated the association between CPs and alcohol use (Indirect effect in unadjusted and adjusted models; β = .06, $p < .0001$).

Reverse Mediation

Each stage of the mediational path of the aforementioned analyses was run in the reverse direction, including the total effect (substance use outcome predicting CPs), A path (Substance use outcome predicting alternative or complementary reinforcers), and B path (alternative or complementary reinforcer predicting CPs). Across the any substance and most of the substance-specific variables, there was evidence of statistically significant reverse mediation whereby greater reports of substance use (entered as the independent variable) was associated with diminished levels of alternative reinforcers and increased levels of complementary reinforcers (entered as a dependent variables), which was in turn associated with greater levels of CPs (entered as a dependent variable). Detailed reports

parameter estimates from the reverse mediation analyses are available upon request to the first author (RK).

Discussion

The current study offers cross-sectional evidence implicating behavioral economic processes as mechanisms underlying the relationship between CPs and adolescent substance use. As described below, these results largely generalized across alternative and complementary forms of reinforcement, any substance outcomes as well as substance-specific outcomes, and both sexes. Additionally, results support the utility of behavioral economic frameworks for informing theoretical models of the etiology of CP-substance use comorbidity and interventions to prevent substance use among teens with CPs. This study expands on prior research in several critical ways: (1) the examination of novel mechanisms underlying the externalizing-substance use comorbidity in a large, current sample of adolescents and (2) the addition of complementary reinforcers as a mechanism associated with substance use.

Diminished Alternative Reinforcement as a Mechanism Linking CPs and Substance Use

Prior research suggests that adolescents with a Conduct Disorder diagnosis report lower levels of arousal and lower autonomic responses to emotionally-valenced stimuli (Herpertz et al., 2005). The degree of arousal and autonomic reactivity in response to a positively-valenced emotional stimulus (i.e., reinforcer) putatively reflects of the magnitude of motivational salience a stimulus is appraised to hold. Thus, teens with higher CPs may find a typical rewarding stimulus as less salient than teens with fewer CPs and therefore require exposure to more potent rewarding stimuli in order to derive reinforcement. In other words, teens who engage in CPs may find most healthy substance-free activities (e.g. volunteering) boring, and therefore, not benefit from the protective effects of alternative reinforcement against substance use. Consequently, such adolescents may be motivated to seek alternative methods of obtaining reinforcement, such as engaging in CP-related behaviors that are more arousing (e.g., fighting) and substance use being potent reinforcers to the population of teens with these externalizing tendencies.

It is also possible that adolescents who engage in CPs may be subject to environmental factors that restrict access to certain alternative reinforcers (e.g., less funds to spend on shopping, limited after school activities offered in the community), which could explain the relations demonstrated herein. That is, diminished alternative reinforcement in teens who engage in CPs may not only reflect a diminished hedonic response when engaging in substance-free activities, but also limited opportunities for such activities. Although we cannot rule out this explanation, the current results were robust after statistically adjusting for parental education and other factors that are likely to pose environmental restrictions on access to alternative reinforcers.

Complimentary Reinforcement as a Mechanism Linking CPs and Substance Use

The current study also found evidence that teens with CPs derived more reinforcement from non-drug rewards if such rewards were experienced concurrently with substance use (i.e. complementary reinforcers). This, in turn, accounted for the association of CPs with

progression from experimentation to more frequent substance use. Some substances have been shown to have reward-enhancing and social facilitative properties that amplify the reinforcing effects of non-drug rewards experienced concurrently during substance use (Beck & Treiman, 1996; Caggiula et al., 2009; MacLatchy-Gaudent & Stewart, 2001; Phillips & Fibiger, 1990; Robbins, 1977; Wall et al., 1998). Thus, in addition to acting as a primary reward that causes direct psychoactive effects irrespective of environmental context, some drugs also alter the reinforcing effects of rewarding stimuli that are present in the environmental context in which substances are consumed. For instance, alcohol has been shown to be a social lubricant that enhances the degree of social reinforcement derived from interpersonal activities (MacLatchy-Gaudent & Stewart, 2001; Wall et al., 1998; Read, Wood, Kahler, Maddock, & Palfai, 2003). Perhaps adolescents whe engage in CPs may be more apt to benefit from the reward-enhancing effects of substances, given that adolescents who derive reinforcement and potential autonomic arousal from deviant, rule-breaking acts may desire pharmacological enhancement of less deviant pleasant activities. Accordingly, substance use may be a means for matching the stimulating properties one derives from their environment when breaking the rules. If adolescents are able to derive greater reinforcement from their environment when using substances, and teens who engage in CPs do not experience healthy alternative reinforcers as rewarding, adolescents may eventually turn to substances as both a primary reward and a reward-enhancer.

Generalizability of Associations Across Substances

Substance-specific analyses of alcohol, cigarettes, and marijuana mirrored the any substance use outcomes, whereby, greater levels of CPs was associated diminished alternative reinforcement, which was associated with increased reports of substance use. The primary exception was that after adjusting for internalizing measures, alternative reinforcers no longer mediated the relationship between CPs and alcohol use frequency. Thus, it could be that the etiological role of alternative reinforcers in the relation of alcohol to CPs is impacted by the presence of comorbid internalizing symptomatology. Certain facets of internalizing symptomatology (e.g. anhedonia, depressive symptoms) may impair a teen's ability to engage in and experience pleasure from healthy activities, which may have affected this association. At the same time, the majority of results were robust to control for internalizing symptoms and various other covariates, suggesting empirical specificity of the pathway involving CPs, alternative reinforcement, and substance use over and above other known risk pathways. Substance-specific results did not unilaterally generalize to mediation analyses involving complementary reinforcers. Although complementary reinforcers significantly mediated the CP-marijuana use relationship, there was a non-significant trend in the hypothesized direction for all models predicting alcohol use frequency and the smoking frequency analyses were not robust after control for all covariates. Consequently, it is possible that there is some distinction of the interrelations of CPs, behavioral economic mechanisms, and substance use across substance. It is also possible that given that base rates of frequent use were low for some of the individual substances, this study lacks sufficient power to test the impact of complementary reinforcers on substance use. The largely consistent results in most statistical models suggest that there may be more consistency across substances than divergence.

Sex Differences in Behavioral Economic Mechanism Linking CPs and Substance Use

In contrast to previous findings (Maughan et al., 2004; Moffitt, 2001), the current study did not find significant sex differences in the overall levels and prevalence of CPs and substance use. The lack of sex differences may be indicative of an emerging trend showing less pronounced sex differences in adolescent risk behavior (Mahalik et al., 2013). Furthermore, few sex differences were found in the interrelation of CPs, behavioral economic mechanisms, and substances. In females only, alternative reinforcers mediated the relationship between CPs and past six-month reports of alcohol use, raising the possibility that the extent to which alternative reinforcers serves as a mechanism linking CPs and alcohol use may differ for males and females. However, the mechanism by which this difference emerges is unclear. It may be that females engage in activities that offer higher levels of reinforcement or experience activities as more reinforcing than males. Engagement with these rewarding activities may deter females from subsequent substance use. However, a more nuanced version of the PES is needed to detect greater variance in the reward saliency of different activities. Lastly, more sex differences may emerge later on in development as the rate in which teens engage in other substances besides alcohol increases. However, more research is needed to understand how sex differences develop and how increased use may impact sex differences longitudinally.

Limitations, Implications, and Conclusions

The cross-sectional, correlational design precludes definitive inferences regarding directionality or causality of these findings. In fact, analyses suggest that reverse mediation was also significant across a number of analyses, raising the possibility that the causal direction of the association involves substance use diminishing alternative reinforcement and increaseing complimentary reinforcement, which in turn lead to CPs (Howard et al., 2012; Loeber, Burke, Lahey, 2002; Myers, Steward, & Brown, 1998). Repeated substance has been shown to raise one's threshold for reinforcement by diminishing responsiveness of the brain's reward circuit to non-drug reinforcers (Hatzgiakoumis, Martinotti, Giannantonio, & Janiri, 2011), which could result in reduced pleasure experienced from alternative reinforcers (Leventhal et al., 2008). Moreover, diminished alternative reinforcers may motivate the pursuit of additional non-substance activities, such as CPs, that provide sufficient thrill to engender reinforcing effects. Also, teens who use substances more may have more opportunities for developing new contexts and activities that may be complimentary to substance use, which could reflect a relationship from substance use to complimentary reinforcement. Each of these alternative explanations for the current findings should be addressed in future prospective longitudinal and experimental research.

To our knowledge, this is the first investigation of behavioral economic mechanisms linking CPs and youth substance use. Along with the several study strengths (e.g. adequate sample size, use of multiple outcomes that reflect different points of the substance use uptake continuum, demographically diverse sample), limitations must be noted. Participants were sampled from a restricted geographic region, which raises limitations on generalizability. Additionally, the CP measure is not a diagnostic tool and does not assess for clinical symptoms of Conduct Disorder. However, the CP measure utilized assessed for frequency of numerous clinically significant delinquent behaviors exhibited fairly often in those with and

without a Conduct Disorder diagnosis. Hence, the measure is useful for assessing variation at the low to moderate end of the externalizing behavior continuum and identifying adolescents engaging in less deviant behaviors but perhaps at a higher rate than their peers. This is particularly important as teens in the current study are approximately 14 years old and may not be engaging in some of the more violent behaviors (e.g. mugging, hurting animals) seen in a Conduct Disorder diagnosis. Indeed, Table 1 shows that teens are endorsing relatively low rates of CPs. However, this is not entirely unexpected given the large sample size and that only 5–10% of teens at this age will meet criteria for a Conduct Disorder diagnosis (Kessler et al., 2005; Maughan et al., 2004).

Finally, several limitations regarding the PES should be noted. This measure did not ask students to report which activities were associated with which particular substance. Thus, a composite outcome of alternative and complementary reinforcers was used that did not assess for substance-specific relations, limiting the explanatory specificity of the measure across specific types of substances, which likely reduced our power to detect results for substance-specific analysis. Relatedly, an activity from the PES was either categorized as an alternative or complementary reinforcer and did not capture instances when an activity was only sometimes associated with substance use. This method created a binary view of the behavioral economic mechanisms, possibly limiting the generalizability of how these constructs occur in everyday life. Future research that has adolescents fill out the PES twice, once for substance-related and once for substance-free associations, may provide a more nuanced understanding of this mechanism (Murphy et al., 2012a; Murphy et al., 2012b). It is also important to note the greater magnitude of correlation between complementary reinforcers and substance use compared to alternative reinforcers and substance use. It is accurate that there is some overlap between complementary reinforcers and substance use, as a teen must engage in substance use for an activity to be considered a complementary reinforcer. However, these constructs are not redundant. Complementary reinforcers refer to activities connected to use and substance use refers to the actual use behavior irrespective of the context. This is most likely at least part of the reason that the correlation between complementary reinforcers and substance use is larger than that of alternative reinforcers and substance use.

This study underscores the utility of using behavioral economic perspectives for understanding the association between CPs and adolescent substance use. These results also provide important implications for adapting substance use interventions to target adolescents already engaging in risky CP-related behaviors. Providing youth prone to CPs with interventions that help them identify and engage in more healthy alternative reinforcers have shown benefits in substance use prevention and intervention efforts (Murphy et al., 2012a; Murphy et al., 2012b). Adapting existing interventions towards adolescents, such as contingency management (Bigelow & Silverman, 1999) or Substance Free-Activity Session (Murphy et al., 2012a; Murphy et al., 2012b), that encourage participation in healthy activities and/or contingent rewards for abstinence and behaviors incompatible with substance use may create a more frequent reinforcing strategy of alternative reinforcers, thereby, altering the reinforcement schedule and relative reinforcing efficacy of substance use. We speculate that providing a diverse range of healthy alternative reinforcers that provide a similar thrill to CPs and substance use (e.g. extreme sports, creative performances

in front of large audiences) may be able to capture adolescents prone to CPs and substance use with a high threshold for deriving reinforcement to prevent escalation into substance use. Additionally, interventions aimed at teaching adolescents to savor pleasant experiences may also increase the intensity and duration of subjective reward derives from the alternative reinforcers (Kahler et al., 2015). These interventions are particularly important given findings that those who use substances engage in activities that facilitate their use patterns. Because adolescent-onset substance use often leads to chronic and severe trajectories of adult addiction with harmful health consequences (Johnston et al., 2014; Toumbourou et al., 2007), research like this may have broad implications for understanding and preventing the progression of substance use across adolescence.

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Public Significance

The current study found teens with behavioral problems were less likely to use substances when they engaged in more healthy, substance-free activities (e.g., hobbies, school clubs, dating, volunteering). Findings highlight the importance of developing interventions that provide teens greater access to after school programs, parks and recreation services, and school organizations that facilitate prosocial behaviors along with interventions that help teens derive more pleasure out of such opportunities.

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Table 1

Sample Characteristics among the overall sample and past six-month substance users stratified by sex.

	Overall Sample	Males		Females	
	Available N (*N* = 3,396)[a]	**Overall Sample (*N* = 1,568)**	**Substance Users (*N* = 393)**	**Overall Sample (*N* = 1,801)**	**Substance Users (*N* = 493)**
Age, *M* (*SD*)	3,360	14.6 (0.4)	14.7 (0.5)	14.5 (0.4)	14.6 (0.4)
Ethnicity, %	3,311				
Hispanic or Latino	--	43.1%	47.1%	48.8%	56.0%
Not Hispanic/Latino	--	54.5%	53.7%	49.8%	42.2%
Highest parental education, %	2,931				
High school graduate or less	--	25.6%	32.6%	26.3%	35.9%
Some college or more	--	60.0%	56.2%	61.7%	54.6%
RCADS- MDD, *M* (*SD*)	3,208	6.2 (6.2)	7.3 (6.7)	9.2 (7.4)	11.3 (7.9)
RCADS- GAD Symptoms, *M* (*SD*)	3,217	7.1 (4.5)	8.2 (4.7)	9.0 (4.6)	10.0 (4.7)
RCADS- PD Symptoms, *M* (*SD*)	3,192	3.4 (4.6)	4.3 (5.5)	5.3 (5.7)	6.7 (6.4)
UPPS-P- Positive Urgency, *M* (*SD*)	3,203	3.4 (0.6)	3.2 (0.6)	3.4 (0.6)	3.1 (0.7)
Peer Substance Use, *M* (SD)	3,329	14.4 (117.5)	5.9 (71.1)	14.9 (119.1)	19.3 (133.7)
Alternative Reinforcers, *M* (*SD*)	3,279	69.3 (29.2)	65.9 (31.4)	73.1 (27.5)	65.2 (28.7)
Complementary Reinforcers, *M* (*SD*)	520[b]	--	22.2 (27.5)	--	13.9 (18.9)
CPs, *M* (*SD*)	3,313	16.2 (6.0)	20.1 (8.3)	15.6 (5.0)	19.0 (7.1)
Past Six-Month Substance Use, %					
Any Substance	3,366	25.1%	100%	27.4%	100%
Alcohol	3,255	11.9%	47.6%	16.5%	60.2%
Cigarette	3,353	3.3%	13.0%	3.7%	13.6%
Marijuana	3,336	8.9%	35.6%	9.3%	33.9%
Past 30-Day Substance Use Frequency, *M* (SD)					
Any Substance	502	--	0.33 (0.7)	--	0.37 (0.7)
Alcohol	390	--	0.65 (1.3)	--	0.86 (1.4)
Cigarette	83	--	0.18 (0.8)	--	0.22 (0.9)
Marijuana	263	--	0.97 (2.0)	--	0.83 (1.8)

Note. Data from ninth grade students in Los Angeles, California, USA collected in 2013. Columns on male and female substance users stratify data by those who used any substance in the last six months.

[a]The overall sample between males and females (1,568+1,801 = 3,369) does not add up to the total available N for the overall sample because 27 teens did not report their gender.

[b]Sample size is low because an individual had to endorse substance use to endorse at least one complementary reinforcer. CPs = Conduct Problems; CESD = Center for Epidemiologic Studies of Depression Scale; 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. Data on complementary reinforcers and substance use frequency is not given in the overall sample because it is not possible to engage in activities that complement substance use if the adolescent does not use substances. Thus, numbers are the same across both columns given.

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Table 2

Correlation matrix of all study variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. CP	**1.00**	−.27	.41	N/A	.16	.27	.36	.55	.39	.31	.49	−.02	.00	.00	−.02	.06	.15	.10	.16
2. Alternative Reinforcers	−.19	**1.00**	−.45	N/A	−.11	−.18	−.28	−.36	−.24	−.22	−.37	−.02	−.02	.02	−.01	−.05	−.09	−.03	−.09
3. Complementary Reinforcers	.42	−.45	**1.00**	N/A	.13	.25	.35	.41	.21	.19	.52	−.02	.00	.03	−.06	.04	.06	.03	.08
4. Past 6-month Any Substance Use	.39	−.13	.24	**1.00**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5. Past 6-month Alcohol Use	.37	−.13	.26	.69	**1.00**	.10	.13	.28	.40	.13	.16	−.04	−.06	−.05	.04	−.01	.08	.06	.08
6. Past 6-month Cigarette Use	.31	−.13	.29	.32	.29	**1.00**	.24	.34	.22	.45	.24	.02	.01	.05	.02	.02	.10	.06	.10
7. Past 6-month Marijuana Use	.43	−.20	.40	.53	.44	.36	**1.00**	.45	.26	.21	.60	−.01	.05	−.03	−.06	.06	.05	.02	.07
8. Past 30 Day Any Use Frequency	.52	−.32	.41	.25	.37	.37	.49	**1.00**	.76	.67	.76	−.03	−.02	.00	−.02	.01	.16	.06	.11
9. Past 30 Day Alcohol Frequency	.43	−.18	.28	.41	.56	.32	.42	.78	**1.00**	.38	.45	−.04	−.04	.02	−.01	.04	.14	.03	.10
10. Past 30 Day Cigarette Frequency	.30	−.14	.21	.19	.22	.48	.38	.66	.41	**1.00**	.31	−.02	−.03	.01	−.01	−.01	.16	.10	.16
11. Past 30 Day Marijuana Frequency	.48	−.24	.53	.36	.36	.33	.66	.77	.53	.35	**1.00**	−.03	.01	.02	−.03	.03	.05	.02	.01
12. Sex	−.02	.02	−.01	.02	−.02	.02	.00	−.02	−.01	−.01	−.01	**1.00**	.22	.05	−.01	.04	−.26	−.05	−.16
13. Ethnicity	.03	−.01	.03	.01	−.03	.01	.03	−.03	−.02	−.02	.01	.47	**1.00**	.22	−.02	.07	−.02	−.02	−.04
14. Parental Education	−.08	.01	−.05	−.11	−.10	−.01	−.07	.02	−.07	.02	−.05	.04	.23	**1.00**	.01	.05	−.08	−.08	−.08
15. Peer Substance Use	−.01	−.01	−.02	−.01	−.03	.01	−.03	−.03	.00	−.01	−.02	.44	.25	−.09	**1.00**	.00	.00	.02	−.03
16. Impulsivity	.05	−.03	.07	.06	.03	.03	.06	.03	.05	.01	.05	.19	.15	.05	.13	**1.00**	−.02	.02	−.02
17. MDD	.21	−.10	.08	.13	.15	.10	.10	.15	.14	.12	.07	−.20	.01	−.04	−.03	.00	**1.00**	.43	.51
18. GAD	.16	−.01	.08	.13	.07	.08	.08	.07	.07	.08	.05	−.05	−.01	−.04	−.01	−.02	.42	**1.00**	.37
19. PD	.19	−.07	.09	.13	.11	.09	.10	.11	.11	.12	.06	−.12	.00	−.05	−.01	−.01	.49	.37	**1.00**

Note. All coefficients are Pearson correlations except the correlation between Parental Education and all other variables are Spearman correlations, as Parental Education is an ordinal variable. Values above the diagonal represent correlations between study variables among those who reported past six-month any substance use ($N = 890$). Values below the diagonal represent correlations between study variables among the overall sample ($N = 3,383$). Shaded cells note correlations that were *not* statistically significant at $p < .05$. MDD = Major Depressive Disorder; GAD = Generalized Anxiety Disorder;

Table 3

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

	Total Effect	Component Paths		Mediation: CP → Mediator → Outcome	
	CP → Outcome	CP → Mediator	Mediator → Outcome Controlling for CP	Indirect effect	Direct effect
	B (95% CI)	*B (95% CI)*	*B (95% CI)*	*B (95% CI)*	*B (95% CI)*
Outcome: Past Six-Month Use Status; Mediator: Alternative Reinforcers (Overall Sample; *N* = 3,202)					
Model 1 (Unadjusted)	.96 (.81, 1.10)†	−.18 (−.21, −.15)†	−.13 (−.22, −.03)**	.02 (.001, .05)**	.95 (.81, 1.09)†
Model 2 (Adjusted)[a]	.96 (.82, 1.11)†	−.17 (−.21, −.14)†	−.14 (−.24, −.04)**	.02 (.002, .05)**	.95 (.82, 1.09)†
Model 3 (Adjusted)[b]	.69 (.58, .80)†	−.14 (−.17, −.11)†	−.11 (−.21, −.01)*	.02 (.002, .03)*	.68 (.57, .79)†
Model 4 (Adjusted)[c]	.68 (.56, .80)†	−.13 (−.16, −.09)†	−.12 (−.23, −.02)*	.02 (.002, .03)*	.67 (.55, .78)†
Outcome: Frequency Use; Mediator: Complementary Reinforcers (Past Six-Month Substance Users; *N* = 340)					
Model 1 (Unadjusted)	.44 (.34, .53)†	.41 (.21, .60)†	.18 (.08, .28)***	.08 (.002, .17)***	.36 (.23, .48)†
Model 2 (Adjusted)[a]	.44 (.35, .53)†	.42 (.22, .61)†	.20 (.09, .30)***	.08 (.002, .17)***	.36 (.25, .47)†
Model 3 (Adjusted)[b]	.34 (.24, .43)†	.37 (.17, .56)†	.18 (.08, .29)***	.07 (.01, .15)**	.27 (.14, .41)†
Model 4 (Adjusted)[c]	.34 (.26, .42)†	.37 (.16, .59)†	.19 (.14, .24)†	.07 (.003, .15)***	.27 (.19, .34)†
Outcome: Frequency Use; Mediator: Alternative Reinforcers (Past Six-Month Substance Users; *N* = 833)					
Model 1 (Unadjusted)	.52 (.46, .58)†	−.28 (−.32, −.23)†	−.46 (−.60, −.31)†	.13 (.05, .22)†	.39 (.33, .46)†
Model 2 (Adjusted)[a]	.53 (.46, .60)†	−.25 (−.32, −.19)†	−.44 (−.59, −.29)†	.11 (.03, .22)†	.41 (.33, .48)†
Model 3 (Adjusted)[b]	.38 (.31, .46)†	−.19 (−.28, −.11)†	−.38 (−.54, −.24)†	.07 (.01, .18)†	.30 (.23, .38)†
Model 4 (Adjusted)[c]	.41 (.35, .46)†	−.18 (−.26, −.10)†	−.35 (−.49, −.22)†	.06 (.004, .16)†	.33 (.26, .40)†

Note. *B* (95% *CI*) = Parameter estimate for predictor from Generalized Estimating Equation with 95% confidence interval. CP = Conduct Problem.

[a]Adjusted model is adjusted for demographic covariates, including ethnicity, sex, and parental education level.

[b]Adjusted model is adjusted for peer substance use and positive urgency in addition to demographic covariates tested in [a]Adjusted.

[c]Adjusted model is adjusted for depression, anxiety, and panic symptoms in addition to covariates tested in [a]Adjusted and [b]Adjusted.

*$p < .05$,

** $p < .01$,

*** $p < .001$,

† $p < .0001$.

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Table 4

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

	Total Effect	**Component Paths**		**Mediation: CP → Mediator → Outcome**	
	CP → Outcome	**CP → Mediator**	**Mediator → Outcome Controlling for CP**	**Indirect effect**	**Direct effect**
	B (95% CI)	***B (95% CI)***	***B (95% CI)***	***B (95% CI)***	***B (95% CI)***
Outcome: Past Six-Month Use Status; Mediator: Alternative Reinforcers (Overall Sample; *N* = 3,104)					
Model 1 (Unadjusted)	.80 (.68, .91)†	−.18 (−.21, −.15)†	−.19 (−.25, −.13)†	.03 (.01, .06)†	.77 (.65, .89)†
Model 2 (Adjusted)[a]	.84 (.74, .94)†	−.17 (−.20, −.14)†	−.22 (−.30, −.14)†	.04 (.01, .07)†	.81 (.71, .91)†
Model 3 (Adjusted)[b]	.56 (.46, .65)†	−.14 (−.17, −.11)†	−.18 (−.29, −.08)***	.03 (.01, .05)**	.53 (.43, .63)†
Model 4 (Adjusted)[c]	.54 (.43, .65)†	−.12 (−.15, −.09)†	−.19 (−.30, −.08)***	.02 (.001, .05)***	.52 (.40, .64)†
Outcome: **Alcohol** Frequency Use; Mediator: Complementary Reinforcers (Past Six-Month Alcohol Substance Users; *N* = 338)					
Model 1 (Unadjusted)	.53 (.28, .88)†	.41 (.21, .60)†	.19 (−.08, .46)	.08 (−.03, .21)	.45 (.19, .72)***
Model 2 (Adjusted)[a]	.61 (.34, .88)†	.40 (.21, .60)†	.24 (−.05, .52)	.10 (−.02, .24)	.51 (.23, .80)***
Model 3 (Adjusted)[b]	.41 (.14, .68)**	.34 (.15, .53)***	.15 (−.12, .43)	.05 (−.04, .17)	.36 (.08, .65)*
Model 4 (Adjusted)[c]	.44 (.18, .71)**	.33 (.14, .55)**	.16 (−.11, .42)	.05 (−.04, .17)	.39 (.11, .67)**
Outcome: **Alcohol** Frequency Use; Mediator: Alternative Reinforcers (Past Six-Month Alcohol Substance Users; *N* = 826)					
Model 1 (Unadjusted)	.73 (.56, .90)†	−.27 (−.31, −.23)†	−.24 (−.39, −.08)**	.06 (.01, .12)**	.66 (.48, .84)†
Model 2 (Adjusted)[a]	.77 (.59, .96)†	−.25 (−.31, −.19)†	−.28 (.42, −.14)**	.06 (.01, .12)**	.72 (.56, .88)†
Model 3 (Adjusted)[b]	.55 (.36, .74)†	−.19 (−.28, −.11)†	−.16 (−.32, −.001)*	.03 (.000, .07)*	.51 (.31, .71)†
Model 4 (Adjusted)[c]	.56 (.38, .74)†	−.18 (−.26, −.09)†	−.16 (−.32, .01)	.03 (−.001, .06)	.53 (.34, .72)†

Note. B (95% *CI*) = Parameter estimate for predictor from Generalized Estimating Equation with 95% confidence interval. CP = Conduct Problem.

[a]Adjusted model is adjusted for demographic covariates, including ethnicity, sex, and parental education level.

[b]Adjusted model is adjusted for peer substance use and positive urgency in addition to demographic covariates tested in [a]Adjusted.

[c]Adjusted model is adjusted for depression, anxiety, and panic symptoms in addition to covariates tested in [a]Adjusted and [b]Adjusted.

*$p < .05$,

** $p < .01$,

*** $p < .001$,

† $p < .0001$.

Table 5

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

	Total Effect	**Component Paths**		**Mediation: CP → Mediator → Outcome**	
	CP → Outcome	**CP → Mediator**	**Mediator → Outcome Controlling for CP**	**Indirect effect**	**Direct effect**
	B (95% CI)	***B (95% CI)***	***B (95% CI)***	***B (95% CI)***	***B (95% CI)***
Outcome: Past Six-Month Use Status; Mediator: Alternative Reinforcers (Overall Sample; *N* = 3,193)					
Model 1 (Unadjusted)	.74 (.57, .91)†	−.18 (−.21, −.15)†	−.42 (−.57, −.26)†	.07 (.02, .14)†	.66 (.50, .82)†
Model 2 (Adjusted)[a]	.75 (.58, .92)†	−.17 (−.20, −.14)†	−.42 (−.57, −.26)†	.07 (.02, 149)†	.68 (.51, .84)†
Model 3 (Adjusted)[b]	.46 (.29, .64)†	−.13 (−.16, −.10)†	−.36 (−.52, −.21)†	.05 (.01, .10)†	.40 (.23, .57)†
Model 4 (Adjusted)[c]	.44 (.26, .61)†	−.11 (−.15, −.08)†	−.36 (−.52, −.19)†	.04 (.003, .10)†	.38 (.21, .55)†
Outcome: **Cigarette** Frequency Use; Mediator Complementary Reinforcers (Past Six-Month Cigarette Substance Users; *N* = 337)					
Model 1 (Unadjusted)	.54 (.30, .79)†	.41 (.21, .61)†	.29 (.05, .54)*	.12 (.02, .25)*	.42 (.14, .70)**
Model 2 (Adjusted)[a]	.58 (.32, .84)†	.41 (.21, .60)†	.30 (.05, .55)*	.12 (.02, .26)*	.45 (.17, .74)**
Model 3 (Adjusted)[b]	.35 (.04, .66)*	.34 (.16, .53)***	.26 (−.02, .54)	.09 (−.01, .22)	.25 (−.11, .60)
Model 4 (Adjusted)[c]	.36 (.04, .68)*	.35 (.14, .55)***	.24 (−.08, .56)*	.08 (−.03, .23)	.26 (−.11, .63)
Outcome: **Cigarette** Frequency Use; Mediator Alternative Reinforcers (Past Six-Month Cigarette Substance Users; *N* = 827)					
Model 1 (Unadjusted)	.65 (.44, .82)†	−.25 (−.32, −.19)†	−.64 (−.98, −.30)***	.18 (.02, .35)***	.48 (.26, .72)†
Model 2 (Adjusted)[a]	.65 (.45, .84)†	−.25 (−.32, −.19)†	−.65 (−1.00, −.30)***	.16 (.05, .31)**	.48 (.26, .70)†
Model 3 (Adjusted)[b]	.36 (.12, .60)**	−.19 (−.28, −.11)†	−.54 (−.87, −.21)**	.11 (.02, .23)**	.25 (.01, .49)*
Model 4 (Adjusted)[c]	.37 (.13, .61)**	−.18 (−.26, −.09)†	−.54 (−.87, −.20)**	.09 (.01, .21)**	.26 (.02, .50)*

Note. *B* (95% *CI*) = Parameter estimate for predictor from Generalized Estimating Equation with 95% confidence interval. CP = Conduct Problem.

[a]Adjusted model is adjusted for demographic covariates, including ethnicity, sex, and parental education level.

[b]Adjusted model is adjusted for peer substance use and positive urgency in addition to demographic covariates tested in [a]Adjusted.

[c]Adjusted model is adjusted for depression, anxiety, and panic symptoms in addition to covariates tested in [a]Adjusted and [b]Adjusted.

*$p < .05$,

** $p < .01$,

*** $p < .001$,

† $p < .0001$.

Table 6

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

	Total Effect	**Component Paths**		**Mediation: CP → Mediator → Outcome**	
	CP → Outcome	**CP → Mediator**	**Mediator → Outcome Controlling for CP**	**Indirect effect**	**Direct effect**
	B (95% CI)	***B (95% CI)***	***B (95% CI)***	***B (95% CI)***	***B (95% CI)***
Outcome: Past Six-Month Use Status; Mediator: Alternative Reinforcers (Overall Sample; *N* = 3,179)					
Model 1 (Unadjusted)	1.00 (.85, 1.14)†	−.18 (−.21, −.15)†	−.41 (−.49, −.33)†	.07 (.04, .11)†	.86 (.76, .97)†
Model 2 (Adjusted)[a]	.99 (.84, 1.13)†	−.17 (−.20, −.14)†	−.43 (−.51, −.35)†	.07 (.04, .12)†	.88 (.78, .98)†
Model 3 (Adjusted)[b]	.68 (.53, .84)†	−.13 (−.17, −.10)†	−.40 (−.50, −.30)†	.05 (.02, .10)†	.61 (.48, .74)†
Model 4 (Adjusted)[c]	.67 (.52, .83)†	−.12 (−.15, −.09)†	−.41 (−.52, −.30)†	.05 (.02, .09)†	.60 (.47, .73)†
Outcome: **Marijuana** Frequency Use; Mediator Complementary Reinforcers (Past Six-Month Marijuana Substance Users; *N* = 335)					
Model 1 (Unadjusted)	.80 (.47, 1.13)†	.41 (.21, .61)†	1.22 (.40, 2.04)**	.50 (.05, 1.17)**	.48 (.15, .80)**
Model 2 (Adjusted)[a]	.77 (.44, 1.10)†	.41 (.21, .61)†	1.28 (.42, 2.13)**	.52 (.09, 1.21)**	.44 (.11, .77)**
Model 3 (Adjusted)[b]	.54 (.22, .87)**	.34 (.23, .45)†	1.15 (.27, 2.03)*	.39 (.09, .71)*	.30 (−.03, .64)
Model 4 (Adjusted)[c]	.62 (.29, .94)***	.34 (.13, .55)**	1.21 (.24, 2.17)*	.41 (.06, .90)*	.37 (.05, .69)*
Outcome: **Marijuana** Frequency Use; Mediator Alternative Reinforcers (Past Six-Month Marijuana Substance Users; *N* = 825)					
Model 1 (Unadjusted)	.97 (.75, 1.20)†	−.28 (−.32, −.23)†	−.63 (−.82, −.44)†	.18 (.07, .31)†	.84 (.60, 1.07)†
Model 2 (Adjusted)[a]	.94 (.71, 1.17)†	−.25 (−.32, −.19)†	−.61 (−.80, −.42)†	.16 (.05, .31)†	.83 (.66, 1.07)†
Model 3 (Adjusted)[b]	.68 (.45, .92)†	−.19 (−.27, −.12)†	−.55 (−.85, −.35)†	.11 (.02, .24)†	.59 (.35, .84)†
Model 4 (Adjusted)[c]	.72 (.49, .95)†	−.18 (−.26, −.09)†	−.56 (−.86, −.36)†	.10 (.01, .25)†	.64 (.40, .88)†

Note. B (95% *CI*) = Parameter estimate for predictor from Generalized Estimating Equation with 95% confidence interval. CP = Conduct Problem.

[a]Adjusted model is adjusted for demographic covariates, including ethnicity, sex, and parental education level.

[b]Adjusted model is adjusted for peer substance use and positive urgency in addition to demographic covariates tested in [a]Adjusted.

[c]Adjusted model is adjusted for depression, anxiety, and panic symptoms in addition to covariates tested in [a]Adjusted and [b]Adjusted.

*$p < .05$,

** $p < .01$,

*** $p < .001$,

† $p < .0001$.

Table 7

Association of Conduct Problems to Past Six-Month Alcohol Use and Mediation by Alternative Reinforcement among Males and Females

	Total Effect	Component Paths		Mediation: Substance Use → Mediator → Outcome	
	Substance Use → Outcome	Substance Use → Mediator	Mediator → Outcome Controlling for Substance Use	Indirect effect	Direct effect
	B (95% CI)	*B (95% CI)*	*B (95% CI)*	*B (95% CI)*	*B (95% CI)*
Outcome: Past Six-Month Use Status among Males; Mediator: Alternative Reinforcers (Overall Sample; *N* = 1,415)					
Model 1 (Unadjusted)	.72 (.57, .87)†	−.16 (−.20, −.11)†	−.08 (−.20, .04)	.01 (−.01, .03)	.71 (.55, .86)†
Model 2 (Adjusted)[a]	.71 (.57, .86)†	−.15 (−.20, −.10)†	−.09 (−.22, .04)	.01 (−.01, .04)	.70 (.55, .85)†
Outcome: Past Six-Month Use Status among Females; Mediator: Alternative Reinforcers (Overall Sample; *N* = 1,682)					
Model 1 (Unadjusted)	1.00 (.92, 1.09)†	−.20 (−.24, −.16)†	−.30 (−.41, −.19)†	.06 (.02, .12)†	.95 (.86, 1.04)†
Model 2 (Adjusted)[a]	1.02 (.93, 1.11)†	−.19 (−.23, −.16)†	−.31 (−.43, −.19)†	.06 (.01, .12)†	.98 (.88, 1.07)†

Note. B (95% *CI*) = Parameter estimate for predictor from Generalized Estimating Equation with 95% confidence interval. CP = Conduct Problem.

[a]Adjusted model is adjusted for demographic covariates, including ethnicity, sex, and parental education level.

*$p < .05$,

**$p < .01$,

***$p < .001$,

†$p < .0001$.