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# Developmental pathways from parental socioeconomic status to adolescent substance use: Alternative and complementary reinforcement

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## Abstract

Although lower socioeconomic status has been linked to increased youth substance use, much less research has determined potential mechanisms explaining the association. The current longitudinal study tested whether alternative (i.e., pleasure gained from activities without any concurrent use of substances) and complementary (i.e., pleasure gained from activities in tandem with substance use) reinforcement mediate the link between lower socioeconomic status and youth substance use. Further, we tested whether alternative and complementary reinforcement and youth substance use gradually unfold over time and then intersect with one another in a cascading manner. Potential

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Research Interests:

Jungeun Olivia Lee—Socioeconomic status; substance use; addiction; behavioral health; life course perspective; developmental cascading process.

Junhan Cho—Substance use; addiction; mental health; childhood adversity.

Yoewon Yoon—Behavioral health; childhood adversity.

Mariel S. Bello—Socioeconomic status; substance use; health disparities; mental health; sociocultural determinants of addiction.

Rubin Khoddam–Substance use; addiction; mental health; externalizing behavior problems.

Adam M. Leventhal—Substance use; addiction; the role of emotion as a determinant of health risk behaviors; behavioral economic theory.

**Authors' Contributions**

JOL conceptualized the study, guided data analyses, led the writing of the article, and coordinated drafting of the manuscript among co-authors; JC performed the statistical analyses; YY and MSB contributed to data preparation for analyses and article preparation including literature search; RK contributed to data analyses and the interpretation of findings; AMH conceptualized the study, contributed to interpretation of findings, and acquired the data. In addition, all authors have been involved in drafting the manuscript and revising it critically for important intellectual content. All authors read and approved the final manuscript.

**Data Sharing Declaration**

This manuscript's data will not be deposited.

**Conflicts of Interest**

No conflict declared.

**Ethical approval**

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All study procedures were approved by the Human Subjects Review Committee of the University of Southern California.

**Informed consent**

Informed consent was obtained from all participants included in the study.

sex differences are also examined. Data were drawn from a longitudinal survey of substance use and mental health among high school students in Los Angeles. Data collection involved four semiannual assessment waves beginning in fall 2013 ($N$ = 3,395; $M$ baseline age = 14.1; 47% Hispanic, 16.2% Asian, 16.1% multiethnic, 15.7% White, and 5% Black; 53.4% female). The results from a negative binomial path model suggested that lower parental socioeconomic status (i.e., lower parental education) was significantly related to an increased number of substances used by youth. The final path model revealed that the inverse association was statistically mediated by adolescents' diminished engagement in pleasurable substance-free activities (i.e., alternative reinforcers) and elevated engagement in pleasurable activities paired with substance use (i.e., complementary reinforcers). The direct effect of lower parental education on adolescent substance use was not statistically significant after accounting for the hypothesized mediating mechanisms. No sex differences were detected. Increasing access to and engagement in pleasant activities of high quality that do not need a reinforcement enhancer, such as substances, may be useful in interrupting the link between lower parental socioeconomic status and youth substance use.

### Keywords

Health disparities; Socioeconomic status; Adolescents; Substance use; Behavioral economics; Cascade model

## Introduction

Adolescence is a developmental period featuring increased risk of substance use (Zucker 2008). The first few years of high school represent particularly high-risk periods during which substance use rapidly increases. According to recent national data (Johnston et al. 2017), 7% of eighth graders reported drinking during the previous 30 days. For 10th graders, the rate of drinking climbed to 20%. Adolescent substance use has been linked to problematic drug use (Guttmannova et al. 2011; Irons et al. 2015) and other psychosocial issues in adulthood (Irons et al., 2015). Further, polysubstance use—using more than one type of substance during a specific period (Connor et al. 2014)—often emerges during adolescence (Tomczyk et al. 2016), which is associated with more debilitating consequences later in life in comparison to monosubstance use (Kelly et al. 2015; Kokkevi et al. 2014). Collectively, adolescent substance use generates a substantial disease burden across the life course, representing an important public health concern.

### Parental Socioeconomic Status and Adolescent Substance Use

Lower socioeconomic status has been linked to increased adolescent substance use (Bachman et al. 2011; Pampel et al. 2010). Relevant existing evidence, however, has been inconsistent (Hanson and Chen 2007; Pampel et al. 2010). Some empirical studies indicated that key indicators of lower socioeconomic status, such as lower parental education (Galobardes et al. 2006), were associated with increased youth substance use (Bachman et al. 2011; Lemstra et al. 2008; Wallace et al. 2009), although emerging evidence has suggested that the strength of these associations might substantially attenuate during late adolescence (Bachman et al. 2011; Wallace et al. 2009). Yet not all empirical studies have confirmed such developmental variations in the strength of the link (Friestad et al. 2003). To

add to the confusion, other studies reported that lower parental education is associated with decreased adolescent substance use (Piko and Fitzpatrick 2007; Ritterman et al. 2009). These inconsistencies in the existing literature call for further investigation of this topic area. Considering existing studies have often relied on cross-sectional data with few exceptions (i.e., Andrabi et al. 2017), an empirical inquiry of prospective longitudinal data could further clarify the nature of the association between socioeconomic status and adolescent substance use. Further, there has been little longitudinal investigation of the extent to which parental socioeconomic status is associated with adolescent polysubstance use, which has been linked to more debilitating consequences (Kelly et al. 2015; Kokkevi et al. 2014).

More importantly, much less research has investigated potential mechanisms explaining the linkage of focus (Hardaway and Cornelius 2014; Pampel et al. 2010), leaving concrete and malleable prevention targets that could break the link between parental socioeconomic status and youth substance use unidentified. This represents an important missed opportunity to interrupt the process leading to disproportionate concentration of substance use among adolescents with lower socioeconomic status earlier in life, before they persist or widen over the life course (Buchmann and Steinhoff 2017; Lee et al. 2017).

## Possible Underlying Mechanisms in Parental Socioeconomic Status and Adolescent Substance Use: Alternative and Complementary Reinforcement

Applications of behavioral economic theory to substance use have highlighted the role of two types of nondrug reinforcement—alternative and complementary reinforcement (Audrain-McGovern et al. 2004; Bickel et al. 2014). The overarching premise is that individuals have an inherent drive to engage in activities that are pleasurable (i.e., reinforcement), and when provided with the opportunity to choose among multiple reinforcement options, they are likely to select the behavior with the highest overall reinforcement value (i.e., highest possible level of pleasure). Substance use may represent very powerful reinforcing behaviors due to its direct pharmacological effects. However, substance use must compete with other alternative reinforcing behaviors (i.e., activities that instill pleasure, such as playing a musical instrument, reading, or participating in school organizations). Thus, the number and quality of alternative nondrug reinforcers available may play a role in adolescent substance use, along with other individual and environmental risk factors known to contribute to youth substance use (Audrain-McGovern et al. 2004; Bickel et al. 2014). Empirical evidence has corroborated this conceptual speculation (Bickel et al. 2014), and diminished engagement in alternative reinforcers has been associated with increased odds of smoking progression in adolescents and young adults (Audrain-McGovern et al. 2004; Leventhal, Bello, et al. 2015).

Diminished engagement in alternative reinforcers could be a mechanism underlying the association between parental socioeconomic status and adolescent substance use. Adolescents with lower socioeconomic status often live in disadvantaged neighborhoods in which resources and opportunities for healthy alternative reinforcers (e.g., community clubs, access to musical instruments) are limited (Estabrooks et al. 2003; Moore et al. 2008; Rigolon 2016). Further, even if available, alternative reinforcers might not be affordable to adolescents from families with lower socioeconomic status due to constrained financial

resources (Afterschool Alliance 2014; Mahoney et al. 2009). Consistently, a cross-sectional study of ninth-grade students in Los Angeles (Leventhal, Bello, et al. 2015) using data from the current study sample found diminished alternative reinforcement mediated the inverse association between parental education and adolescent substance use. A follow-up prospective study of the same sample documented that diminished healthy activities mediated the link between parental education and adolescent substance use at 12-month follow-up (Andrabi et al. 2017).

In contrast to alternative reinforcement, complementary reinforcement is related to activities that, when engaged in simultaneously, amplify the reinforcing value of one another (Audrain-McGovern et al. 2004; Bickel et al. 2014). Specifically, in the case of substance use, certain pleasant activities are typically incompatible with drug use and function as alternative reinforcers (e.g., excelling in academics, fulfilling job responsibilities, spending time with non-drug-using family members). Not all activities, however, act as competitive alternatives to substance use. In many cases, substance use can act as a complement; when used in conjunction with certain activities, substance use enhances the degree of pleasure that a given pleasant activity might generate. Basic psychopharmacology literature has reported that concurrent use of nicotine (Perkins and Karelitz 2013, 2014) or cannabis (Mahler et al. 2007) enhances the reinforcing effects (i.e., pleasure) of some pleasant activities (e.g., music or dance; Perkins and Karelitz 2014). Use of alcohol in conjunction with social activities (Shinew and Parry 2005) represents a common example, whereby alcohol complements social activities, such as team sports, rendering them more enjoyable (Finlay et al. 2012; Yusko et al. 2008).

Along with diminished alternative reinforcement, elevated complementary reinforcement could be another mechanism linking lower parental socioeconomic status to increased youth substance use. For adolescents with lower socioeconomic status, the need for reward enhancement for activities might be particularly heightened, considering that pleasant activities accessible to them may lack quality, and thus their baseline reinforcing efficacy (i.e., the degree of reinforcement that a given activity can generate by itself) might be limited. Because of this low baseline reinforcing efficacy of available activities, youth with lower socioeconomic status may be more motivated to pair substance use with a given activity to increase overall level of reinforcement derived from that activity, in comparison to youth from higher socioeconomic status backgrounds, who might have little need to enhance already enjoyable activities. Substances might represent an affordable and easily accessible way to increase the level of reinforcement of those activities for youth with low socioeconomic status, considering their limited resources. In addition, the density of and proximity to alcohol (Romley et al. 2007), tobacco (Henriksen et al. 2008), and cannabis (Németh and Ross 2014) retail outlets; visibility of drug sales (Saxe et al. 2001); prevalence of substance use; and drug use norms are often elevated in disadvantaged neighborhoods (Linton et al. 2014; Rhew et al. 2017); hence, using substances may be a highly accessible and easy strategy to increase the level of pleasurable experiences, complementing activities with low baseline reinforcing efficacy for youth with low socioeconomic status. To the best of our knowledge, no previous study has tested whether complementary reinforcement functions as a mechanism underlying the link between parental socioeconomic status and adolescent substance use.

## Cascading Processes: Alternative and Complementary Reinforcement Over Time

Because substance use has been widely understood as an inherently developmental phenomenon (Zucker 2008) and the negative impact of earlier socioeconomic status on various health measures is known to either persist or possibly widen across the life course (Buchmann and Steinhoff 2017; Lee et al. 2017), it is critical to understand how alternative reinforcement, complementary reinforcement, and substance use gradually unfold and intersect with one another over time. The developmental cascade model (Cicchetti and Lynch 1993; Masten et al. 2005) posits that a potent risk factor in the childhood environment, such as low socioeconomic status (Freese and Lutfey 2011; Link and Phelan 1995), can significantly disrupt a child's initial adaptation and competencies, which may result in the progression of maladaptive behaviors and collateral compromise in other developmental systems during subsequent developmental periods in an reciprocal or cascading manner. Specifically, the key tenets of the developmental cascade model include (a) continuity in functioning of individuals and contexts across time; (b) bidirectional influences between individuals and contexts; and (c) amplification of the risk process across domains and over time. Several studies illustrated the utility of this framework in understanding the developmental processes involved in youth substance use (e.g., Dodge et al. 2009; Rogosch et al. 2010).

It is feasible that a developmental risk process underlying the link between parental socioeconomic status and adolescent substance use might unfold in a cascading manner. First, lower parental socioeconomic status might set the detrimental cascade process in motion by elevating a youth's initial substance use risk. As previously noted, adolescents from lower socioeconomic status backgrounds might live in a socioenvironmental context in which opportunities for alternative reinforcement are reduced and accessibility to complementary reinforcement is elevated—both may increase risk of future substance use. Youth who use a greater variety of substances may have more opportunities to engage in drug-involved complementary activities. Such bidirectional transactions between alternative or complementary reinforcement and youth substance use may continue and possibly become stronger over time. No studies, to our knowledge, have tested for possible cascading effects in the developmental risk process underlying the link between parental socioeconomic status and youth substance use.

## Sex Differences

Some conceptual discussions and findings of several published studies posited possible sex differences in the hypothesized processes underlying the link between low parental socioeconomic status and adolescent substance use, complementary and alternative reinforcement, and youth substance use. Gender socialization (Chodorow 1978) posits that women might be less likely to be involved in substance use in general, because externalizing behaviors such as substance use might not fit gendered behavioral norms (Broidy and Agnew 1997; Chaplin and Aldao 2013; Nolen-Hoeksema 2004). Yet gendered behavioral norms have changed, including those related to substance use, as evidenced by sex convergence in substance use (Kuntsche et al. 2011; White et al. 2015). Similarly, types of reinforcing activities also differ across sexes: young men might be more involved in social

activities that are often paired with substance use, such as athletics (Finlay et al. 2012; Rockafellow and Saules 2006), in comparison to young women.

Possible sex differences in the association of parental socioeconomic status and adolescent substance use have been also examined in few studies (Andrabi et al. 2017; Lintonen et al. 2000; Melotti et al. 2013)—evidence is mixed regarding for which sex the impact of parental socioeconomic status on youth substance use is more prominent (for reviews, see Hanson and Chen 2007; Wiles et al. 2007). Further, sex differences might also exist in the association between reinforcers and substance use, but consensus in the evidence has not yet emerged. The role of reinforcers in substance use was found to be stronger for girls in some studies (Khoddam and Leventhal 2016; Tucker et al. 2002) but more prominent for boys in others (Murphy et al. 2006; Vieno et al. 2007). Still others reported no sex differences (Goldstein et al. 2013). Taken together, this evidence suggests a need to evaluate sex differences in the hypothesized processes underlying the link between parental socioeconomic status, complementary and alternative reinforcement, and adolescent substance use.

## Current Study

The current longitudinal study examined associations between parental education, a key indicator of family socioeconomic status (Galobardes et al. 2006), and adolescent substance use in a cohort of adolescents aged 14.5 to 16. We addressed four central hypotheses. First, we hypothesized that diminished alternative reinforcement (i.e., pleasure gained from substance-free activities) and elevated complementary reinforcement (i.e., pleasure gained from substance-involved activities) would serve as mediating mechanisms explaining the link between parental education and adolescent substance use during mid adolescence. Second, we couched this hypothesis within the cascading model, whereby complementary and alternative reinforcement would predict further reductions in alternative reinforcement and increases in complementary reinforcement (i.e., continuity in each domain), which in turn would further increase youth substance use (see Figure 1). Adolescent substance use would then affect alternative and complementary reinforcement during subsequent years (i.e., bidirectional influence). We further hypothesized that the risk process would be strengthened over time (i.e., amplification over time). Third, given that the association of parental socioeconomic status with youth substance use might be influenced by a complex network of sociocultural factors (i.e., not entirely captured by alternative and complementary reinforcement), we expected that a significant portion of the association between parental education and youth substance would not be explained by the hypothesized mediators. Finally, we examined a nondirectional exploratory hypothesis evaluating sex differences in the hypothesized cascading process, considering concepts of gender socialization, empirical evidence suggesting such differences, and a lack of consensus regarding for which sex the impact is more amplified. Of note, key advancements of the current study beyond two previous reports (i.e., Andrabi et al. 2017; Leventhal, Bello, et al. 2015) using the data from the same sample include (a) testing the role of complementary reinforcement in addition to alternative reinforcement; (b) conceptually integrating behavioral economic theory with the developmental cascade model and empirically testing the integrated conceptual model; (c)

using a past-30-day polysubstance use; and (d) analyzing data with a more extended period of assessment.

## Methods

### Participants and Procedures

Data were drawn from a longitudinal survey of substance use among high school students in Los Angeles. Of 40 public high schools approached to participate in the study because of their diverse demographic characteristics and proximity, 10 schools participated (see Table S1 for characteristics of participating schools). Of the 4,100 eligible ninth-grade students, 3,396 students and their parents provided active written or verbal assent and consent, respectively, and enrolled in the study. Data collection involved four semiannual assessment waves beginning in fall 2013: baseline (W1; *M* age = 14.58; *N* = 3,383, 99.6%) and 6-month (W2; *M* age = 15.10; *N* = 3,292, 96.9%), 12-month (W3; *M* age = 15.52; *N* = 3,281, 96.6%), and 18-month (W4; *M* age = 16.09; *N* = 3,251, 95.7%) follow-ups. At each assessment, participants spent approximately 1 hour completing paper-and-pencil surveys during a regularly scheduled class period. Students not in class during data collection completed surveys by alternative modes such as telephone, internet, or mail (6-month follow-up: *n* = 51, 12-month follow-up: *n* = 153, 18-month follow-up: *n* = 215). Each school received approximately $2,500 for participation in the study; students were not individually compensated for participation, but received small incentives (e.g., pens, key chains). The sample was ethnically diverse and sex balanced, as shown in Table 1. More details about the sample are available in prior published papers (Leventhal, Strong, et al. 2015). The study was approved by the human subjects review committee at an affiliated university.

### Measures

**Substance use in past 30 days—**At each wave, use of six substances was measured using six well-validated items based on the Monitoring the Future survey (Johnston et al. 2014). Participants reported the number of days they had used each substance for recreational purposes or to “get high” during the previous 30 days: alcohol, combustible cigarette, marijuana, stimulant, prescription stimulant pill, and prescription painkiller on a forced-choice 9-level ordinal scale from 0 (*0 days*) to 8 (*all 30 days*). These six substances were selected based on their high respective prevalence in previous samples drawn from the study region (Unger, 2014). The distributions of responses were highly positively skewed with inflated proportions of zeros. Thus, for the primary outcome, each response was recoded into a binary indicator based on any use (0 = *no*, 1 = *yes*), then summed into a composite index summarizing different substances used during the previous 30 days for each wave (range = 0–6).

**Parental educational level—**At baseline, youth reported the highest grade completed by their mother and father with two questions using an ordinal forced-choice item for each parent (1 = 8th grade or less, 2 = some high school, 3 = high school graduate, 4 = some college, 5 = college graduate, 6 = advanced degree). The highest education level was recoded as 0 (high school graduate or higher degree) or 1 (no high school diploma), which is consistent with prior studies using a binary parental education measure as a proxy for

socioeconomic status (Cho and Kogan 2016; Gardner et al. 2008). Of note, high school completion has been recognized to be a critical marker in educational trajectories, because it is a minimum requirement for postsecondary education and many jobs (Laird et al. 2006) and has been reported to cast long-lasting impacts throughout the life course (Kenkel et al. 2006).

**Alternative and complementary reinforcement—**At each time point, alternative and complementary reinforcement were assessed by a modified version of the Pleasant Events Schedule (MacPhillamy and Lewinsohn 1976) for adolescents, as in prior research (Audrain-McGovern et al. 2011). Participants initially rated 44 typically pleasant activities (e.g., reading, going out to eat at a restaurant, drawing or painting art, playing musical instruments, participating in school organizations, visiting or hanging out with friends) regarding 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*) during the prior 30 days. Additionally, participants were asked to indicate whether they engaged in each pleasant activity while drinking alcohol, smoking, or using drugs—we did not have a priori classification regarding which activities generate alternative reinforcement (i.e., a given activity generates pleasure without any concurrent use of substances) and which activities generate complementary reinforcement (i.e., a given activity generates pleasure with concurrent use of substances).

Consistent with prior methods of measuring reinforcement, each item's engagement frequency and pleasure scores were multiplied to provide a product score, indicating the amount of total reinforcement derived from the given activity based on the frequency of engagement and the pleasure derived (Audrain-McGovern et al. 2011). For example, regarding the activity of reading, if a participant reported that they read "7 or more times" in the past month and found it "somewhat pleasurable," they received a total score of 2 for that activity. If the activity was marked as not being associated with substance use, it was classified as an alternative reinforcer. If the activity was marked as being associated with substance use, it was classified as a complementary reinforcer. Thus, any given activity was either a complementary or alternative reinforcer. The product score for the activities marked as alternative versus complementary reinforcers were then added separately to provide two unique sum scores.

**Covariates—**Covariates included age, sex, four dummy race and ethnicity variables, living situation (0 = *other type of living situation* [e.g., single-parent household, other relative], 1 = *living with both parents*), and family history of cigarette, alcohol, or drug use by siblings, parents, or grandparents (0 = *no*, 1 = *yes*). These factors may be associated with substance use or socioeconomic status and therefore may confound key associations (Choi et al. 1997; Ellickson et al. 2001; Flay et al. 1998; Jefferis et al. 2004).

## Analytic Plan

The hypotheses for the present study (see Figure 1) were tested using path analysis. Considering that the distributional nature of substance use outcome measures (i.e., nonnegative integers showing positive skewness with evidence of overdispersion), negative

binomial regression modeling was the main modeling strategy (Hilbe 2011). Because respondents were clustered in schools, complex analysis was used to address interdependence in the data, and thus adjust parameter standard errors.

Three models were estimated. First, we examined a path model to evaluate the total effect of parental education on adolescent substance use at W4 after controlling for baseline substance use and covariates. Second, we tested whether a cascading process involving alternative and complementary reinforcement mediated the association of parental education with adolescent substance use. We specified our hypothesized cascading process model in accordance with a recommended strategy (Masten et al. 2010; Masten et al. 2005) by modeling associations of substance use within and across domains over time. We tested indirect effects linking low parental education level to substance use at ages 15 and 16 using Monte Carlo integration methods due to the nested nature of our sampling design (Thoemmes et al. 2010). Effect sizes were calculated based on the mediation ratio (Ditlevsen et al. 2005)—the proportion of indirect effect to the total effect (Preacher and Kelley 2011). Further, a possible amplification in the hypothesized risk process, one of tenets of the cascade model, was tested by comparing model fit between a constrained model wherein the paths linking alternative and complementary reinforcement to youth substance use from W1 to W2 and the same paths from W3 to W4 were constrained to be equal and an unconstrained model wherein the same paths were allowed to vary across waves. Differences in model fit across these models were tested using a robust nested chi-square test. Finally, multiple-group path analysis was employed to examine whether path coefficients in the model varied by sex. A configural path model was estimated first as a base model—the same pattern of pathways was specified for both boys and girls and all path coefficients were free to be estimated for each sex. The fit of this configural path model was then compared to the fit of a more constrained model, wherein each path coefficient of interest was constrained to be equal for both boys and girls using a robust nested chi-square test. A significant result would indicate that the model would fit better if specified path coefficients were free to be estimated for each sex group rather than constrained to be equal. All the analyses were conducted in Mplus version 7 (Muthén and Muthén 2015). Missing data were managed with full information likelihood estimation, a recommended method to handle missingness (Schlomer et al. 2010). The resultant final analytic sample included 3,395 participants, representing 99.9% of the original sample enrolled.

## Results

### Association between Parental Education and Adolescent Substance Use

Descriptive statistics are presented in Table 1 and bivariate correlations among analysis variables are presented Table 2. Bivariate analyses suggested that lower parental education was significantly associated with adolescent substance use at W4 ($r = .10$, $p < .01$). Results from a path model testing the association between low parental education and substance use at W4 after controlling for all covariates suggested that low (vs. high) parental education level was significantly related to an increased number of substances used at W4 ($\beta = .08$, 95% CI = [0.004, 0.158], $p = .04$).

## Test of Indirect Mediated Effects and Cascade Process

**Alternative reinforcement—**Figure 2 presents standardized coefficients and standard errors for the hypothesized pathways. Table 3 shows the results of indirect effect tests. Alternative reinforcement significantly mediated the inverse association between parental education and adolescent substance use—youth with parents who did not (vs. did) attain a high school diploma reported diminished alternative reinforcement at W1 (β = −.11, 95% CI = [−0.129, −0.090]), which in turn was negatively associated with adolescent substance use at W2 (β = −.07, 95% CI = [−0.109, −0.031]). W2 substance use was associated with a further reduction in engagement in alternative reinforcers at W3 (β = −.12, 95% CI = [−0.159, −0.081]), which in turn was predictive of adolescent substance use at W4 (β = −.21, 95% CI = [−0.308, −0.112]). As presented in Table 3, this indirect effect of low parental education on changes in substance use via transactional relations between alternative reinforcement and substance use across all survey waves was statistically significant ($p$ = .01).

**Complementary reinforcement—**Higher complementary reinforcement significantly mediated the association between low parental education and adolescent substance use (Figure 2). Low parental education was positively associated with complementary reinforcement at W1 (β = .08, 95% CI = [0.041, 0.119]), which was related to increased adolescent substance use at W2 (β = .10, 95% CI = [0.041, 0.159]). Elevated substance use at W2 was significantly associated with increased complementary reinforcement at W3 (β = .24, 95% CI = [0.162, 0.318]), which in turn predicted substance use at W4 (β = .20, 95% CI = [0.141, 0.258]). As presented in Table 3, the indirect effect of low parental education on changes in substance use via transactional relations between complementary reinforcement and substance use across all survey waves was statistically significant ($p$ = .01).

**Amplification of risk process over time—**Results from robust nested chi-square tests showed that the magnitude of the association of alternative reinforcement at W3 with substance use at W4 (β = −.21) was not statistically different than the earlier association of alternative reinforcement at W1 with substance use at W2 (β = −.07, $\Delta\chi^2[1] = 3.58$, $p$ = .06). Similarly, the association of W3 complementary reinforcement with W4 substance use (β = .20) was not statistically different than the corresponding association from W1 to W2 (β = .10, $\Delta\chi^2[1] = 2.76$, $p$ = .096). We also tested robust nested chi-square tests wherein both alternative and complementary reinforcement were included and found the same results—paths of alternative or complementary reinforcement to youth substance use from W3 to W4 were not stronger than those from W1 to W2 ($\Delta\chi^2[4] = 8.34$, $p$ = .080).

**Remaining direct effect of socioeconomic status on adolescent substance use—**The remaining direct effect of low parental education on adolescent substance use at W4 was not statistically significant (β = .02, 95% CI = [−0.098, 0.137], $p$ = .78), after accounting for alternative and complementary reinforcement over time.

**Sex differences—**Multiple-group analyses across boys and girls showed no evidence of significant robust nested chi-square tests for any path ($\Delta\chi^2$ = 0.11–3.08, $p$ > .15; see Table S2 for more details).

### Sensitivity Analysis

First, to determine whether using a different operational definition of youth substance use may alter the substantive findings, we conducted a sensitivity analysis with youth substance use measure assessing the frequency of use during the prior 30 days. Response options ranged from 0 (*0 days*) to 8 (*All 30 days*). All substantive findings remained the same in the sensitivity analysis, alleviating the concern that our substantive findings are sensitive to the operational definition used in our study (results available from the first author).

Second, to address questions about students' reporting biases, we conducted a sensitivity analysis using an item assessing use of a fictitious drug called "derbisol"—this item was intentionally included in the survey to capture possible reporting biases. Fifty-three (1.6%) students reported that they used derbisol at least once across the four assessment waves, raising questions about reporting biases of their responses. As such, we retested the final model presented in Figure 2 without these 53 students ($N$ = 3,342) and found that the substantive findings remained the same.

Third, to address questions concerning whether dichotomizing parental education may influence our findings, we retested the final model using a continuous variable of low parental education level (6 = *8th grade or less*, 5 = *some high school*, 4 = *high school graduate*, 3 = *some college*, 2 = *college graduate*, 1 = *advanced degree*). All substantive findings remained the same.

Fourth, to further mitigate concern regarding potential estimation bias due to the missing data, we retested our main model (Figure 2) using only data from the sample that completed the 18-month follow-up assessment ($N$ = 3,251, 95.7%). No meaningful changes were detected in comparison to the results presented in Figure 2.

Finally, to test whether varying modes of surveys (i.e., by telephone, internet, or mail) influenced the study results, we retested the final model in Figure 2 after excluding students who completed their survey by an alternate mode of survey administration (i.e., telephone, internet, or mail). All substantive conclusions remained the same in this sensitivity analysis.

## Discussion

Lower parental socioeconomic status has been linked to increased adolescent substance use (Bachman et al. 2011; Pampel et al. 2010). Relevant empirical findings, however, have been mixed and inconclusive (Hanson and Chen 2007; Pampel et al. 2010), calling for further investigation in this topic area. In particular, there has been little longitudinal investigation of the extent to which parental socioeconomic status is associated with youth polysubstance use, which is known to emerge during adolescence and has been linked to more debilitating consequences later in life in comparison to monosubstance use (Kelly et al. 2015; Kokkevi et al. 2014). More importantly, much less is known potential mechanisms explaining the association between low parental socioeconomic status and increased adolescent substance use (Hardaway and Cornelius 2014; Pampel et al. 2010), leaving concrete and malleable prevention targets that could break the link between parental SES and adolescent substance use unidentified.

To remedy these gaps, the current longitudinal study, the first inquiry in this topic area, tested whether alternative (i.e., pleasure gained from substance-free activities) and complementary (i.e., pleasure gained from substance-involved activities) reinforcement mediate the link between lower socioeconomic status and youth substance use. Further, we proposed a novel conceptual model that integrates alternative and complementary reinforcement with the developmental cascade model and tested the integrated model, in which alternative and complementary reinforcement and youth substance use are hypothesized to gradually unfold over time and then intersect with one another in a cascading manner. Potential sex differences were also examined. Findings from the current study generally suggest that diminished alternative reinforcement and elevated complementary reinforcement may function as mechanisms underlying the inverse association between parental socioeconomic status and youth substance use for both sexes.

## Alternative Reinforcement, Lower Parental Socioeconomic Status, and Increased Adolescent Substance Use

Extending results from a prior cross-sectional study (Leventhal, Bello, et al. 2015) and 12-month follow-up analysis (Andrabi et al. 2017) in this cohort, the current study found that lower alternative reinforcement mediated the inverse association between parental education and youth substance use. A key advancement beyond previous reports is the longer follow-up and use of a past-30-day polysubstance use score in the current analysis, which has higher specificity for distinguishing escalation-of-use patterns. The prior longitudinal report relied on a binary indicator of use of any substance during the prior 6 months (yes or no), lacking such specificity.

## Complementary Reinforcement, Lower Parental Socioeconomic Status, and Increased Adolescent Substance Use

The current report provides the first evidence supporting complementary reinforcement as a mediator underlying the inverse association between parental education and adolescent substance use. Several explanations might explicate this result. It is possible that complementary reinforcement is a byproduct of alternative reinforcement—i.e., the two constructs are functionally redundant and merely the inverse of each other. Although the cross-sectional correlations between alternative and complementary reinforcement were significant and inverse, they were moderate in size (−.11 to −.21), suggesting that they represent related yet nonredundant constructs. Furthermore, our analytic strategy, which involved modeling alternative and complementary reinforcement simultaneously, allowed us to parcel out any empirical overlap in their respective influences on the association between parental socioeconomic status and substance use. Taken together, as implicated in behavioral economic theory (Audrain-McGovern et al. 2004; Bickel et al. 2014) and further conceptually articulated in the context of tobacco-related health disparities (Leventhal 2016), alternative and complementary reinforcement might represent unique mechanisms underlying the link between lower parental socioeconomic status and increased youth substance use.

## Cascading Processes of Alternative and Complementary Reinforcement

We adopted three specific tenets of the developmental cascade model: (a) continuity in functioning in individuals and contexts across time; (b) bidirectional influences between individuals and contexts; and (b) amplification of the risk process across domains and over time.

We found evidence of continuity in adolescent substance use across three waves of assessment. These findings suggest that early substance use—influenced by parental socioeconomic status—and its continuation due to alternative and complementary reinforcement might not be transient. Along with prior studies reporting the association between early initiation of substance use and later substance problems (Guttmannova et al. 2011; Irons et al. 2015), our results suggest that earlier adolescent substance use might serve as the initial link in the negative cascade of compromised behavioral functioning that may lead to more serious types of substance use later in life.

Lower parental education was also predictive of diminished alternative reinforcement and elevated complementary reinforcement at W1, which subsequently predicted adolescent substance use at W2. Adolescents' elevated substance use at W2 in turn was associated with levels of alternative and complementary reinforcement at W3. Both reinforcement measures at W3 were then predictive of adolescent substance at W4. These findings suggest that earlier substance use may feed back into risk of future substance use by biasing reinforcement-seeking behavior toward an environment in which complementary reinforcers are easily accessible and away from an environment in which alternative reinforcers are encouraged.

In addition, the hypothesized amplification over time was not supported in our study. The amplification of risk might become more evident when the assessment period includes late adolescence and young adulthood, which include the normative peak age for substance use, as implicated in studies that applied the developmental cascade model to youth substance use (Dodge et al. 2009; Rogosch et al. 2010). A future study with extended coverage of later developmental periods might be useful to further clarify whether the behavioral economic cascading process for youth substance use associated with parental socioeconomic status and its possible mechanisms intensifies over time.

The direct and indirect tests of the final model with all hypothesized pathways showed that the remaining direct effect of lower parental education on adolescent substance use (W4) was not statistically significant. These findings appear to contradict prior studies (Andrabi et al. 2017; Leventhal, Bello, et al. 2015) relying on the same study sample, which reported that the direct effect of lower parental education on adolescent substance use remained statistically significant after taking into account alternative reinforcement. However, these prior studies either relied on cross-sectional data (Leventhal, Bello, et al. 2015) or exclusively focused on alternative reinforcement with truncated assessment periods (Andrabi et al. 2017). In addition, neither of the studies focused on the possible cascading effects among all hypothesized mediators over time. As such, the difference in findings may stem from differences in the conceptual focus and data coverage. Thus, the current findings might not necessarily conflict with prior findings with this sample. Rather, the current findings

suggest that elevated complementary reinforcement may function as an important mechanism linking parental socioeconomic status to youth substance use and highlight the importance of cascading effects. However, considering the relatively small effect sizes associated with the main effect of parental socioeconomic status on adolescent substance, interpretation and generalization of these findings should be conducted with caution. Replication of study findings with other datasets could contribute to a deeper understanding of the role of complementary reinforcement.

## Sex Differences

We did not detect sex differences in the association between lower parental education and adolescent substance use or its hypothesized mediating mechanisms, placing our findings in line with some prior studies (Andrabi et al. 2017; Goldstein et al. 2013). Living in a disadvantaged family might be equally stressful for adolescents, and thus equally detrimental to substance use for both boys and girls. Similarly, reduced opportunities for engaging in activities that generate alternative reinforcement and elevated opportunities for engaging in activities that generate complementary reinforcement might serve as concrete and effective intervention targets for both sexes. Historical changes in social roles and behavioral norms and associated sex convergence in substance use (Kuntsche et al. 2011; White et al. 2015) might provide an alternative explanation for the absence of sex differences in the current study.

## Limitations

Our findings should be interpreted in the context of several methodological limitations. First, all measures relied on participants' self-report, raising questions about reporting biases and problems. Second, the complementary reinforcement measure did not allow teens to identify which specific substance (e.g., alcohol or tobacco) was used in conjunction with the reported activity. This was by design to increase the simplicity and thus reduce the burden on students as they completed an already fairly complex assessment module. It is feasible that the association of lower parental education with adolescent substance use and its mechanisms differ across substances because of varying pharmacological reactions to each substance (e.g., stimulants vs. depressants), potential for dependence (Galea and Tracy 2007), or legal restrictions. Third, items from the Pleasant Events Schedule did not capture whether an activity was only occasionally associated with substance use. Future research that requests adolescents to indicate the regularity of pairing a given activity with substance may provide a more nuanced understanding of the role of complementary reinforcement in the link between parental socioeconomic status and youth substance use. Fourth, we used parental education to approximate parental socioeconomic status, which might have limited our statistical power to detect the unabated effect of earlier parental socioeconomic status on adolescent substance use at W4. However, parental education is a critical socioeconomic status indicator (Galobardes et al. 2006). Further, a recent study (Patrick et al. 2012) reported convergence across three parental socioeconomic status measures—income, wealth, and parental education—with respect to their associations with young adult substance use, suggesting that using one measure, when constrained by survey design like our study, may not necessarily bias conclusions regarding the association between parental socioeconomic status and substance use. Nevertheless, investigating the effects of other socioeconomic

dimensions (i.e., income and wealth) might be a fruitful future direction to further clarify the link between parental socioeconomic status and youth substance use and its mechanisms. Fifth, several coefficients in our study were small. Such small effect sizes may suggest that the current study might be limited with respect to practical significance. However, the present study focused on testing a hypothesized conceptual model rather than documenting the magnitude of impacts of parental socioeconomic status on youth substance use at the population level. In addition, because the effects of socioeconomic status on health outcomes tend to accumulate over time, determining the true effect sizes associated with paths in our hypothesized model might require considering later developmental periods. A future study testing the proposed conceptual model with data covering later developmental periods, particularly young adulthood, which features the peak age of substance use, might further explicate the magnitude of the effects of socioeconomic status on youth substance use and the extent that the hypothesized mechanisms contribute to the association. Finally, the study featured a regional sample. Generalization of findings should be carried out with caution and replication of study findings with other datasets and contexts may be a productive avenue for future research.

### Implications

Prevention efforts are needed to eliminate the desire for a reinforcement enhancer to complement the reinforcing value of low-qualitity activities by increasing access to affordable high-quality activities for adolescents from low socioeconomic backgrounds. In parallel, prevention efforts, such as the Community Trials Project (Grube 1997; Holder et al. 2000), should aim to reduce adolescents' access to substances, because restricted accessibility might increase costs associated with using a substance as a possible reinforcement enhancer. Relatedly, changes in substance use policies, such as legal restrictions on recreational cannabis use, should be evaluated with respect to their potential impact on the availability of substances to adolescents from low socioeconomic families, considering the positive association between legal restrictions on a drug and its availability (Hawkins et al. 1992) and disproportionate concentration of cannabis outlets in disadvantaged neighborhoods (Henriksen et al. 2008; Németh and Ross 2014; Romley et al. 2007). Psychological intervention programs that cultivate awareness of the costs and reinforcing benefits associated with substance use, such as brief motivational (Miller and Rollnick 2012) or mindfulness-based (Burke 2010; Chiesa and Serretti 2014) interventions, might be effective micro-level interventions that can break the link between earlier exposure to lower socioeconomic status and adolescent substance use.

## Conclusion

The current study suggests that diminished alternative reinforcement and elevated complementary reinforcement may function as mechanisms underlying the association between lower parental education, a proxy for lower parental socioeconomic status in our study, and increased adolescent substance use for both sexes. Despite its limitations, our study extended the existing literature in at least three important ways. First, the current study represents the first inquiry in this topic area, investigating the mediational role of complementary reinforcement in the link between parental socioeconomic status and

adolescent substance use. Second, by integrating behavioral economic theory with the developmental cascade model, the study conceptually articulated the potential developmental process linking lower parental education and adolescent substance use. By capitalizing on longitudinal data, our investigation provided a robust test of how the developmental risk process of hypothesized pathways unfolds over time. Third, the present study tested sex differences in the hypothesized pathways. To our knowledge, no other existing studies have incorporated these unique strengths. Collectively, the current study shed light on modifiable and actionable prevention targets to interrupt the link between parental socioeconomic status and substance use earlier in life, before it becomes stronger and solidifies over the life course.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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**Compliance with Ethical Standards**

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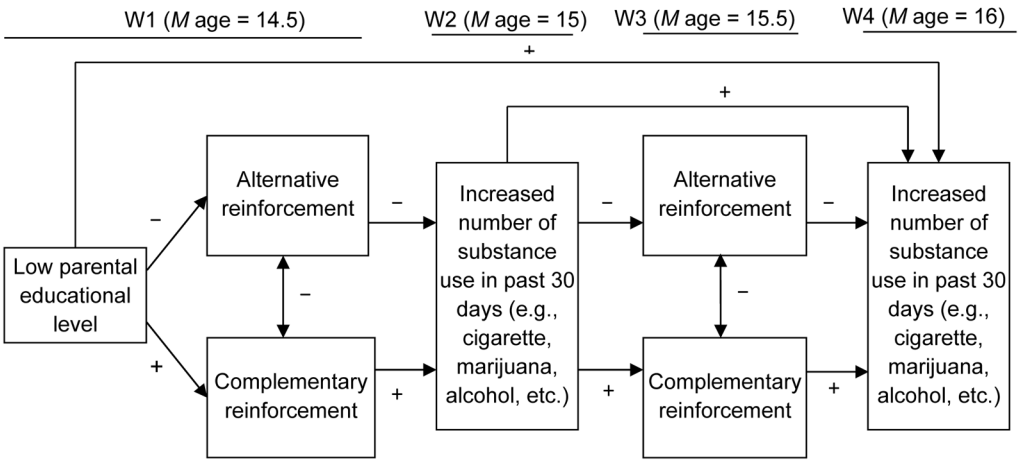


**Figure 1. Conceptual model**

*Note. M* age = mean age of youth (years). Signs adjacent to paths (+ and −) indicate hypothesized positive and negative associations, respectively. All key mediators and outcome (alternative reinforcement and complementary reinforcement at W1 and W3, substance use at W1, W2, and W4) were regressed on covariates (i.e., youth age, sex, dummy-coded race [White as reference], living situation, family substance use history, and delinquent behaviors).

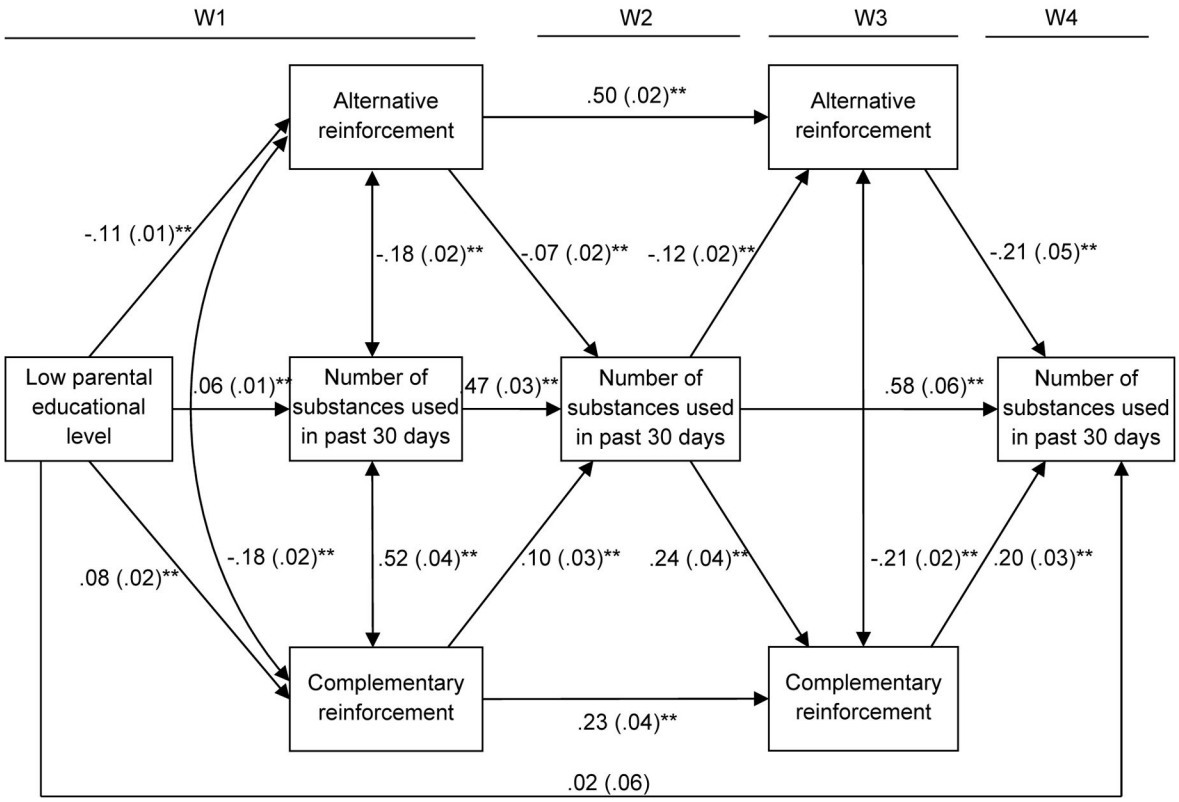


**Figure 2. Mediational cascading processes between alternative and complementary reinforcement and number of substances used in prior 30 days**

*Note.* $N = 3{,}395$. Standardized coefficients (standard errors) are shown. Nonsignificant pathways are not pictured other than the direct path from low parental education to W4 youth substance use. Paths with one-sided arrows reflect unidirectional causal paths. Paths with two arrows reflect correlational and nondirectional paths. Youth age, sex, race and ethnicity, family history of substance use, and living situation (living with vs. without both parents) at baseline were controlled. All key mediators and outcome (alternative reinforcement and complementary reinforcement at W1 and W3, substance use at W1, W2, and W4) were regressed on covariates (i.e., youth age, sex, dummy-coded race [White as reference], living situation, family substance use history, and delinquent behaviors).
$^{*}p < .05$. $^{**}p < .01$.

## Table 1

Descriptive statistics

| Variable[a] | *n* (%) or *M* (*SD*) range (kurtosis) |
|---|---|
| Sex (*n* = 3,395) | |
| Female | 1,812 (53.4) |
| Male | 1,583 (46.6) |
| Age (*n* = 3,379) | 14.58 (0.40) 12–16 |
| Race and ethnicity (*n* = 3,311) | |
| Non-Hispanic White | 520 (15.7) |
| Hispanic | 1,557 (47.0) |
| Black | 166 (5.0) |
| Asian | 535 (16.2) |
| Multiethnic or other | 533 (16.1) |
| Living situation (*n* = 3,360) | |
| Other type of living situation | 1,226 (36.5) |
| Living with both parents | 2,134 (63.5) |
| Family history of substance use (*n* = 3,223) | |
| None | 975 (30.3) |
| Having family substance use history | 2,248 (69.7) |
| Parental education level (n=2931)[b] | |
| High school graduate or higher degree | 2,548 (86.9) |
| Lower than high school graduate | 383 (13.1) |
| Alternative reinforcement W1 (*n* = 3,279) | 58.20 (24.07) 0–172 (0.32) |
| Alternative reinforcement W3 (*n* = 2,984) | 52.12 (25.03) 0–176 (0.81) |
| Complementary reinforcement W1 (*n* = 3,288) | 0.85 (3.56) 0–120 (24.40) |
| Complementary reinforcement W3 (*n* = 3,006) | 1.65 (6.02) 0–176 (33.39) |
| Substance use in past 30 days W1 (*n* = 3,375) | 0.27 (0.71) |
| Substance use in past 30 days W2 (*n* = 3,258) | 0.41 (0.92) |
| Substance use in past 30 days W4 (*n* = 3,207) | 0.46 (0.97) |

[a] Available (nonmissing) data; for categorical variables, denominator for within-column percentages.

[b] Participants who marked “don’t know” response (*N* = 422) recoded as missing.

**Table 2**

Correlations of study variables at baseline

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Sex | – | | | | | | | | | | |
| 2. Age | .08** | – | | | | | | | | | |
| 3. Living situation | .04* | −.07** | – | | | | | | | | |
| 4. Family substance use history | −.07** | −.01 | −.14** | – | | | | | | | |
| 5. Low parental education level | −.06** | .01 | −.03 | .04* | – | | | | | | |
| 6. Alternative reinforcement W1 | −.10** | −.03 | .08** | −.05** | −.13** | – | | | | | |
| 7. Alternative reinforcement W3 | −.11** | −.02 | .07** | −.04* | −.09** | .51** | – | | | | |
| 8. Complementary reinforcement W1 | .03 | .08** | −.08** | .04* | .09** | −.19** | −.12** | – | | | |
| 9. Complementary reinforcement W3 | .04* | .06** | −.05* | .04* | .05* | −.11** | −.21** | .30** | – | | |
| 10. Number of substances used in past 30 days W1 | −.04* | .04* | −.11** | .11** | .15** | −.20** | −.15** | .50v | .23** | – | |
| 11. Number of substances used in past 30 days W2 | −.06** | .06** | −.11** | .11** | .16** | −.15** | −.20** | .35** | .31** | .54** | – |
| 12. Number of substances used in past 30 days W4 | −.02 | .02 | −.08** | .08** | .10** | −.10** | −.20** | .22** | .33** | .41** | .54** |

*Note*. Low parental education level was coded as follows: 0 = *high school graduate or higher degree*, 1 = *parent(s) without high school diploma*. Sex was coded as follows: 0 = *female*, 1 = *male*. Living situation was coded as follows: 0 = *other type of living situation*, 1 = *living with both parents*. Family substance use history was coded as follows: 0 = *none*, 1 = *family history of substance use*.

* $p < .05$.

** $p < .01$.

**Table 3**

Indirect effect analyses

| Predictor | Mediator(s) | Outcome | Indirect effect (β) | 95% CI | Effect size |
|---|---|---|---|---|---|
| • Low parental education W1 | • Alternative reinforcement W1 | • Substance use W2 | .013 | 0.006, 0.019 | 12.3% |
| • Low parental education W1 | • Complementary reinforcement W1 | • Substance use W2 | .029 | 0.008, 0.051 | 23.8% |
| • Low parental education W1 | • Alternative reinforcement W1<br>• Substance use W2<br>• Alternative reinforcement W3 | • Substance use W4 | .002 | 0.001, 0.010 | 9.5% |
| • Low parental education W1 | • Complementary reinforcement W1<br>• Substance use W2<br>• Complementary reinforcement W3 | • Substance use W4 | .003 | 0.001, 0.011 | 13.6% |

*Note. N* = 3,395. Substance use = number of substance use in prior 30 days. CI = confidence Interval. Effect size = proportion of total effect mediated by mediator(s).