Published in final edited form as:

Dev Psychopathol. 2017 August ; 29(3): 887–900. doi:10.1017/S0954579416000559.

Time-varying Effects of Families and Peers on Adolescent Marijuana Use: Person-environment Interactions Across Development

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Abstract

Studies have demonstrated that the effects of two well-known predictors of adolescent substance use, family monitoring and antisocial peers, are not static but change over the course of adolescence. Moreover, these effects may differ for different groups of youth. The current study uses time-varying effect modeling (TVEM) to examine the changes in the association between family monitoring and antisocial peers and marijuana use from ages 11 to 19, and to compare these associations by gender and levels of behavioral disinhibition. Data are drawn from the Raising Healthy Children study, a longitudinal panel of 1,040 youth. The strength of association between family monitoring and antisocial peers and marijuana use was mostly steady over adolescence, and was greater for girls than boys. Differences in the strength of the association were also evident by levels of behavioral disinhibition: youth with lower levels of disinhibition were more susceptible to the influence of parents and peers. Stronger influence of family monitoring on girls and less disinhibited youth was most evident in middle adolescence, whereas the stronger effect of antisocial peers was significant during middle and late adolescence. Implications for the timing and targeting of marijuana preventive interventions are discussed.

Keywords

marijuana use; adolescence; family monitoring; antisocial peers; time-varying effect modeling

Marijuana is the most commonly used illicit drug among U.S. adolescents, and use significantly increases with age. Although only 1% of U.S. youth aged 12 to 13 reported past-month use in 2013, this number rose to 5.8% among youth aged 14 to 15, and to 14.2% among youth aged 16 to 17 (Substance Abuse and Mental Health Services Administration, 2014). By 12th grade, 21% of students reported having used marijuana in the past month, and almost half (44%) reported use in the past year (Johnston, O'Malley, Bachman, Schulenberg, & Miech, 2014). Although marijuana use among adolescents has remained

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An earlier version of this paper was presented in May 2015 at the annual meeting of the Society for Prevention Research held in Washington, DC.

stable over the past decade (Substance Abuse and Mental Health Services Administration, 2014), data from young adults (aged 19 – 28) indicate a steady increase in use since 2010 (Johnston et al., 2014), which the authors attribute to a decline in perceived harm of the drug as more states debate marijuana legalization. Legalization of marijuana for adults also raises concerns over increased availability of marijuana to younger adolescents, for whom marijuana use has been associated with school failure, mental health problems, and increased risk of addiction (Arseneault et al., 2002; Copeland, Rooke, & Swift, 2013; Macleod et al., 2004; Silins et al., 2014). As marijuana legalization for adults spreads, a heightened focus on the factors driving marijuana etiology during adolescence will inform the development of adolescent preventive interventions.

Past research suggests that family and peer environmental factors—such as parent monitoring, affiliation with antisocial or deviant peers, and peer pressure—are influential predictors of substance use among adolescents (Hoeve et al., 2009; Lac & Crano, 2009; Reboussin, Hubbard, & Ialongo, 2007; Steinberg, Fletcher, & Darling, 1994). However, the effects of parents and peers are not static. As adolescents gain autonomy, studies have typically shown a decrease in the effect of family influence and an increase in the influence of peers (Cleveland, Feinberg, Bontempo, & Greenberg, 2008; Ellickson, Tucker, Klein, & Saner, 2004; Tang & Orwin, 2009; Van Ryzin, Fosco, & Dishion, 2012). In addition, theories of differential susceptibility (Belsky & Pluess, 2009; Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van Ijzendoorn, 2011) recognize that individuals vary in their vulnerability or susceptibility to environmental influences and posit that there may be evolutionary and neurodevelopmental explanations to this variability (e.g., Wiebe et al., 2015). In a recent update to the differential susceptibility work, Ellis and colleagues outline fundamental features of differential susceptibility, including that susceptible individuals are more affected by both positive and negative environmental experiences and that variability in susceptibility is likely to change over development (Ellis et al., 2011). One such vulnerability may be driven by dispositional characteristics, such as impulsivity, sensation seeking, and lack of constraint, which together form the construct behavioral disinhibition (Dever et al., 2012; Sher & Trull, 1994; Slater, 2003; Stephenson & Helme, 2006). Studies have also begun to examine gender as a source of susceptibility, and whether the effect of parents and peers on marijuana use may be different for boys and girls (Choquet, Hassler, Morin, Falissard, & Chau, 2008; Fagan, Van Horn, Antaramian, & Hawkins, 2011; Parsai, Voisine, Marsiglia, Kulis, & Nieri, 2009). Few studies have examined whether the differences in the effects of parents and peers vary both over time and between these groups. The current study is the first to use a longitudinal approach to test these time-varying interactions with gender and behavioral disinhibition over the course of adolescence.

Theoretical Framework

The current work is based in two complementary theoretical approaches: the Social Development Model (SDM; Catalano & Hawkins, 1996; Hawkins & Weis, 1985) and the developmental psychopathology framework (Cicchetti & Rogosch, 2002; Cicchetti & Toth, 2009). The choice of environmental factors examined here is based in the Social Development Model which organizes known risk and protective factors into causal mechanisms (Catalano & Hawkins, 1996). Rooted in previous psychological, sociological,

and delinquency theories, the SDM is a developmentally informed model that outlines two parallel paths that lead to prosocial and antisocial outcomes. The SDM posits that reduced opportunities to engage in antisocial behavior (through, for example, parental monitoring of activities), coupled with rewards for prosocial actions, leads to adopting a prosocial value system and eventual engagement in more healthy behavior. The model also specifies a second parallel path, in which individuals have increased opportunities to bond with antisocial peers and adults (through, for example, limited family monitoring) and engage in antisocial actions, leading to the development of unhealthy behavior, such as substance use. The current work examines the protective effect of family management, operationalized as the combination of high monitoring and high prosocial rewards, on adolescent marijuana use. The presence of antisocial peers is hypothesized to present opportunities for antisocial behavior, combined with implicit social rewards that peers bring to one another.

Although the Social Development Model recognizes the importance of both development and individual characteristics, the interplay of environmental and individual factors over time is well articulated by the developmental psychopathology integrative framework (Cicchetti & Rogosch, 2002; Cicchetti & Toth, 2009). The developmental psychopathology perspective emerged in response to a need to identify and prevent mental illness and combines a focus on development with an emphasis on psychopathology (Masten, 2006). The perspective highlights the interactive nature of multiple systems of development, including individual characteristics and environmental influences, and recognizes the importance of examining this interplay over time. We are guided by the developmental psychopathology perspective in our approach to examining how individual difference characteristics known to be related to substance use—gender and behavioral disinhibition—interact with environmental factors over the course of development. The perspective highlights that psychopathology needs to be examined in the context of development and would suggest that interactions are likely to be found at developmentally critical periods, such as during a transition or a sensitive period. This framework also highlights multifinality that occurs when risk and protective factors have divergent outcomes for different individuals or at different points in development. For example, boys might be more susceptible to peer pressure than girls. Conversely, equifinality occurs when individuals with different risk and protective factors in childhood exhibit similar outcomes later on. One example of equifinality might be that girls are more affected by family management during adolescence but that parental influence wanes for both boys and girls as they approach young adulthood. The potential for identifying critical periods when families and peers are particularly influential is important for the timing and delivery of interventions.

To sum, the Social Development Model provides guidance in the selection of family management and antisocial peers as important environmental forces. Developmental psychopathology perspective leads us to examine the interaction between individual characteristics and these environmental factors. The current investigation connects these theoretical approaches to (a) examine the interplay of individual and environmental systems over the course of development and (b) focus on multifinality to explore differences in effects of families and peers over time by gender and level of behavioral disinhibition.

Differential Effects of Family Monitoring and Antisocial Peers on Marijuana Use by Gender and Behavioral Disinhibition

The links between family and peer factors and a range of adolescent outcomes has been widely demonstrated. Family management, or family monitoring, has been shown to be particularly associated with reduced substance use, including marijuana, among adolescents (Hoeve et al., 2009; Lac & Crano, 2009; Shillington et al., 2005; Steinberg et al., 1994). This protective effect of family management and monitoring on marijuana use, in particular, has been shown for younger and older adolescents (Chilcoat & Anthony, 1996; DiClemente et al., 2001; Hayatbakhsh et al., 2008; Lac & Crano, 2009), in nationally representative (Dever et al., 2012; Martins, Storr, Alexandre, & Chilcoat, 2008; Rodgers-Farmer, 2000) and community samples (Dishion, Nelson, & Kavanagh, 2003; Hill et al., 2010; Kosterman, Hawkins, Guo, Catalano, & Abbott, 2000), and for a range of socioeconomic and ethnic groups (Bohnert, Anthony, & Breslau, 2012; Griffin, Botvin, Scheier, Diaz, & Miller, 2000; Lac & Crano, 2009; Moon, Blakey, Boyas, Horton, & Kim, 2014; Yabiku et al., 2010). In a similar vein, the negative association between drug-using or antisocial peers and substance use has also been well established. Associating with antisocial or drug-using peers has been linked to marijuana use in multiple samples and in diverse populations of adolescents (Dishion & Owen, 2002; Donohew et al., 1999; Hampson, Andrews, & Barckley, 2008; Kosterman et al., 2000; Moon et al., 2014; Rodgers-Farmer, 2000; Steinberg et al., 1994; Van Ryzin et al., 2012; Yanovitzky, 2005). The main effects of gender and behavioral disinhibition on substance use are similarly robust and well documented (Donohew et al., 1999; Kopstein, Crum, Celentano, & Martin, 2001; Newcomb & McGee, 1991; Sargent, Tanski, Stoolmiller, & Hanewinkel, 2010; Teichman, Barnea, & Ravav, 1989).

Researchers also have investigated interactions between monitoring and antisocial peers on one hand and gender and behavioral disinhibition on the other, based on the hypothesis that boys or highly disinhibited youth may be more or less responsive to environmental influence than girls or less disinhibited youth. Among studies that have examined differential influence of family monitoring and antisocial peers by gender, no consistent pattern of results emerged. For example, two studies of European (McArdle et al., 2002) and U.S. (Griffin et al., 2000) adolescents found that family monitoring and supervision were more related to boys' than girls' alcohol use. Other investigations and a recent meta-analysis of 17 studies found that family influence had greater effects on curbing girls' marijuana use (e.g., Choquet et al., 2008; Lac & Crano, 2009). Still, others have reported no gender difference in the effect of family monitoring on substance use (Chen & Jacobson, 2013; Fagan et al., 2011). Studies of peer effects on substance use have found similar discrepancies in whether boys or girls are more susceptible to peer influence. For example, in a study of Mexican American adolescents, perception of peer use and peer norms was more related to boys' than girls' marijuana use (Parsai et al., 2009), but another study found that the association between antisocial peers and alcohol use was equally strong for boys and girls (Simons-Morton, Haynie, Crump, Eitel, & Saylor, 2001).

Few studies to date have examined whether the link between family monitoring and substance use varies by behavioral disinhibition, and the results are inconsistent. One study

found that sixth to eighth graders with higher behavioral disinhibition reported less intent to use marijuana when family management was high (Stephenson & Helme, 2006), whereas another investigation found no difference in marijuana dependence by adolescent parental monitoring and levels of behavioral disinhibition among college students (Kaynak et al., 2013). Studies of differential influence of peers by behavioral disinhibition, however, suggest a clearer story. Most studies found that adolescents who reported high behavioral disinhibition and also had antisocial peers had greater rates of substance use than less disinhibited youth (Epstein & Botvin, 2002; Knyazev, Slobodskaya, Kharchenko, & Wilson, 2004; Slater, 2003). We found no studies where the effect of peers was greater for individuals with lower behavioral disinhibition.

Change in Risk and Protective Factors Over the Course of Adolescence

Throughout the course of adolescence, young people spend increasing amounts of time away from home, most often in the company of their peers (Furman & Buhrmester, 1992), and less time under parental supervision. Thus, it is often believed that family monitoring decreases both in amount and in effectiveness to reduce problem behavior as young people move toward legal adulthood (Cleveland et al., 2008; Cleveland, Feinberg, & Jones, 2012). At the same time, as peers become more salient during the transition from childhood to adolescence, their influence is thought to increase as well (Van Ryzin et al., 2012).

Studies examining the effects of parents and peers over time generally confirm the decline of parent influence (Jang, 2002; Kelly et al., 2011; Reboussin et al., 2007; Seydlitz, 1991; Van Ryzin et al., 2012), although the results are not always consistent. For example, in a large cross-sectional sample from the Pennsylvania Youth Risk Study, Cleveland and colleagues found that the relationship between family risk factors and alcohol use declined from 6th to 12th grade, although the relationship with marijuana use from 8th to 12th grade remained steady (Cleveland et al., 2012). However, another large study of high school students in 24 U.S. communities found no change in the relationship between family factors and substance use, even though the amount of family monitoring declined from 8th to 12th grade (Fagan et al., 2011). The declining levels, rather than effectiveness, of family monitoring may provide a clue as to why, at a population level, the influence of the family appears to wane as children mature. In contradiction, however, a meta-analysis of over 350 studies found that the effect of family on drug use increases with age (Allen, Donohue, Griffin, Ryan, & Turner, 2003).

A review of the literature examining the change in the strength of peer influence on substance use over the course of adolescence did not unilaterally support the notion that peers become more influential. Although some studies (Cleveland et al., 2008; Jang, 2002; Van Ryzin et al., 2012), including a meta-analysis (Allen et al., 2003), found that peer influence increased over time, several notable exceptions reported that peer influence declined (Abadi, Shamblen, Thompson, Collins, & Johnson, 2011; Fergusson, Swain-Campbell, & Horwood, 2002). In addition, two separate longitudinal studies reported that the effect of delinquent peers on substance use followed a curvilinear trend such that peer influence peaked in mid- to late adolescence and then plateaued (Cleveland et al., 2012; Jang, 2002).

Adding to the complexity is the possibility that the effects of peers and parents on substance use over time may follow a different trend for different groups. For example, Dever, Schulenberg, and Dworkin (2012) found that the association between family management and drug use varied by gender and level of behavioral disinhibition, as well as over time. Since the effect sizes of risk and protective factors vary over the course of development, it is likely that the interactions of those effects with gender and behavioral disinhibition are also specific to certain developmental periods. It could be that some interactions are most evident during younger or older adolescence, or even during periods of change, such as the transition to middle school or high school. An underlying curvilinear pattern to the influence of environmental factors on substance use could explain the inconsistency in results from studies reporting an effect at a single point in time from different parts of the effect curve. Methods that are able to model nonlinear change in effects and can test interactions longitudinally can shine a light on this complexity.

The current study bridges several literatures that investigate risk and protective factors related to adolescent marijuana use. Specifically, the current work uses an innovative longitudinal method to examine nonlinear change in the association between family management and antisocial peers and marijuana use. Analyses using time-varying effect modeling assess the change in the associations throughout adolescence and examine the degree to which they are moderated by gender and behavioral disinhibition. Specifically, the study has three research aims:

1. To examine changes in the strength of the association (main effects) between adolescent marijuana use and four predictors: family management, antisocial peers, gender, and behavioral disinhibition,
2. To test time-varying interactions between family management and gender and behavioral disinhibition in predicting adolescent marijuana use, and
3. To test time-varying interactions between antisocial peers and gender and behavioral disinhibition in predicting adolescent marijuana use.

Methods

Participants

Participants were from the Raising Healthy Children (RHC) project, a longitudinal study of students recruited from public elementary schools in a suburban Pacific Northwest school district. The project was designed to study the etiology of problem behaviors and to test a randomized preventive intervention (for detailed descriptions of the RHC intervention see Catalano et al., 2003). Two cohorts of families with students in first and second grade in the project schools were invited to participate in the study. Active consent was obtained from 76% of eligible families and 1,040 students were enrolled in 1993 and 1994. Parental consent and children's assent (until age 18 when child consent was required) procedures were approved by the University of Washington's Human Subjects Review Committee. Participant surveys were administered at least annually in the spring until 2011 when participants were 24 and 25 years old (younger and older cohort, respectively). Parent and teacher data were collected annually through ages 14/15 (younger/older cohort) for teachers

and through age 18 for parents. The current study used participant data from ages 10 through 18 (grade 12) with 8,320 available person-occasions. Retention was high, with > 85% of participants retained from study inception to the last time point.

Of this original sample 53% were male and 38% were low income, defined by eligibility for the National School Lunch Program or family receipt of food stamps or Temporary Aid for Needy Families (TANF) in elementary school. The ethnic composition of the sample was 75% White, 7% Asian American or Pacific Islander, 4% African American, 2% Native American, and 12% mixed ethnicity. Half (54%) of the sample was randomly assigned to receive a preventive intervention during Grades 1 – 12. Previous examinations of the differences between control and intervention groups did not find differences in outcome behaviors, including marijuana use (Brown, Catalano, Fleming, Haggerty, & Abbott, 2005).

Measures

Marijuana use was based on participant self-reports from ages 11 to 19. At age 11/12 participants were asked if they ever used marijuana; starting at age 12/13, participants reported past-month use. Marijuana use was coded at each age as 1 if participants indicated any use and 0 if they indicated no use over the specified period. Because only 3% of the sample reported using any marijuana at age 11/12, we felt comfortable combining the “ever” measure for one time point with past-month measures in the rest of the analyses.

Family management was assessed using a five-item scale based on participant self-reports from Grades 10 – 19. Each year, participants were asked about parents’ practices around monitoring, discipline, and rewards. Examples include: *When you are not home, do your parents know where you are and who you are with? Are the rules in your family clear? Does your mom or dad notice when you’ve helped out at home?* Responses were scored on a 4-point scale (NO!, no, yes, YES!). Items were averaged at each age and then standardized (average Cronbach alpha = .71). Family management variables were treated as time-varying predictors and were lagged one year. For example, age 10 family management was used to predict age 11 marijuana use.

Antisocial peers. Antisocial peer behavior was assessed using a three-item scale based on participant self-reports from ages 11 – 19. Each year, participants were asked: *How many of your ten best friends get into fights? How many of your ten best friends skip school or class?* and *How many of your ten best friends get in trouble with their teacher?* Responses for each item were scored on a 5-point scale (1 = none to 5 = a lot) and scores were averaged at each age and then standardized (average Cronbach alpha = .72). Similar to family management, antisocial peers variables were treated as time-varying predictors and were lagged one year.

Behavioral disinhibition was assessed through a three-item scale assessing impulsivity, reward orientation, and sensation seeking based on participant self-reports from ages 14 to 19. Each year, participants reported how often in the past year they have done: *crazy things even if they were a little dangerous? something dangerous because someone dared you to do it?* and *what feels good no matter what?* Responses for each item were scored on a 6-point scale (1 = never to 6 = once a week or more) and averaged across all ages, then standardized (average Cronbach alpha = .66).

Gender was self-reported.

Analysis

Time-varying effect modeling. Time-varying effect modeling (TVEM) in SAS was used to examine the effects of family management and antisocial peers on marijuana use across adolescence. Time-varying effect modeling is based in spline regression and estimates an association which is allowed to vary as a nonparametric function of time. That is, the TVEM method makes no assumptions about change as being parametric (linear, quadratic, etc.). Instead, the effect size curve is based on the strength of the association at each point in development and is assumed to be smooth at the population level (Tan, Shiyko, Li, Li, & Dierker, 2012). TVEM has been effectively used to model ecological momentary assessment data (Lanza, Vasilenko, Liu, Li, & Piper, 2014) as well as data from longitudinal panels (Vasilenko & Lanza, 2014). TVEM macros are designed to work with outcomes that are normally distributed, binary, or Poisson. Macros are available to download from methodology.psu.edu (Li, Tan, Huang, Wagner, & Yang, 2014). TVEM effects can be modeled as both time-fixed and time-varying; that is, a time-varying effect can be estimated for a static predictor like gender or a predictor that changes over time, such as family management.

TVEM analyses were based on participants' exact age (as opposed to wave) at the time of the interview which was calculated from birth dates and interview dates. Participant age ranged from 10.18 to 20.36 years but data was sparse at the upper and lower ends of the age distribution. For analyses involving family management, participants younger than 11 and older than 19 were excluded, reducing the person occasions from 8,320 to 7,754. Because antisocial peer variables were only available starting at age 11 and variables were lagged 1 year, we limited those analyses to ages 12 to 19, reducing person occasions to 7,045. This created a continuous distribution of data over the target age span (for further detail on the use of TVEM for longitudinal data, see Vasilenko & Lanza, 2014). In keeping with the time-varying effect modeling language we use the word "effect" here to refer to the strength of the association rather than a causal inference. Because of its nonparametric nature, TVEM does not formally estimate whether the effect magnitude is larger or smaller at different points in development; however, nonoverlapping confidence intervals are indicators of significant difference in the association.

Research aims. In response to Research Aim 1, we first show the probability of marijuana use in the past month by gender and behavioral disinhibition (Figure 1). Time-varying main effects (without an interaction term) of family management (Model 1) and antisocial peers (Model 2) are shown in Figure 2; and time-varying main effects of gender (Model 3) and behavioral disinhibition (Model 4) are shown in Figure 3.

Next, to address Research Aim 2 we tested two time-varying interaction models with family management: Model 5 family management $\times$ gender (Figure 4), and Model 6 family management $\times$ behavioral disinhibition (Figure 5). In a similar vein, Research Aim 3 was addressed in Model 7 antisocial peers $\times$ gender (Figure 6) and Model 8 antisocial peers $\times$ behavioral disinhibition (Figure 7). On the left side of the panel in Figures 4 – 7, we include the time-varying interaction effects with 95% confidence intervals which were significant in

the regions where the confidence interval does not cross the value of 1. Adjacent on the right, we plot the main effects by the moderator (gender or by behavioral disinhibition) to illustrate the interaction term. These illustrations were estimated by stratifying the sample by gender or the top tertile of the distribution of behavioral disinhibition and estimating a main effects only model with control variables. This approach is laid out in the TVEM macro guide (Li et al., 2014). (Although the full range of behavioral disinhibition was tested in the interaction models, for illustration purposes in Figures 6 and 7 we show odds ratios for the participants in the top 33% of the distribution of behavioral disinhibition versus those in the bottom two thirds.)

Controls. All Models 1 – 8 included time-fixed control variables: ethnicity (dummy coded), childhood socioeconomic status, sample cohort, and treatment condition. In addition, models testing group differences by behavioral disinhibition (Models 6 & 8) included gender, which was entered as a time-varying variable. For example, Model 6, estimating the relationship between family management and marijuana use by behavioral disinhibition (Figure 5), included family management (FM), behavioral disinhibition (BD), their interaction term (FM $\times$ BD), and gender as time-varying predictors; ethnicity, childhood socioeconomic status, and cohort were included as time-fixed. Time-fixed effects of the controls for each Models 5–8 are shown in Table 1.

Results

Research Aim 1: Main Effects

Figure 1 shows the rate of marijuana use from ages 12 to 19 for the full sample, and separately by gender and levels of behavioral disinhibition (top third vs. bottom two thirds). In the full sample, about 30% of participants reported past-month marijuana use at age 19. Boys and girls reported mostly similar rates of marijuana use across adolescence. Among those in the top third of the behavioral disinhibition distribution, past-month marijuana use by age 19 was about 90% whereas among those in the bottom two thirds it was about 20%.

Models 1 and 2, showing the main effects of family management and antisocial peers (each lagged by 1 year) on marijuana use, are shown in Figure 2. The y-axis presents the odds of past-month marijuana use for each standard deviation of family management or antisocial peers. The solid lines represent estimates of the strength of the association between family management and marijuana use (left side) and antisocial peers and marijuana use (right side). The 95% confidence interval is shown as the shaded area around the solid line. The horizontal line at the value of 1 shows the significance for odds ratios; when the 95% confidence interval crosses the line, the significance of the estimate falls below $p = .05$.

The left side of the panel (Model 1) shows that odds ratios of marijuana use were < 1 , indicating that family management was significantly associated with lower odds of marijuana use from ages 12 to 19. The effect was significant (confidence interval values did not cross 1) from ages 12.3 to 18.2. Effect sizes for the full sample ranged from an odds ratio of .73 at age 15.5 to an odds ratio of .86 at age 19. This pattern suggests a possible decline in the protective power of family management across adolescence. The main effect of antisocial peers (Model 2), presented on the right hand side of Figure 2, shows values > 1 ,

suggesting that the presence of antisocial peers in the previous year was associated with a significant increase in the odds of marijuana use from ages 12.5 to 19. The odds of marijuana use varied from approximately 2.5 at age 12 to 1.85 at age 19, suggesting a decrease in the effect of peers over the adolescent period.

Figure 3 shows the time-varying main effect of the moderators: (male) gender (Model 3) and behavioral disinhibition (Model 4). On the left hand side, the main effect of gender had odds ratios > 1 , revealing that being male was associated with significantly greater odds of marijuana use than being female. This difference was significant in early and late adolescence (approximately $< \text{age } 13.3$ and $> \text{age } 17$). The gender odds varied from just under 3 at age 11.5 to 1.58 at age 15; that is, at age 11.5, the odds of marijuana use for a boy were three times as high as for a girl, whereas the difference in odds was closer to .01 – .05 and not significantly different by gender at age 15. The right side of Figure 3 shows the main effect of behavioral disinhibition on marijuana use, which was relatively stable and significant throughout adolescence. With odds ratios > 1 , greater behavioral disinhibition predicted higher odds of marijuana use, with one standard deviation change in the behavioral disinhibition measure increasing the odds of using marijuana 2.8 times at age 12 and approximately 2.2 times at age 15.

Research Aim 2: Interactions with Family Management

We tested whether family management had a differential effect on marijuana use for girls vs. boys (Model 5) and for adolescents with high vs. low behavioral disinhibition (Model 6). Figure 4 shows the time-varying interaction for Model 5, then plots the main effects of family management for boys and girls separately. The left panel shows the time-varying interaction term, which is significant in the region where the confidence interval does not cross the value of 1. This region is demonstrated on the right panel by a black box. The gender interaction was significant for a period of adolescence consistent with the transition to high school (approximate ages 14.6 to 15.1). That is, the significant main effect shows that consistent family management was associated with a lower likelihood of marijuana use for both girls and boys. However, during the transition to high school, the significant interaction suggests that this association was stronger for girls than for boys. On the right side of Figure 4, this can be observed as the curve for boys being closer to the reference line at 1 (i.e., weaker effect of family management for boys). The interaction value (exponentiated) was around 1.25. at age 15, meaning that the odds of girls using marijuana was 25% lower than the odds of boys using marijuana at average levels of family management.

Next, Model 6 tested whether the effect of family management was different for adolescents with high versus lower levels of behavioral disinhibition (controlling for the time-varying effect of gender). The interaction shown on the left hand side of Figure 5 was significant at approximately ages 13.4 to 16, roughly the same period of the transition to high school during which the effect of family management differed by gender. The right hand side of Figure 5 plots the effect of family management on marijuana use separately by levels of behavioral disinhibition, showing that the effect was greater for adolescents with lower levels of behavioral disinhibition than more disinhibited adolescents. The exponentiated

interaction value was about 1.15 throughout the significant region, corresponding to about 15% higher odds of marijuana use for youth with lower behavioral disinhibition. However, for all youth, family management had a consistent protective main effect. A three-way interaction with family management, gender, and behavioral disinhibition was also tested and showed a small region of significance between ages 11 – 13.

Research Aim3: Interactions with Antisocial Peers

We followed a parallel process to test interactions with antisocial peers by gender and behavioral disinhibition. Figure 6 shows the interaction between antisocial peers and gender (Model 7). The interaction was significant from ages 12.1 to 18.4 (Figure 6, left side). The magnitude of the interaction effect ranged from over 2 at age 12 to 1.30 at age 18. The right side of Figure 6 shows that the presence of antisocial peers was associated with greater (30%–200%) odds of marijuana use for girls than for boys during most of adolescence.

Figure 7 presents the interaction of antisocial peers with behavioral disinhibition (Model 8). Similar to family management, results on the left side of Figure 7 show significant interactions in mid-adolescence (around age 14.5) and up to age 18.4. The right side of Figure 7 shows that adolescents with lower levels of behavioral disinhibition were more susceptible to the influence of antisocial peers; the interaction values ranged from .84 – .89. Thus, antisocial peers had 12% to 19% more influence on marijuana use for adolescents with lower levels of behavioral disinhibition than for more disinhibited youth (although, for all youth, it was associated with generally more marijuana use). A three-way interaction with gender and behavioral disinhibition was not significant at any time.

Control Variables

Table 1 shows estimates for time-fixed covariates for Models 5 – 8. In all models, identifying as Black or Native American was associated with greater odds of marijuana use, compared to being White. Identifying as Asian reduced the odds in all models. Mixed ethnicity was significantly associated with higher odds of marijuana use only in Model 6 (family management $\times$ behavioral disinhibition). Childhood socioeconomic status was related to greater odds of marijuana use in all analyses except in Model 7 (antisocial peers $\times$ gender). Finally, cohort and intervention condition were unrelated to marijuana use in any of the four analyses.

Discussion

The current study aimed to clarify questions related to changes in the strength of association between known risk and protective factors and marijuana use over the course of adolescence. Previous investigations have yielded few consistent findings about whether the strength of family and peer predictors increases or decreases over time, and whether some youth are more susceptible to their influence. Some of the confusion is likely due to differential age sampling in different studies, to the fact that changes in the size of predictive effects may be nonlinear (e.g., Cleveland et al., 2012), and to limited availability of methodologies that test changes in effect size over time. In this study we attempted to address these limitations by using time-varying effect modeling (TVEM), which allowed us to fully utilize the

longitudinal data from the Raising Healthy Children study and to test interactions between individual and environmental factors throughout adolescence.

Results from this investigation show that family management had a consistent negative association with marijuana use. For the entirety of the developmental period examined in the current analysis (ages 12 – 19), we observed that good family management was associated with reduced likelihood of marijuana use for all adolescents. This association remained unchanged until the late adolescence around the time when youth tend to leave the parental home. However, some multifinality in the effect of family management was observed: girls and adolescents with lower levels of behavioral disinhibition may have benefitted more from good family management than boys and more disinhibited adolescents, and these differences were most pronounced during the transition to high school. It is important to note, however, that family management was also associated with significantly lower odds of marijuana use for boys and less inhibited youth across adolescence, even if the size of the effect was slightly smaller. Analyses also showed that exposure to antisocial peers was associated with higher odds of using marijuana for the same developmental period (ages 12 – 19). Peer effects were also robustly related to marijuana use and were relatively stable over time. Here, multifinality by gender and behavioral disinhibition was also observed but the timing was different than for family management. Association with antisocial peers was linked to higher odds of marijuana use, and this relationship was stronger for girls than boys in the late teenage years. The relationship between antisocial peers and marijuana use was also stronger for youth with lower levels of behavioral disinhibition; this effect was significant throughout middle and late adolescence.

Comparison with Previous Findings

Our main findings are consistent with prior studies that have shown both family management and exposure to antisocial peers to be related to adolescent substance use. Prior research examining the interaction of antisocial peers and family management with gender has produced inconsistent results as to which gender is more susceptible to environmental influences (Choquet et al., 2008; McArdle et al., 2002; Parsai et al., 2009; Simons-Morton et al., 2001). In the current study, we found that the association of family management with antisocial peers was stronger for girls than for boys, but only during the transition to high school. Some researchers have raised questions about the role that child disclosure plays in parents' knowledge (a part of parental management) about the child's whereabouts. For example, Eaton et al. (2009) reported associations between gender, child personality traits, and disclosure, suggesting that some children are more likely to facilitate monitoring by volunteering information. Girls with greater harm avoidance (lower behavior disinhibition) tendencies disclosed more than more disinhibited girls—a pattern of results generally consistent with our findings. In fact, families are believed to monitor girls more closely than boys as part of a sexual double standard that makes it more acceptable for boys to engage in some antisocial behaviors (Smetana & Daddis, 2002; Tucker, McHale, & Crouter, 2003; Varner & Mandara, 2014). It is possible that parents expect greater disclosure from girls and provide greater sanctions for girls' misbehavior, thereby increasing the likelihood of disclosure.

In a similar vein, gender differences in peer influence may be explained by gender-based substance use norms (Schulenberg, 1999; Simons-Morton et al., 2001). Boys, for whom marijuana use is more normative than for girls, may be less dependent on peer influence to engage in marijuana use. Some of the inconsistency in gender effects in the literature may be due to the relatively low prevalence of girls reporting antisocial peers compared to boys in some samples (Mears, Ploeger, & Warr, 1998; Svensson, 2004), such that girls who have antisocial peers are relative outliers, and thus may be more likely to use marijuana.

The current study also found that the association between family management and antisocial peers and marijuana use differed by behavioral disinhibition and that *less* disinhibited youth were more susceptible to outside influence. This is interesting given that some advocates of selective intervention recommend identifying and selecting for intervention youths at higher risk (see Bröning et al., 2012), when in this case, the lower risk youth were most responsive to these environmental experiences. These findings are not without precedent. Several studies have found that antisocial peers had the strongest effect on youth who are less impulsive and have higher self-control (Meldrum, Miller, & Flexon, 2013; Thomas & McGloin, 2013; Vitulano, Fite, & Rathert, 2010). It is possible that more disinhibited youth choose peers who, like them, are more likely to engage in substance use. Similar to the case of boys vs. girls, for disinhibited youth, marijuana use would be driven more by their own sensation seeking than by peer influence, whereas less disinhibited youth might start using marijuana only in the presence of antisocial peers. Another possible explanation, as put forth by Thomas and McGloin (2013), is that high- and low-impulsive youth may be differentially susceptible to different types of peer influence. They posit that low-impulsive youth may be more susceptible to normative peer influence—shared values and behavior reinforcement, whereas high-impulsive youth may be most susceptible to situational peer influences—opportunities that arise during unstructured or unsupervised time with peers. This might partially explain why these contradictory results have emerged.

Our finding that family management had a greater effect for less disinhibited youth deviates from the few studies that have examined this interaction (Chen & Jacobson, 2013; Hill et al., 2010; Kaynak et al., 2013; Stephenson & Helme, 2006). It may be that traditional family management approaches are not as effective for more disinhibited youth because these youth are less likely to voluntarily disclose to parents or to consider the consequences of their actions. This might suggest the need for more targeted parenting techniques for families with more disinhibited youth in addition to consistent family management. For example, programs teaching interpersonal skills to temper behavioral disinhibition also seem promising (e.g., Conrod, Stewart, Comeau, & Maclean, 2006) in reducing substance use and could be explored as preventive interventions for marijuana use.

Limitations and Implications

Limitations of the current study should be noted. First, the sample size afforded a relatively few number of person-occasions in our analytic sample (7,754 person-occasions for family management effects and 7,045 person-occasions for peer effects) compared to other TVEM studies (Evans-Polce, Vasilenko, & Lanza, 2015; Shiyko, Lanza, Tan, Li, & Shiffman, 2012; Vasilenko et al., 2014), which might have led to lower analytic power. Still, some TVEM

studies have been conducted with less than 2,000 person-occasions (Shiyko, Burkhalter, Li, & Park, 2014) and even as few as 1,116 (Wright, Hallquist, Swartz, Frank, & Cyranowski, 2014). Furthermore, as the presence of antisocial peers was not measured until age 12/13, only a few cases contributed to the early part of the curve, making precise estimation of peer effects on marijuana use during early adolescence difficult. Likewise, family management was measured only until age 18. It is possible that other changes in its effect size or in its interaction with gender and behavioral disinhibition might have emerged later in development. Future studies should examine time-varying interactions with other individual characteristics that could suggest other targets of intervention. One of the strengths of the TVEM method is that the change in effect size over time is modeled freely, without a predetermined multivariate trend (e.g., linear, quadratic). However, this also means that determining whether a predictor is increasing or decreasing in influence over time is difficult. In addition, our analyses relied on two different measures of marijuana use: lifetime use at age 11/12 and past-month use at all subsequent ages. Although it is possible that use of a lifetime measure may have led to an overestimation of marijuana use at age 11/12, we believe it is unlikely to have had a significant impact on our findings, as only 3% of the sample reported use at that initial time point. Finally, analyses were conducted in a community intervention sample; future studies should examine these effects in other samples, and in samples with greater geographic and ethnic diversity.

The current study approach and findings are of great interest to other disciplines that examine person-environment interactions. One of the advantages of time-varying effect modeling is that analyses are based on person-year observations rather than number of participants, as each participant contributes more than one data point. This greatly increases power to detect interactions. The TVEM approach may be of particular interest to studies of gene-environment interaction where insufficient power is often an issue (Duncan & Keller, 2011). Further, there have been some questions as to whether gene-environment interactions are more likely to be found in adolescence or adulthood (Burt & Neiderhiser, 2009; Kretschmer, Dijkstra, Veenstra, Ormel, & Verhulst, 2013; Lee, 2011). The present paper is part of a larger program of study seeking to clarify the contributions of genes (and other individual difference measures) and environment to addiction over the course of development. As strong, reliable genetic markers of addiction are developed, the current TVEM approach could be used in this and other longitudinal studies to identify specific developmental periods when gene-environment interactions are present.

The practical implications of these findings are threefold. First, parents and peers emerged as important targets of preventive intervention, with some suggestion about the timing of intervention delivery. For example, the transition to high school is one of the key times during which adolescents gain more autonomy and are exposed to older adolescents who may increase the availability of drugs and opportunities to try marijuana. This is an important period for parents to intervene with their children and, according to results of the current study, an opportunity to exercise family management techniques to prevent teen marijuana use. Second, and more importantly, these findings challenge the notion that interventions should be selective based on the identification of high-risk youth. For all youth in the current study, consistent family management and antisocial peers were important predictors of marijuana use, suggesting that all youth could benefit from universal preventive

efforts that strengthen families and curb exposure to antisocial peers. Selecting only the higher risk youth (boys and those with greater behavioral disinhibition) would miss the potential benefit to those youth who are low risk and who, in this study, were more responsive to family management and antisocial peers. Finally, higher and lower risk youth in this study were differentially responsive to their environment during certain periods in adolescence, which also suggests that interventions should be designed with these differential effects in mind. Universal interventions that contain program elements targeting boys and disinhibited youth hold promise for more effective marijuana prevention.

Acknowledgments

Funding for this study was provided by grants from the National Institute on Drug Abuse (R01DA024411; R01DA08093). The content of this paper is solely the responsibility of the authors and does not necessarily represent the official views of the funding agency. Richard F. Catalano is a board member of Channing Bete Company, distributor of Supporting School Success® and Guiding Good Choices®. Although the intervention effects are not studied in this paper, these programs were tested in the studies that produced the data sets used in this paper. The authors gratefully acknowledge RHC study participants for their continued contribution to the longitudinal study. They also acknowledge the SDRG Survey Research Division for their hard work maintaining high panel retention, and the SDRG editorial and administrative staff for their editorial and project support.

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Figure 1.
Probability of marijuana use by gender and behavioral disinhibition

Figure 2.

The time-varying main effect of family management (lagged 1 year) and antisocial peers (lagged 1 year) on marijuana use, with 95% confidence intervals

Note. Model 1 is presented on the left-hand side;

Model 2 is on the right.

Models are adjusted for ethnicity, childhood SES, cohort, and intervention status.

Figure 3.

The time-varying main effect of gender and behavioral disinhibition on marijuana use, with 95% confidence intervals

Note. Model 3 is presented on the left-hand side;

Model 4 is on the right.

Models are adjusted for ethnicity, childhood SES, cohort, and intervention status.

Figure 4.

Time-varying main effect of family management on marijuana use, by gender (family management $\times$ gender interaction)

Note: Time-varying interaction of Model 5 is plotted on the left. The difference in the main effects is illustrated on the right.

The area inside the box represents time span during which the gender interaction is significant at the $p < .05$ level.

Models are adjusted for ethnicity, childhood SES, cohort, and intervention status.

Figure 5.

Time-varying main effect of family management on marijuana use, by behavioral disinhibition (family management $\times$ behavioral disinhibition interaction)

Note: Time-varying interaction of Model 6 is plotted on the left. The difference in the main effects is illustrated on the right.

The area inside the box represents time span during which the behavioral disinhibition interaction is significant at the $p < .05$ level.

Models are adjusted for gender, ethnicity, childhood SES, cohort, and intervention status.

Figure 6.

Time-varying main effect of antisocial peers on marijuana use, by gender (antisocial peers $\times$ gender interaction)

Note: Time-varying interaction of Model 7 is plotted on the left. The difference in the main effects is illustrated on the right.

The area inside the box represents time span during which the gender interaction is significant at the $p < .05$ level.

Models are adjusted for ethnicity, childhood SES, cohort, and intervention status.

Figure 7.

Time-varying main effect of antisocial peers on marijuana use, by behavioral disinhibition (antisocial peers $\times$ behavioral disinhibition interaction)

Note: Time-varying interaction of Model 8 is plotted on the left. The difference in the main effects is illustrated on the right.

The area inside the box represents time span during which the behavioral disinhibition interaction is significant at the $p < .05$ level.

Models are adjusted for gender, ethnicity, childhood SES, cohort, and intervention status.

Table 1

Time-fixed coefficient estimates

Analysis	Covariate	Estimate (SE)	p-Value
Family management × gender (Model 5, Figure 4)	Black	.60 (.18)	.0010
	Asian	-.91 (.19)	<.0001
	Native	.91 (.19)	<.0001
	Mixed	.14 (.10)	.1961
	Childhood SES	.26 (.07)	.0005
	Cohort	.10 (.07)	.1896
	Treatment	-.09 (.07)	.2342
Family management × behavioral disinhibition (Model 6, Figure 5)	Black	.89 (.18)	<.0001
	Asian	-.60 (.19)	.0013
	Native	.83 (.20)	<.0001
	Mixed	.24 (.10)	.0207
	Childhood SES	.28 (.07)	.0001
	Cohort	.03 (.07)	.6714
Antisocial peers × gender (Model 7, Figure 6)	Treatment	-.12 (.07)	.1039
	Black	.47 (.19)	<.0001
	Asian	-.84 (.20)	<.0001
	Native	.49 (.21)	.0206
	Mixed	.08 (.11)	.4331
	Childhood SES	.14 (.08)	.0781
	Cohort	.01 (.08)	.8780
Antisocial peers × behavioral disinhibition (Model 8, Figure 7)	Treatment	-.08 (.07)	.2667
	Black	.71 (.19)	.0002
	Asian	-.51 (.21)	.0084
	Native	.58 (.21)	.0062
	Mixed	.20 (.11)	.0706
	Childhood SES	.17 (.08)	.0274
	Cohort	-.03 (.08)	.7241
	Treatment	-.11 (.07)	.1454

Note. Ethnicity referent was White.