HHS Public Access

Author manuscript

Dev Psychol. Author manuscript; available in PMC 2023 January 05.

Published in final edited form as:

Dev Psychol. 2021 December ; 57(12): 2250–2264. doi:10.1037/dev0001267.

The Externalizing and Internalizing Pathways to Marijuana Use Initiation: Examining the Synergistic Effects of Impulsiveness and Sensation Seeking

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Abstract

Adolescent marijuana use has become increasingly more problematic compared to the past; thus, understanding developmental processes that increase the liability of marijuana use is essential. Two developmental pathways to adolescent substance use have been proposed: an externalizing pathway that emphasizes the expression of aggressive and delinquent behavior and an internalizing pathway that emphasizes the role of depressive symptoms and negative affect. In this study, we aimed to examine the synergistic role of impulsiveness and sensation seeking in the two risk pathways to determine if both high and low levels of the traits are risk factors for marijuana use. Our study included 343 adolescents (52% were girls, 78% identified as Hispanic) that oversampled high-risk youth (78% had a family history of substance use disorder), assessed biannually between the ages of 13–16 years old. Moderated mediation analyses revealed that high levels of sensation seeking indirectly predicted marijuana use through higher mean levels of externalizing behavior. The positive relationship between sensation seeking and externalizing behavior was only significant at high levels of impulsiveness. Conversely, low levels of sensation seeking indirectly predicted marijuana use through higher mean levels of internalizing behavior. The negative relationship between sensation seeking and internalizing behavior was only significant at low levels of impulsiveness. Collectively, these results demonstrate that high and low levels of both impulsiveness and sensation seeking confer increased risk of marijuana use, albeit through different mechanisms.

Author Note

Research reported in this publication was supported by NIDA of the National Institutes of Health under award numbers R01-DA026868 and T32-DA031115. Dr. Dougherty is also supported by the William and Marguerite Wurzbach Distinguished Professorship. The funding entities had no role in the study design, collection, analysis or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication. The study was not preregistered and study materials are available upon request.

Keywords

impulsivity; sensation seeking; externalizing behavior; internalizing behavior; marijuana use

Adolescence is a developmental stage when marijuana use typically begins; recent estimates indicate that 29.6% of youth reported initiating marijuana use by age 16 years old (Chen et al., 2017). Initiation before the age of 16 has serious implications for adolescent well-being, including: poor executive function (Dahlgren et al., 2016), learning difficulties (Schuster et al., 2016), low academic achievement (Melchior et al., 2017), structural brain aberrations (Filbey et al., 2015), escalation of substance use (Yu & Williford, 1992), and later substance use disorder (Sonon et al., 2016). Thus, understanding factors that are an antecedent to marijuana use initiation is crucial to prevent escalation of use and later maladjustment.

Two developmental pathways have been implicated in the etiology of substance use initiation: an externalizing and internalizing pathway. The externalizing pathway emphasizes the role of aggressive and delinquent behavior as a precursor to adolescent substance use (Edwards et al., 2016; Hussong et al., 2007; Zucker et al., 2011), while the internalizing pathway emphasizes the role of negative affect and depressive symptoms as precursors to adolescent substance use (Hardee et al., 2018; Hussong et al., 2011). Though these two risk pathways can be applied to a variety of substances (e.g., alcohol, tobacco), we decided to focus on marijuana because of recent trends in adolescent substance use. For example, lifetime marijuana use has increased steadily and has reached a historic peak (Miech et al., 2020). Even more concerning, marijuana use initiation is more strongly associated with transitioning to frequent use among youth of today than previous generations. (Terry-McElrath et al., 2020). In contrast, multiple indicators of alcohol and tobacco use (e.g., recent use, lifetime use, binge drinking) have been declining over the years (Clark Goings et al., 2019; Miech et al., 2020). Given the declining trends of alcohol or tobacco use over the years among youth, recent increases in adolescent marijuana use pose a significant risk to adolescent health and well-being.

One gap in the recent scientific literature is the identification of the traits during early adolescence that are associated with the initiation of marijuana use through the externalizing and internalizing pathways. In particular, we propose to examine the role of impulsiveness and sensation seeking, both of which are relevant to adolescent substance use (Quinn & Harden, 2013; Romer et al., 2009; Tarter et al., 2004; Wasserman et al., 2020). While both have been linked to substance use, impulsiveness and sensation seeking are distinct constructs. In the present study, we define impulsiveness as the tendency to act on prepotent tendencies with disregard to the negative outcomes or consequences, while sensation seeking refers to the pursuit of novel, thrilling, and rewarding experience, even when doing so confers some level of risk (Steinberg et al., 2008). Additionally, the two constructs have also been linked to different brain structures. Impulsiveness has been linked to immaturities within the prefrontal cortex (Horn et al., 2003) whereas sensation seeking has been linked to activity in a network of subcortical structures such as the ventral striatum, which are recognized for their role in the processing of reward and emotionally relevant stimuli (Cardinal et al., 2002; Delgado, 2007). Lastly, factor analyses provide even further support

that impulsiveness and sensation seeking are distinct constructs (Sharma et al., 2014; Whiteside & Lynam, 2001).

Prior research has traditionally focused on the role of disinhibitory traits (i.e., high levels of impulsiveness and sensation seeking) as they pertain to substance use whereas the role of inhibitory traits (i.e., low levels of impulsiveness and sensation seeking) remains understudied. We propose that either *high* or *low* levels of impulsiveness and sensation seeking can also increase the risk for marijuana use, albeit through different pathways. Specifically, disinhibitory traits are central to expression of aggressive and delinquent behavior (Nigg, 2000; Romer et al., 2009); thus, we posit that high levels of impulsiveness and sensation seeking would be related to adolescent marijuana use through the externalizing pathway. Conversely, inhibitory traits are central to expression of depressive behaviors and negative affect (Gladstone & Parker, 2006; Trucco et al., 2018); thus, we posit that low levels of impulsiveness and sensation seeking would be related to adolescent marijuana use through the internalizing pathway. Consistent with neurobiological theories such as the dual systems model (Casey et al., 2008; Steinberg, 2010), we also tested if impusliveness and sensation seeking acted synergistically to increase the risk of marijuana use initiation through the two pathways. Overall, the goal of the present study is to examine if differences in impulsiveness and sensation seeking during early adolescence may discern between the externalizing and internalizing pathways to marijuana use.

The Externalizing Pathway

Externalizing behavior increases from childhood to adolescence and then declines into adulthood (Bongers et al., 2003, 2004). Though there is some overlap, externalizing behavior is distinguishable from health risk behaviors in that the former are antisocial behaviors that result in acting out (e.g., aggressive acts) and the latter are behaviors that have negative consequences on health (e.g., marijuana use). Importantly, there are substantial individual differences in the stability and developmental trajectories of externalizing behavior that may be an antecedent to adolescent substance use. As posited by Dodge and colleagues (2009), the early expression of externalizing problems increases the likelihood of adolescent substance use through a series of transactional processes involving key social domains. For example, adolescents who display high levels of externalizing behaviors may affiliate with deviant peers or have less school connectedness, and in turn, initiate substance use. Notably, non-social domains (e.g., temperament) also contribute to the onset of substance use through transactional processes involving externalizing behavior (Trucco et al., 2016). Therefore, elucidating factors that contribute to stable or developmental differences in the display of externalizing behaviors is crucial for the prevention of adolescent substance use.

Sensation seeking is one risk factor shown to promote the expression of externalizing behavior (Zuckerman, 2007). Logically, individuals who have high levels of sensation seeking may be prone to engage in behavior that is emotionally arousing or exciting such as delinquent or aggressive acts, a possibility largely supported by previous research (Harden et al., 2012; Mann et al., 2015; Wilson & Scarpa, 2011). Given that the expression of externalizing behavior has been shown to be an antecedent to substance use (Dodge et

al, 2009), we propose that sensation seeking may also be related indirectly to adolescent substance use through the externalizing pathway.

Trait impulsiveness is another key risk factor shown to have a robust relationship with externalizing behavior (Olson et al., 1999; Romer et al., 2009; White et al., 1994). While impulsiveness may have an independent effect on externalizing behavior, it may also modulate the effects of sensation seeking. According to neurobiological theories, such as the dual systems model, sensation seeking as it pertains to risky behaviors is particularly problematic in the context of an inability to regulate impulsive tendencies (Steinberg, 2010). Therefore, the capacity to regulate impulsive behavior is crucial for modulating individual differences in the propensity for engaging in thrill-seeking behaviors. Overall, there have been mixed results on the synergistic relationship between impulsiveness and sensation seeking, with some finding support (Patrick et al., 2008; Peeters et al., 2017) and others finding no support (Duell et al., 2016; Wasserman et al., 2017). In an extension of prior work (Rhodes et al., 2013), we examined if impulsiveness and sensation seeking may interact to predict externalizing behavior. Conceivably, adolescents with heightened sensation seeking coupled with impulsive tendencies may be especially likely to exhibit externalizing behaviors. Rather than simply testing if impulsiveness and sensation seeking interact to predict marijuana use directly, we tested for an indirect path through externalizing behavior (i.e., moderated mediation).

The Internalizing Pathway

An alternative pathway to substance use is through internalizing behavior, which increases from childhood to adolescence and then declines into adulthood (Bongers et al., 2003). According to the self-medication hypothesis, individuals with internalizing problems are prone to engage in substance use as a way of coping with their subjective distress or emotional dysfunction (Khantzian, 1997). Similar to externalizing behavior, it has been tied to a host of adjustment problems in the adolescent years, including substance use problems (Bohnert et al., 2008; Cerdá et al., 2013; Weidman et al., 2015). These findings have generated interest in identifying developmental risk pathways to explain how internalizing symptomology early in life might heighten the risk for substance use during adolescence and beyond. Even as a growing body of evidence supports the possibility that internalizing symptoms may impact patterns of substance use (Chassin et al., 1993; Clark, 1998), the specific developmental trajectories through which these relationships operate remain relatively understudied.

One of the aims of the present study was to examine the role of trait impulsiveness and sensation seeking in the expression of internalizing behavior. In particular, while prior research has often framed sensation seeking as a liability, some have also highlighted the adaptive functions of the trait. It has been proposed that sensation seeking during adolescence might promote many of the exploratory behaviors that allow youth to reach critical developmental milestones, such as establishing independence from the family or pursuing romantic relationships (Duell & Steinberg, 2019; Telzer, 2016). Conversely, adolescents who are low in sensation seeking may be averse to engaging in healthy exploratory behaviors and thus have difficulty approaching opportunities for social

connection or self-development. Indeed, Yoneda and colleagues (2019) found support for the adaptive role of sensation seeking, demonstrating that adolescents who exhibit moderate levels of sensation seeking report greater occupational achievement, social adjustment, and emotional well-being than those with either high or low levels of the trait. Sensation seeking can be adaptive and youth with low levels of the trait might be at risk for internalizing problems because they are less likely to engage in exploratory behaviors that promote healthy development.

Neurobiological research has also supported the possibility that low levels of sensation seeking might be associated with poor mental health outcomes in adolescence. Blunted activity in reward-sensitive circuits has been found to be significantly diminished among adolescents who are at risk for major depressive disorder both during rest (Pan et al., 2017) and when receiving positive compared to negative feedback (Hanson et al., 2015). While sensation seeking is not synonymous with neural reward sensitivity, sensation seeking has been shown to be correlated with reward-sensitive regions such as the ventral striatum (Cservenka et al., 2012; Weiland et al., 2013); thus, there is some degree of overlap. Collectively, this body of research suggests that both high and low levels of sensation seeking may lead to maladjustment in adolescence. The mechanisms underlying these relationships differ in important ways, with high sensation seeking being associated with greater externalizing behavior and low sensation seeking with internalizing behavior.

Impulsiveness is widely recognized as a robust correlate of externalizing problems, though some research has also suggested that low levels of the trait (e.g., behavioral inhibition) might heighten the risk for internalizing disorders. Adolescents who have impulsive tendencies are likely to have difficulty inhibiting behavioral urges or making decisions without consideration of the long-term consequences. Conversely, adolescents expressing low levels of impulsiveness may have the opposite behavioral profile, such as being overly regulated, cautious, and socially withdrawn. Though not a widely studied area of research, some findings within the literature have supported the possibility that these patterns of over-regulation may be associated with the development of internalizing disorders. For example, in a series of studies (Eisenberg et al., 2001, 2004, 2009; Wang et al., 2015), children exhibiting low levels of impulsiveness were found to have higher levels of internalizing symptomology. Other research has linked early expressions of low impulsiveness with the development of a number of mood disorders (Broeren & Muris, 2010; Gladstone et al., 2005; Muris et al., 2003; Schwartz et al., 1999). Thus, similar to sensation seeking, both high and low levels of impulsiveness can be maladaptive.

Integrating these findings, we propose that trait impulsiveness and sensation seeking may act synergistically to predict marijuana use through the internalizing pathway. Prior literature has largely examined the possibility of a synergetic relationship between impulsiveness and sensation seeking in the context of disinhibitory traits. That is, youth with high levels of impulsiveness may have more difficulty managing sensation-seeking tendencies, increasing the likelihood of marijuana use through the externalizing pathway. We suggest that the synergistic relationship between impulsiveness and sensation seeking can be extended to inhibitory traits, though the nature of the synergistic relationship would be dissimilar compared to youth with disinhibitory traits. Specifically, youth with low levels of

impulsiveness may be excessively cautious and less inclined to engage in healthy sensation-seeking behaviors, increasing the likelihood of marijuana use through the internalizing pathway. Thus, we anticipate that trait impulsiveness would modulate the relationship between sensation seeking and internalizing behavior, serving as a pathway to marijuana use.

The Present Study

The present study aimed to examine the roles of trait impulsiveness and sensation seeking in an externalizing and internalizing pathway to marijuana use initiation during adolescence. In particular, we propose to test if high and low levels of both impulsiveness and sensation seeking increase the risk of early initiation of marijuana use through the different pathways. As can be seen in Figure 1, we hypothesized that high levels of sensation seeking would predict earlier marijuana use initiation through externalizing behavior, whereas low levels of sensation seeking would predict earlier initiation through internalizing behavior. Lastly, we also hypothesized that trait impulsiveness would moderate these pathways such that the externalizing pathway would operate in the context of heightened impulsiveness and that the internalizing pathway would operate in the context of low impulsiveness. To test the study hypotheses, we used data from a longitudinal study that oversampled high-risk youth to determine if the externalizing and internalizing pathways predicted marijuana use initiation by age 16.

Methods

Participants

The present study examined data from a longitudinal study of 386 adolescents and their parent(s) who were recruited through various media advertisements (e.g., radio advertisements and flyers). The study was enriched to increase the occurrence of substance use by oversampling high-risk youth who had a family history of substance use disorder (n = 305, 79.02%). The purpose of this strategy was to elucidate developmental predictors of substance use problems. Exclusion criteria included (at study entry): 1) a positive pregnancy test, urine drug screening, or breathe alcohol concentration; 2) a diagnosis of DSM-IV psychiatric disorders with the exception of attention-deficit/hyperactivity disorder and/or oppositional defiant disorder because they typically co-occur with the development of substance use disorder; or 3) an IQ < 70; or any other significant disability. Moreover, youth were identified as high-risk if their father had a substance use disorder or low-risk if they did not have any parents or grandparents with a substance use disorder. Youth were ethnically (78% identified as Hispanic) and racially diverse (87% identified as White, 11% as Black or African American, and 2% as another race or multiracial). Written informed consent was obtained from parents and informed assent was obtained from adolescents at study entry and re-affirmed at subsequent follow-up visits. Data are protected by a Certificate of Confidentiality from the Department of Health and Human Services. The Association of Adolescent Substance Use with the Development of Impulse Control project was approved by the IRB at the University of Texas Health Science Center at San Antonio (ID: HSC20100116HU).

Participants who completed a phone screening and met inclusion criteria (and did not meet exclusion criteria) were invited to the lab and completed a baseline assessment when the adolescent was between 10–12 years old. Participants (and their parents, most often their mother) returned to the lab every six months thereafter for follow-up appointments for a total of seven assessments between the ages of 13–16. Importantly, all adolescents were substance-use naïve at baseline. The baseline assessment took about six hours to complete. Parents and adolescents were each compensated $120 for completing the baseline assessment. The follow-up assessments took about four hours to complete and parents were compensated $75 while adolescents were compensated $120. During lab visits, participants completed self-report questionnaires, structured interviews, computer tasks (adolescents only), and provided a urine sample for a drug panel analysis (adolescents only). Both the adolescent and parents were offered breaks and lunch. See Ryan et al. (2016) for further descriptions of the study sample, design, and measures. The study was not preregistered and study materials are available upon request.

Analytic Sample.

The analytic sample included participants (youth with or without a family history of substance use disorder) who had data for both predictor variables (i.e., impulsiveness, sensation seeking) and the outcome variables (i.e., externalizing and internalizing behavior, marijuana use) for at least one time-point between 13 to 16 years old. A total of n = 43 did not meet this criteria, resulting in an analytic size of n = 343, none of whom initiated marijuana use. Attrition rates for the seven assessments between the ages of 13 to 16 years old ranged from 3.4% to 10.3% (average rate was 6.6%) and participants completed a median of six assessments. Data were determined to be missing completely at random (MCAR) because Little's MCAR test (Little, 1988) was non-significant, χ^2 = 1390, df = 1395, p = .53. To ensure there was no difference between youth who had available data at age 16 (n = 219) and those who did not (n =167), attritions analyses (i.e., t-tests, chi-square) were conducted comparing the two groups. Attrition analyses revealed no significant mean differences between the two groups in baseline measures of impulsiveness, sensation seeking, externalizing and internalizing behavior, or demographics including gender, socioeconomic status, and race/ethnicity. All variables used in the present study were screened for normality and skewness

Follow-Up Measures

Impulsiveness (Age 13).—Impulsiveness was measured with adolescent reports of the Barratt Impulsiveness Scale (BIS; Patton et al., 1995). The BIS is a well-validated and reliable (Stanford et al., 2009) 30-item self-report measure of the tendency towards impulsive behavior. An example item includes "I act on spur of the moment" and possible responses range from 1 = *Rarely/never* to 4 = *Almost always/always*. Standardized scores at the age of 13 were used for the present study with higher scores reflecting higher levels of impulsiveness. Reliability assessed with Cronbach's alpha was acceptable, α = .81.

Sensation Seeking (Age 13).—Sensation seeking was measured with adolescent reports of the Sensation Seeking Scale for Children (SSS-C; Russo et al., 1993). Prior work has shown that the SSS-C is a valid and reliable measure of sensation seeking. For this

scale, adolescent participants were shown two statements (e.g., “I’d like to try mountain climbing” and “I think people who do dangerous things like mountain climbing are foolish”) and instructed to select the one they most agree with. Thus, the response option was dichotomous. Standardized total scores at the age of 13 were used for the present study with higher scores interpreted as higher levels of sensation seeking. Reliability assessed with Kuder-Richardson (KR-20) was acceptable at .85.

Externalizing and Internalizing Behavior (Ages 13–16).—Externalizing and internalizing behavior were measured with parent reports of the Child Behavior Checklist (CBCL; Achenbach, 1991). The CBCL is a 113-item measure that assesses their child’s behavioral problems. The 18-item Aggressive Behavior scale (e.g., “argues a lot”) summary score was used as the measure of externalizing behavior. The Rule Breaking Subscale was not included because these items asked about substance use; thus, any relationship between externalizing behavior and marijuana use could be inflated. The sum of the 13-item Depressive Symptoms scale (e.g., “unhappy, sad, depressed”) was used as the measure of internalizing behavior. The raw total scores for externalizing and internalizing behavior were positively skewed, ranging from 1.38–4.25 and 1.80–6.01, respectively. Due to positive skewness, the constant one was added to the summary scores for both externalizing and internalizing behavior and subsequently log transformed, a similar method used by previous research (Gilliom & Shaw, 2004; Wang & Liu, 2018). After the transformation, skewness was acceptable for both externalizing (0.01–0.37) and internalizing (0.58–0.77) behavior. We were unable to compute Cronbach’s alpha coefficient because we only had access to raw total scores and not individual item scores, though the CBCL is a widely used and psychometrically validated measure of externalizing and internalizing behavior (Achenbach, 1991; Nakamura et al., 2009).

Marijuana Use (Ages 13–16).—Marijuana use was determined using a combination of the drug history questionnaire (DHQ; Sobell et al., 1995), timeline follow-back (TLFB) interview (Sobell & Sobell, 1992), and a drug panel urinalysis. For the DHQ, adolescents reported whether or not they used different substances, when they last used, lifetime total use, and current pattern of use. For the TLFB, adolescents reported the specific days and amount of substance use in the past six months using a calendar method that included holidays to improve recall. The age of marijuana initiation was determined if they reported using within the past six months on the DHQ, reported any use on the TLFB, or a positive drug screen. Per Muthén & Masyn (2005) marijuana use initiation was coded as dichotomous with 0 = “Did not initiate marijuana use at the current or previous age time-points” and 1 = “Initiated marijuana use at current age time-point.” Once marijuana use was initiated, subsequent time-points were coded as missing. Lastly, the frequency of marijuana use at age 16 was also modeled as an outcome in additional analyses. In the analytic sample, frequency of marijuana use at age 16 had the following distribution: 0 = “No use” (n = 166, 75.8%); 1 = “< 1 use a month” (n = 28, 12.8%); 2 = “≤ 1 use in a week” (n = 10, 4.6%); and 3 = “At least several uses per week” (n = 15, 6.68%).

Analytic Method

All multivariate analyses were conducted in Mplus 8.1 (Muthén & Muthén, 2017) with full-information maximum likelihood estimation with robust standard errors (MLR) to account for missing data. Whenever possible, relative model fit indices including the chi-square difference test and absolute fit indices including 90% confidence intervals (CI) for the root mean error of approximation (RMSEA), and comparative fit index (CFI) are reported. Cutoffs for acceptable fit include a CFI > .90 and RMSEA <.10 (Barrett, 2007) and cutoffs for excellent model fit include a CFI > .95 and RMSEA <.05 (Hu & Bentler, 1999). For models that include marijuana use initiation as the outcome, model fit indices were not available.

The analytic method included the following steps to test the study hypotheses: 1) descriptive analyses were conducted to report the observed data; 2) unconditional growth models were estimated to describe the average rate of the time-varying measures (i.e., externalizing and internalizing behavior) for the seven assessments between the ages of 13–16 as well as any individual differences therein; 3) an unconditional survival model was estimated to describe the likelihood of initiating marijuana use at each specific age time-point between 13–16 and; and 4) lastly, a moderated mediation model was estimated to test the primary study hypotheses. Details for each of the steps in the analytic plan are described below.

Descriptive analyses.

Means and standard deviations for all variables are reported for descriptive analyses. Instead of standardized scores for impulsiveness and sensation seeking, summary scores for each are reported to increase the comparability to other studies that have used the same measures. Similarly, raw scores for externalizing and internalizing behavior are reported instead of log-transformed scores. To test for the presence of early initiation of marijuana use, use was dichotomously scored as whether or not they initiated by age 16 with 0 = “did not initiate by age 16” and 1 = “initiated by age 16.” Lastly, bivariate correlations were conducted to report the unconditional relationship between the study variables.

Unconditional growth curve models.

The unconditional growth curve models were estimated through a latent variable framework by estimating an intercept factor (i.e., individual differences in mean levels at age 13) and a slope factor (i.e., individual differences in the rate of change between ages 13–16 years old). Time was treated as discrete six-month intervals between the ages of 13–16 for a total of seven time-points. The intercept factor was estimated by fixing each of the seven loadings to one. To account for both linear and non-linear change (e.g., quadratic), a latent basis slope was estimated in which the age 13 loading was fixed to zero, the age 16 loading was fixed to one, and the intermediate age loadings were freely estimated. A covariance was also estimated between the intercept and slope factors.

Unconditional survival model.

Marijuana use initiation between the ages of 13–16 years old was modeled as a discrete-time survival analysis. A latent variable framework was used to estimate the survival function,

such that the factor loadings for all seven-measurement occasions were fixed to one and the factor mean and variance were both fixed to zero. The time-specific thresholds at each measurement occasion were freely estimated. Thus, the thresholds can be interpreted as the time-specific hazard probabilities (i.e., the likelihood of initiation given that they did not initiate at an earlier occasion).

Moderated mediation models.

Two moderated mediation models (Preacher et al., 2007) that included externalizing behavior and internalizing behavior as mediators were tested separately. The present study hypothesized that externalizing/internalizing behavior would mediate the relationship between sensation seeking and marijuana use initiation. However, the mediated pathway was also expected to be moderated by impulsiveness. Moderation was first tested to examine the levels of impulsiveness at which sensation seeking significantly predicted externalizing/internalizing behavior. Then, mediation was tested, but only at levels of impulsiveness in which the direct effect from sensation seeking to the externalizing/internalizing behavior growth factors was significant. The approach for testing moderation and mediation is described below.

Moderation.—The simple slopes procedure as described by Aiken and West (1991) was used to test for moderation. Specifically, if the interaction term between impulsiveness and sensation seeking was significant, the moderated effect was probed further by centering impulsiveness at one standard deviation (SD) below the mean, at the mean, and at one SD above the mean in order to determine at what levels of impulsiveness sensation seeking was related to externalizing/internalizing behavior. A total of $n = 61$ (18.2%) had scores one SD below the mean, $n = 60$ (17.9%) one SD above the mean, and the remainder n = 214 (63.8%) were within one SD above or below the mean.

Mediation.—The significance of mediated effects (MacKinnon et al., 2004) was tested with bias-corrected bootstrapped standard errors, given the tendency of sampling distributions of indirect effects to be non-normal. Per recommendations from (Preacher & Hayes, 2008), the 95% confidence intervals of the mediated effect are reported. If both the upper and lower bounds of the confidence interval do not contain zero, the mediated was determined to be statistically significant. Thus, mediation analyses are reported in the following format: β = Estimate [Lower bound, Upper bound].

Results

Descriptive Statistics

See Table 1 for means, standard deviations, and bivariate correlations for all study variables. As can be seen in the table, externalizing behavior tended to decrease between the ages of 13–16 whereas internalizing behavior tended to increase. Both impulsiveness and sensation seeking had a positive relationship with externalizing behavior at each time-point whereas only impulsiveness had a significant positive association with internalizing behavior. Sensation seeking, impulsiveness, and externalizing and internalizing behavior were all related to an increased likelihood of marijuana use initiation by age 16.

Unconditional Growth Curve Models

For externalizing behavior, the unconditional growth model had acceptable overall fit, χ^2 = 35.36, *df* = 24, *p* = .06; CFI = .99; RMSEA [90% CI] = .04 [.00, .06]. Externalizing behavior decreased on average between the ages of 13–16 years old and there was significant between-person variability in both the initial levels and rate of change. For internalizing behavior, the unconditional growth model had acceptable overall fit, χ^2 = 35.9, *df* = 24, *p* = .06; CFI = .98; RMSEA [90% CI] = .04 [.00, .06]. Internalizing behavior increased on average between the ages of 13–16 years old and there was between-person significant variability in both the initial levels and rate of change.

Unconditional Survival Model.

See Figure 2 for a plot of the likelihood of marijuana use initiation between the ages of 13–16 years old. The percentages were converted from the model estimated hazard functions. As would be expected, the risk of marijuana use initiation was low at ages 13 and 13.5 and had a stable pattern thereafter, reaching a peak at age 16. Overall, 99/343 (28.9%) of the youth included in the analytic sample initiated marijuana use by age 16.

Moderated Mediation Models

Two models were tested: one with externalizing behavior as the mediator and the other with internalizing behavior. For both models, impulsiveness, sensation seeking, and their interaction term directly predicted the intercept and slope factors for externalizing/internalizing behavior and marijuana use initiation. In turn, the intercept (i.e., between-person differences in mean levels at age 13) and slope (i.e., between-person differences in the rate of change between ages 13–16) factors for externalizing/internalizing behavior directly predicted marijuana use initiation. Gender was included as a covariate. Additional analyses were conducted with the frequency of marijuana use at age 16 as the outcome to ensure the robustness of results. If there are substantive differences between the models for marijuana use initiation compared to the frequency of use, the results for frequency of use are discussed in more detail. Otherwise, they are kept succinct.

Externalizing behavior.

See Figure 3 and Table 2 for the externalizing behavior model results. For the figure, solid black lines represent significant direct effects, thicker solid black lines represent significant indirect effects, and dashed gray lines represent non-significant effects. As can be seen under the Effects for Externalizing Behavior Intercept Factor heading in Table 2, the interaction between impulsiveness and sensation seeking was significant. Upon probing the interaction, results revealed that higher levels of sensation seeking predicted higher mean levels of externalizing behavior at age 13, but only at one SD above the mean of impulsiveness. Neither sensation seeking nor impulsiveness predicted the slope factor (see Effects for Externalizing Behavior Slope Factor heading in Table 2). Higher levels of sensation seeking and externalizing behavior at age 13 both predicted earlier marijuana use initiation (see Effects for Marijuana Use Initiation heading in Table 2). The slope factor for externalizing behavior was unrelated to marijuana use initiation[1]. As hypothesized, higher levels of sensation seeking also indirectly predicted earlier marijuana use initiation

through the externalizing behavior intercept factor (β = 0.13 [0.04, 0.24]), following the thicker solid lines in Figure 2, but only at one SD above the mean of impulsiveness. Higher levels of impulsiveness indirectly predicted marijuana use initiation through the externalizing behavior intercept factor (β = 0.12 [0.04, 0.21]) but there was no significant direct relationship. The results for the externalizing behavior model were replicated for frequency of marijuana use as the outcome (see Table S1 for model estimates and fit indices).

Internalizing Behavior.

See Figure 4 and Table 3 for the internalizing behavior model results. As can be seen under the Effects for Internalizing Behavior Intercept Factor heading in Table 3, the interaction between impulsiveness and sensation seeking was significant. Upon probing the interaction, dissimilar from the externalizing behavior model, results revealed that lower levels of sensation seeking predicted higher mean levels of internalizing behavior at age 13, but only at one SD below the mean for impulsiveness. Similar to the externalizing behavior model, neither impulsiveness nor sensation seeking predicted the slope factor (see Effects for Internalizing Behavior Slope Factor heading in Table 3). Higher levels of sensation seeking and internalizing behavior at age 13 both predicted marijuana use initiation. The slope factor for internalizing behavior was unrelated to marijuana use initiation. As hypothesized, lower levels of sensation seeking indirectly predicted marijuana use initiation through the internalizing behavior intercept factor, but only at one SD below the mean of impulsiveness (β = –0.11 [–0.23, –0.01]). Thus, *higher* levels of sensation seeking directly predicted marijuana use initiation whereas *lower* levels of sensation seeking indirectly predicted marijuana use initiation. Higher levels of impulsiveness also indirectly predicted earlier marijuana use initiation through the internalizing behavior intercept factor (β = 0.15 [0.06, 0.25]) but there was no direct effect of impulsiveness. The results for the internalizing behavior model were replicated for frequency of marijuana use as the outcome (see Table S2 for model estimates and fit indices).

Discussion

The present study aimed to examine the role of trait impulsiveness and sensation seeking during early adolescence in the externalizing and internalizing pathways to marijuana use. In support of the externalizing pathway, sensation seeking was related to marijuana use (initiation and frequency of use) through its positive association with mean levels of externalizing behavior at age 13. Impulsiveness moderated this pathway such that sensation seeking was only associated with externalizing behavior at high levels of impulsiveness. In support of the internalizing pathway, sensation seeking was related to marijuana use (initiation and frequency of use) through its negative association with mean levels of internalizing behavior at age 13. Impulsiveness moderated this pathway such that sensation seeking was only associated with internalizing behavior at low levels of impulsiveness. However, the indirect effects should be interpreted with caution given that the lower bounds

[1]We included the slope factor in the model to control for individual differences in the rate of change when interpreting the relationship between the intercept factors and marijuana use initiation. The supplemental analysis with the frequency of marijuana at age 16 as the outcome demonstrated no effect for the slope factors, similar to results of the survival analysis.

of the confidence intervals were near zero. We did not find evidence that the rate of change in externalizing or internalizing behavior were related to marijuana use; rather, the pathways operated through individual differences in mean levels of externalizing and internalizing behavior. The lack of findings for the rate of change in externalizing and internalizing behavior could be due to minimal change or between-person variability, the nature of the high-risk cohort, or the age range of the study sample (13–16 years old). Notably, similar to the present investigation, other studies have found that externalizing behavior generally decreases during adolescence while internalizing behavior increases (Bongers et al., 2003, 2004). Thus, the lack of findings for individual differences in the rate of change may not be specific to this study.

To summarize, the results of the present study demonstrate that high and low levels of both impulsiveness and sensation seeking increase the likelihood of marijuana use, albeit through divergent processes. We consider the most innovative findings to be the ways in which the present study refines the roles of impulsiveness and sensation seeking in adolescent marijuana use and elucidating distinct pathways through which externalizing and internalizing behavior are related to adolescent marijuana use. Thus, the discussion will focus on these topics.

Refining the Role of Impulsiveness and Sensation Seeking in Adolescent Marijuana Use

A gap in the literature that the present study aimed to address was to determine if trait impulsiveness and sensation seeking during early adolescence were related to the externalizing and internalizing pathways to marijuana use. Independent of these pathways, impulsiveness and sensation seeking have been shown to have a well-established relationship with adolescent substance use (Quinn & Harden, 2013; Romer et al., 2011; Wasserman et al., 2020). Other lines of research have examined the possibility of a synergistic relationship, such that the effect of sensation seeking on substance use is accentuated by heightened impulsiveness (Mccabe et al., 2015; Peeters et al., 2017). Our findings refine the role of impulsiveness and sensation seeking as they relate to adolescent marijuana use in two key ways. First, we found that the interactive relationship between impulsiveness and sensation seeking was indirectly related to marijuana use through externalizing and internalizing behavior; however, we did not find support for a direct relationship. While previous research only considered the possibility that the synergistic relationship was directly associated with substance use, our findings refine the role of impulsiveness and sensation seeking by demonstrating that the synergistic relationship may operate through intervening processes (e.g., externalizing and internalizing behavior) as well.

Second, we found that there were two unique combinations of impulsiveness and sensation seeking that conferred increased risk of marijuana use. Consistent with the existence of a disinhibited phenotype (Romer, 2010; Tarter et al., 2004), the combination of high levels of impulsiveness and sensation seeking increased the likelihood of marijuana use through externalizing behavior. In contrast, the combination of low levels of impulsiveness and sensation seeking also increased the likelihood of marijuana use, albeit through internalizing behavior. Notably, these results also imply the existence of an inhibited phenotype. That

is, inverse to the disinhibited phenotype, youth with inhibited characteristics may be excessively cautious and unwilling to engage in healthy exploratory behavior that is necessary to develop a sense of well-being (Telzer, 2016; Yoneda et al., 2019), increasing the risk of internalizing problems and marijuana use. Overall, the findings from the present extend the current literature by considering alternative means by which impulsiveness and sensation seeking act synergistically to predict adolescent marijuana use.

The Externalizing and Internalizing Pathways to Adolescent Marijuana Use

Developmental theory speculates that the externalizing and internalizing pathways are distinct processes leading to substance use (Edwards et al. 2016, Hussong et al., 2011; Zucker et al., 2011). The externalizing pathway posits that aggressive and/or delinquent behavior are the impetus for developmental cascades involving social and non-social domains that lead to substance use. The internalizing pathway posits that individuals who exhibit negative affect and depressive behaviors engage in substance use as a way of self-medicating or coping with their underlying mood disorder (Hussong et al., 2011; Khantzian, 1997). Though distinct pathways are hypothesized, the expression of externalizing and internalizing behaviors often co-occur (Nivard et al., 2017). Thus, it remains unclear the degree to which the externalizing and internalizing pathways are truly distinct mechanisms, or whether these processes are mutually occurring.

The findings from the present study extend the current literature by specifying unique processes through which externalizing and internalizing behavior are related to adolescent marijuana use. Consistent with previous research, our results demonstrate that youth with disinhibitory traits were likely to express externalizing behaviors (Harden et al., 2012; Mann et al., 2017; Romer et al., 2009) whereas youth with inhibitory traits were more likely to express internalizing behaviors (Gladstone & Parker, 2006; Trucco et al., 2018). In turn, the expression of both externalizing and internalizing behavior were related to marijuana use. Collectively, these results elucidate distinct mechanisms from impulsiveness and sensation seeking to externalizing and internalizing behavior that increases the risk of marijuana use. Importantly, we also acknowledge that there are shared mechanisms as well. For example, other research has shown that the parent–child relationship (Hollenstein et al., 2004; Lansford et al., 2014) and difficulties with emotion regulation (Wills et al., 2016) are related to both externalizing and internalizing behaviors. As such, future research should continue to delineate unique and shared risk factors relevant to the externalizing and internalizing pathways.

Implications

The findings from the present have implications for the prevention of adolescent marijuana use. Depending on the youth's combination of impulsiveness and sensation seeking, different prevention strategies may be more appropriate. For youth who exhibit disinhibitory traits and are prone to externalize, parenting strategies to monitor their behavior or provide support to regulate their impulsive tendencies may prove beneficial and reduce adolescent substance use (Barnes et al., 2006; Branstetter & Furman, 2013). Similarly, parental support can improve youths' capacity to regulate their disinhibitory tendencies (Moilanen & Rambo-Hernandez, 2017; Qu et al., 2015), which in turn may reduce the likelihood of engaging

in marijuana use (Wills et al., 2004). Thus, the parent–adolescent relationship may be an effective modality to prevent marijuana use, either directly through parents' monitoring efforts or by mitigating the influence of youth's disinhibitory traits.

For youth who exhibit inhibitory traits and are prone to internalize, psychotherapy and/or medication addressing the underlying mood disorder may be beneficial for preventing marijuana use. Through treating the internalizing disorder, there may be a "secondary benefit" (O'Neil et al., 2011) in that the emerging substance use problems are avoided. Indeed, prior clinical trials have shown that adolescents who receive treatment for anxiety and depression are subsequently less likely to engage in substance use or develop a substance use disorder compared to adolescents who receive a placebo treatment (Stice et al., 2008). However, this secondary benefit may be specific to adolescents who respond to treatment (Curry et al., 2012). Analogous to externalizing problems, parents can also reduce their child's expression of internalizing problems, particularly through providing a supportive relationship (Cumsille & Epstein, 1994; Galambos et al., 2003; Scaramella et al., 1999). To summarize, the parent–adolescent relationship may serve as a context that can provide additional support to both disinhibited and inhibited youth (see Kuntsche & Kuntsche [2016] for a review of parenting interventions to reduce adolescent substance use). By reducing the youth's externalizing or internalizing behavior, a supportive relationship can prevent the onset of substance use problems. In addition to the parent–adolescent relationship, substance use may also be prevented among inhibited youth as a secondary benefit of treating the underlying internalizing problem.

Limitations and Strengths

When discussing the findings, there are limitations of the study that are worth noting. The assessments for marijuana use relied on adolescent's self-reports, which may be underreported if youth are unwilling to disclose their substance use. To reduce this possibility, we developed procedures and ensured confidentiality to encourage accurate reporting. Additionally, we supplemented youth reports with a drug panel analysis that provides an objective measure of marijuana, although urinalysis can only detect recent use. Another limitation is that low impulsiveness may not fully capture the construct of behavioral inhibition and other measures may better capture the full spectrum of the construct. Notably, other research used measures of impulsiveness to quantify inhibition and relate it to internalizing problems (Eisenberg et al., 2004, 2009; Wang et al., 2015). Lastly, impulsiveness and sensation seeking were assessed at a single time-point when these constructs develop over the course of adolescence (Harden & Tucker-Drob, 2011; Wasserman et al., 2020). While longitudinal assessments may be best suited to capture trait levels of the constructs, age was held constant by measuring impulsiveness and sensation seeking at age 13. With age held constant, variation in impulsivity and sensation-seeking scores are primarily attributable to trait levels rather than developmental change. We used a single time-point to assess these constructs in order to simplify the already complex analyses and test for moderation with an interaction term.

Despite these limitations, the present study has strengths as well. First, we were able to include both adolescent self-reports (i.e., impulsiveness, sensation seeking, marijuana use)

and parent reports (i.e., externalizing and internalizing behavior) to reduce the likelihood of inflating the relationships among variables compared to data collected from a single reporter. Second, our study oversampled high-risk youth. This strategy increased the rates of marijuana use initiation and allowed us to study factors that are related to problematic substance use that may not be possible with a traditional sample. Third, our longitudinal study assessed youth every six months, which increases the confidence of the growth parameter estimates and sensitivity to detect the developmental timing of marijuana use initiation compared to longitudinal studies that collected the data annually or longer.

Conclusions

The present study extends current theory by examining the synergistic role of trait impulsiveness and sensation sensations as they relate to the externalizing and internalizing pathways. The novel findings demonstrate that impulsiveness and sensation seeking interact with each other in two unique ways to predict marijuana use indirectly. Specifically, we found that sensation seeking was positively related to externalizing behavior but only at high levels of impulsiveness. Alternatively, we also found that sensation seeking was negatively related to internalizing behavior but only at low levels of impulsiveness. In turn, higher levels of externalizing and internalizing behavior were positively associated with earlier marijuana use. Thus, the combination of high levels of impulsiveness and sensation seeking and low levels of the two constructs operate through distinct pathways (externalizing and internalizing behavior, respectively) to increase the propensity for adolescent marijuana use. Overall, our study highlights the complexity of individual differences in impulsiveness and sensation seeking as they relate to adolescent marijuana use.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

Achenbach TM. (1991). Manual for the Child Behavior Checklist/4–18 profile. Burlington, VT: University of Vermount, Department of Psychiatry.

Aiken LS, & West SG. (1991). Multiple Regression: Testing and Interpreting Interactions. Thousand Oaks, CA: SAGE Publications, Inc.

Barnes GM, Hoffman JH, Welte JW, Farrell MP, & Dintcheff BA. (2006). Effects of parental monitoring and peer deviance on substance use and delinquency. Journal of Marriage and Family, 68(4), 1084–1104. 10.1111/j.1741-3737.2006.00315.x

Barrett P. (2007). Structural equation modelling: Adjudging model fit. Personality and Individual Differences, 42(5), 815–824. 10.1016/j.paid.2006.09.018

Bohnert AM, Kane P, & Garber J. (2008). Organized activity participation and internalizing and externalizing symptoms: Reciprocal relations during adolescence. Journal of Youth and Adolescence, 37(2), 239–250. 10.1007/s10964-007-9195-1

Bongers IL, Koot HM, Van Der Ende J., & Verhulst FC. (2004). Developmental trajectories of externalizing behaviors in childhood and adolescence. Child Development, 75(5), 1523–1537. [PubMed: 15369529]

Bongers IL, Koot HM, van der Ende J, & Verhulst FC. (2003). The normative development of child and adolescent problem behavior. Journal of Abnormal Psychology, 112(2), 179–192. 10.1037/0021-843X.112.2.179 [PubMed: 12784827]

Branstetter SA, & Furman W. (2013). Buffering effect of parental monitoring knowledge and parent-adolescent relationships on consequences of adolescent substance use. Journal of Child and Family Studies, 22(2), 192–198. 10.1007/s10826-012-9568-2 [PubMed: 23869161]

Broeren S, & Muris P. (2010). A psychometric evaluation of the Behavioral Inhibition Questionnaire in a non-clinical sample of Dutch children and adolescents. Child Psychiatry and Human Development, 41(2), 214–229. 10.1007/s10578-009-0162-9 [PubMed: 19921537]

Cardinal RN, Parkinson J.a , Hall J, & Everitt BJ. (2002). Emotion and motivation: the role of the amygdala, ventral striatum, and prefrontal cortex. Neuroscience and Biobehavioral Reviews, 26(3), 321–352. http://www.ncbi.nlm.nih.gov/pubmed/12034134 [PubMed: 12034134]

Casey BJ, Getz S, & Galvan A. (2008). The adolescent brain. Developmental Review, 28(1), 62–77. 10.1016/j.dr.2007.08.003 [PubMed: 18688292]

Cerdá M, Bordelois PM, Keyes KM, Galea S, Koenen KC, & Pardini D. (2013). Cumulative and recent psychiatric symptoms as predictors of substance use onset: Does timing matter? Addiction, 108(12), 2119–2128. 10.1111/add.12323 [PubMed: 23941263]

Chassin L, Pillow DR, Curran PJ, Molina BSG, & Barrera M. (1993). Relation of parental alcoholism to early adolescent substance use: A test of three mediating mechanisms. Journal of Abnormal Psychology, 102(1), 3–19. 10.1037/0021-843X.102.1.3 [PubMed: 8436697]

Chen X, Yu B, Lasopa SO, & Cottler LB. (2017). Current patterns of marijuana use initiation by age among US adolescents and emerging adults: implications for intervention. American Journal of Drug and Alcohol Abuse, 43(3), 261–270. 10.3109/00952990.2016.1165239 [PubMed: 27211100]

Clark DB. (1998). Psychopathology in adolescent alcohol abuse and dependence. Alcohol Research and Health, 22(2), 117–121.

Clark Goings T, Salas-Wright CP, Belgrave FZ, Nelson EJ, Harezlak J, & Vaughn MG. (2019). Trends in binge drinking and alcohol abstention among adolescents in the US, 2002–2016. Drug and Alcohol Dependence, 200(December 2018), 115–123. 10.1016/j.drugalcdep.2019.02.034 [PubMed: 31121494]

Cservenka A, Herting MM, Seghete KLM, Hudson K a, & Nagel BJ (2012). High and low sensation seeking adolescents show distinct patterns of brain activity during reward processing. NeuroImage, 66C, 184–193. 10.1016/j.neuroimage.2012.11.003

Cumsille PE, & Epstein N. (1994). Family cohesion, family adaptability, social support, and adolescent depressive symptoms in outpatient clinic families. Journal of Family Psychology, 8(2), 202–214. 10.1037/0893-3200.8.2.202

Curry J, Silva S, Rohde P, Ginsburg G, Kennard B, Kratochvil C, Simons A, Kirchner J, May D, Mayes T, Feeny N, Albano AM, Lavanier S, Reinecke M, Jacobs R, Becker-Weidman E, Weller E, Emslie G, Walkup J, … March J. (2012). Onset of alcohol or substance use disorders following treatment for adolescent depression. Journal of Consulting and Clinical Psychology, 80(2), 299–312. 10.1037/a0026929 [PubMed: 22250853]

Dahlgren MK, Sagar KA, Racine MT, Dreman MW, & Gruber SA. (2016). Marijuana use predicts cognitive performance on tasks of executive function. Journal of Studies on Alcohol and Drugs, 77(2), 298–308. 10.15288/jsad.2016.77.298 [PubMed: 26997188]

Delgado MR. (2007). Reward-related responses in the human striatum. Annals of the New York Academy of Sciences, 1104, 70–88. 10.1196/annals.1390.002 [PubMed: 17344522]

Dodge K a, Malone PS, Lansford JE, Miller S, Pettit GS, & Bates JE. (2009). A dynamic cascade model of the development of substance-use onset. Monographs of the Society for Research in Child Development, 74(3), 1–23. 10.1111/j.1540-5834.2009.00528.x

Duell N, & Steinberg L. (2019). Positive risk taking in adolescence. Child Development Perspectives, 13(1), 48–52. 10.1111/cdep.12310 [PubMed: 30774707]

Duell N, Steinberg L, Chein J, Al-Hassan SM, Bacchini D, Lei C, Chaudhary N, Di Giunta L, Dodge KA, Fanti KA, Lansford JE, Malone PS, Oburu P, Pastorelli C, Skinner AT, Sorbring E, Tapanya S, Tirado LMU, & Alampay LP. (2016). Interaction of reward seeking and self-regulation in the prediction of risk taking: A cross-national test of the dual systems model. Developmental Psychology, 52(10), 1593–1605. 10.1037/dev0000152 [PubMed: 27598251]

Edwards AC, Gardner CO, Hickman M, & Kendler KS. (2016). A prospective longitudinal model predicting early adult alcohol problems: Evidence for a robust externalizing pathway. Psychological Medicine, 46(5), 957–968. 10.1017/S0033291715002457 [PubMed: 26670459]

Eisenberg N, Cumberland A, Spinrad TL, Fabes R.a , Shepard S. a, Reiser M, Murphy BC, Losoya SH, & Guthrie IK. (2001). The relations of regulation and emotionality to children's externalizing and internalizing problem behavior. Child Development, 72(4), 1112–1134. 10.1111/1467-8624.00337 [PubMed: 11480937]

Eisenberg N, Spinrad TL, Fabes RA, Reiser M, Cumberland A, Shepard SA, Valiente C, Losoya SH, Guthrie IK, Thompson M, & Murphy B. (2004). The relations of effortful control and impulsivity to children's resiliency and adjustment. Child Development, 75(1), 25–46. 10.1111/j.1467-8624.2004.00652.x [PubMed: 15015673]

Eisenberg N, Valiente C, Spinrad TL, Cumberland A, Liew J, Reiser M, Zhou Q, & Losoya SH. (2009). Longitudinal relations of children's effortful control, impulsivity, and negative emotionality to their externalizing, internalizing, and co-occurring behavior problems. Developmental Psychology, 45(4), 988–1008. 10.1037/a0016213 [PubMed: 19586175]

Filbey FM, McQueeny T, DeWitt SJ, & Mishra V. (2015). Preliminary findings demonstrating latent effects of early adolescent marijuana use onset on cortical architecture. Developmental Cognitive Neuroscience, 16, 16–22. 10.1016/j.dcn.2015.10.001 [PubMed: 26507433]

Galambos NL, Barker ET, & Almeida DM. (2003). Parents do matter: Trajectories of change in externalizing and internalizing problems in early adolescence. Child Development, 74(2), 578–594. 10.1111/1467-8624.7402017 [PubMed: 12705574]

Gilliom M, & Shaw DS. (2004). Codevelopment of externalizing and internalizing problems in early childhood. Development and Psychopathology, 16(2), 313–333. 10.1017/S0954579404044530 [PubMed: 15487598]

Gladstone GL, & Parker GB. (2006). Is behavioral inhibition a risk factor for depression? Journal of Affective Disorders, 95(1–3), 85–94. 10.1016/j.jad.2006.04.015 [PubMed: 16808978]

Gladstone GL, Parker GB, Mitchell PB, Wilhelm KA, & Malhi GS. (2005). Relationship between self-reported childhood behavioral inhibition and lifetime anxiety disorders in a clinical sample. Depression and Anxiety, 22(3), 103–113. 10.1002/da.20082 [PubMed: 16149043]

Hanson JL, Hariri AR, & Williamson DE. (2015). Blunted ventral striatum development in adolescence reflects emotional neglect and predicts depressive symptoms. Biological Psychiatry, 78(9), 598–605. 10.1016/j.biopsych.2015.05.010 [PubMed: 26092778]

Hardee JE, Cope LM, Martz ME, & Heitzeg MM. (2018). Review of neurobiological influences on externalizing and internalizing pathways to alcohol use sisorder. Current Behavioral Neuroscience Reports, 5(4), 249–262. 10.1007/s40473-018-0166-5 [PubMed: 31768306]

Harden KP, Quinn PD, & Tucker-Drob EM. (2012). Genetically influenced change in sensation seeking drives the rise of delinquent behavior during adolescence. Developmental Science, 15(1), 150–163. 10.1111/j.1467-7687.2011.01115.x [PubMed: 22251301]

Harden KP, & Tucker-Drob EM. (2011). Individual differences in the development of sensation seeking and impulsivity during adolescence: further evidence for a dual systems model. Developmental Psychology, 47(3), 739–746. 10.1037/a0023279 [PubMed: 21534657]

Hollenstein T, Granic I, Stoolmiller M, & Snyder J. (2004). Rigidity in parent-child interactions and the development of externalizing and internalizing behavior in early childhood. Journal of Abnormal Child Psychology, 32(6), 595–607. 10.1023/B:JACP.0000047209.37650.41 [PubMed: 15648527]

Horn NR, Dolan M, Elliott R, Deakin JFW, & Woodruff PWR. (2003). Response inhibition and impulsivity: An fMRI study. Neuropsychologia, 41(14), 1959–1966. 10.1016/S0028-3932(03)00077-0 [PubMed: 14572528]

Hu L, & Bentler PM. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal, 6(1), 1–55. 10.1080/10705519909540118

Hussong AM, Jones DJ, Stein GL, Baucom DH, & Boeding S. (2011). An internalizing pathway to alcohol and substance use disorders. Psychology of Addictive Behaviors, 25(3), 390–404. 10.1037/a0024519 [PubMed: 21823762]

Hussong AM, Wirth RJ, Edwards MC, Curran PJ, Chassin LA, & Zucker RA. (2007). Externalizing symptoms among children of alcoholic parents: Entry points for an antisocial pathway to alcoholism. Journal of Abnormal Psychology, 116(3), 529–542. 10.1037/0021-843X.116.3.529 [PubMed: 17696709]

Khantzian EJ. (1997). The self-medication hypothesis of substance use disorders: A reconsideration and recent applications. Harvard Review of Psychiatry, 4(5), 231–244. 10.3109/10673229709030550 [PubMed: 9385000]

Kuntsche S, & Kuntsche E. (2016). Parent-based interventions for preventing or reducing adolescent substance use — A systematic literature review. Clinical Psychology Review, 45, 89–101. 10.1016/j.cpr.2016.02.004 [PubMed: 27111301]

Lansford JE, Laird RD, Pettit GS, Bates JE, & Dodge KA. (2014). Mothers' and fathers' autonomy-relevant parenting: Longitudinal links with adolescents' externalizing and internalizing behavior. Journal of Youth and Adolescence, 43(11), 1877–1889. 10.1007/s10964-013-0079-2 [PubMed: 24337705]

Little RJA. (1988). A test of missing completely at random for multivariate data with missing values. Journal of the American Statistical Association, 83(404), 1198–1202. 10.1080/01621459.1988.10478722

MacKinnon D, Lockwood CM, & Williams J. (2004). Confidence limits for the indirect effect: Distribution of the product and resampling methods. Multivariate Behavioral Research, 39(1), 1–24. 10.1207/s15327906mbr3901 [PubMed: 26759933]

Mann FD, Engelhardt L, Briley DA, Grotzinger AD, Patterson MW, Tackett JL, Strathan DB, Heath A, Lynskey M, Slutske W, Martin NG, Tucker-Drob EM, & Harden KP. (2017). Sensation seeking and impulsive traits as personality endophenotypes for antisocial behavior: Evidence from two independent samples. Personality and Individual Differences, 105, 30–39. 10.1016/j.paid.2016.09.018 [PubMed: 28824215]

Mann FD, Kretsch N, Tackett JL, Harden KP, & Tucker-Drob EM. (2015). Person×environment interactions on adolescent delinquency: Sensation seeking, peer deviance and parental monitoring. Personality and Individual Differences, 76, 129–134. 10.1016/j.paid.2014.11.055 [PubMed: 25908885]

Mccabe CJ, Louie KA, & King KM. (2015). Premeditation moderates the relation between sensation seeking and risky substance use among young adults. Psychology of Addictive Behaviors, 29(3), 753–765. 10.1037/adb0000075 [PubMed: 26415063]

Melchior M, Bolze C, Fombonne E, Surkan PJ, Pryor L, & Jauffret-Roustide M. (2017). Early cannabis initiation and educational attainment: Is the association causal? Data from the French TEMPO study. International Journal of Epidemiology, 46(5), 1641–1650. 10.1093/IJE/DYX065 [PubMed: 28520946]

Miech RA, Johnston LD, O'Malley PM, Bachman JG, Schulenberg JE, & Patrick ME. (2020). Monitoring the Future national survey results on drug use, 1975–2019: Volume I, Secondary school students. Ann Arbor: Institute for Social Research, The University of Michigan.

Moilanen KL, & Rambo-Hernandez KE. (2017). Effects of maternal parenting and mother-child relationship quality on short-term longitudinal change in self-regulation in early adolescence. The Journal of Early Adolescence, 37(5), 618–641. 10.1177/0272431615617293

Muris P, Meesters C, & Spinder M. (2003). Relationships between child- and parent-reported behavioural inhibition and symptoms of anxiety and depression in normal adolescents. Personality and Individual Differences, 34(5), 759–771. 10.1016/S0191-8869(02)00069-7

Muthén B, & Masyn K. (2005). Discrete-time survival mixture analysis. Journal of Educational and Behavioral Statistics, 30(1), 27–58. 10.3102/10769986030001027

Muthén LK, & Muthén BO. (2017). Mplus User's Guide. Eighth Edition. Los Angeles, CA: Muthén & Muthén.

Nakamura BJ, Ebesutani C, Bernstein A, & Chorpita BF. (2009). A psychometric analysis of the child behavior checklist DSM-oriented xcales. Journal of Psychopathology and Behavioral Assessment, 31(3), 178–189. 10.1007/s10862-008-9119-8

Nigg JT. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. Psychological Bulletin, 126(2), 220–246. 10.1037/0033-2909.126.2.220 [PubMed: 10748641]

Nivard MG, Lubke GH, Dolan CV, Evans DM, St Pourcain B, Munafò MR, & Middeldorp CM. (2017). Joint developmental trajectories of internalizing and externalizing disorders between childhood and adolescence. Development and Psychopathology, 29(3), 919–928. 10.1017/S0954579416000572 [PubMed: 27427290]

O'Neil KA, Conner BT, & Kendall PC. (2011). Internalizing disorders and substance use disorders in youth: Comorbidity, risk, temporal order, and implications for intervention. Clinical Psychology Review, 31(1), 104–112. 10.1016/j.cpr.2010.08.002 [PubMed: 20817371]

Olson SL, Schilling EM, & Bates JE. (1999). Measurement of impulsivity: Construct coherence, longitudinal stability, and relationship with externalizing problems in middle childhood and adolescence. Journal of Abnormal Child Psychology, 27(2), 151–165. 10.1023/A:1021915615677 [PubMed: 10400061]

Pan PM, Sato JR, Salum GA, Rohde LA, Gadelha A, Zugman A, Mari J, Jackowski A, Picon F, Miguel EC, Pine DS, Leibenluft E, Bressan RA, & Stringaris A. (2017). Ventral striatum functional connectivity as a predictor of adolescent depressive disorder in a longitudinal community-based sample. American Journal of Psychiatry, 174(11), 1112–1119. 10.1176/appi.ajp.2017.17040430 [PubMed: 28946760]

Patrick ME, Blair C, & Maggs JL. (2008). Executive function, approach sensitivity, and emotional decision making as influences on risk behaviors in young adults. Journal of Clinical and Experimental Neuropsychology, 30(4), 449–462. 10.1080/13803390701523109 [PubMed: 18938681]

Patton JH, Stanford MS, & Barratt ES. (1995). Factor structure of the Barratt Impulsiveness Scale. Journal of Clinical Psychology, 51(6), 768–774. [PubMed: 8778124]

Peeters M, Oldehinkel T, & Vollebergh W. (2017). Behavioral control and reward sensitivity in adolescents' risk taking behavior: A longitudinal TRAILS study. Frontiers in Psychology, 8(FEB), 1–11. 10.3389/fpsyg.2017.00231 [PubMed: 28197108]

Preacher KJ, & Hayes AF. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods, 40(3), 879–891. 10.3758/BRM.40.3.879 [PubMed: 18697684]

Preacher KJ, Rucker DD, & Hayes AF. (2007). Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. Multivariate Behavioral Research, 42(1), 185–227. 10.1080/00273170701341316 [PubMed: 26821081]

Qu Y, Fuligni AJ, Galvan A, & Telzer EH. (2015). Buffering effect of positive parent-child relationships on adolescent risk taking: A longitudinal neuroimaging investigation. Developmental Cognitive Neuroscience, 15, 26–34. 10.1016/j.dcn.2015.08.005 [PubMed: 26342184]

Quinn PD, & Harden KP. (2013). Differential changes in impulsivity and sensation seeking and the escalation of substance use from adolescence to early adulthood. Development and Psychopathology, 25(1), 223–239. 10.1017/S0954579412000284 [PubMed: 22824055]

Rhodes JD, Colder CR, Trucco EM, Speidel C, Hawk LW, Lengua LJ, Eiden R Das, & Wieczorek W. (2013). The interaction between self-regulation and motivation prospectively predicting problem behavior in adolescence. Journal of Clinical Child and Adolescent Psychology, 42(5), 681–692. 10.1080/15374416.2013.773515 [PubMed: 23477426]

Romer D. (2010). Adolescent risk taking, impulsivity, and brain development: Implications for prevention. Developmental Psychobiology, 52(3), 263–276. 10.1002/dev.20442 [PubMed: 20175097]

Romer D, Betancourt L, Giannetta JM, Brodsky NL, Farah M, & Hurt H. (2009). Executive cognitive functions and impulsivity as correlates of risk taking and problem behavior in preadolescents. Neuropsychologia, 47(13), 2916–2926. 10.1016/j.neuropsychologia.2009.06.019 [PubMed: 19560477]

Romer D, Betancourt LM, Brodsky NL, Giannetta JM, Yang W, & Hurt H. (2011). Does adolescent risk taking imply weak executive function? A prospective study of relations between working memory performance, impulsivity, and risk taking in early adolescence. Developmental Science, 14(5), 1119–1133. 10.1111/j.1467-7687.2011.01061.x [PubMed: 21884327]

Russo MF, Stokes GS, Lahey BB, Christ MAG, McBurnett K, Loeber R, Stouthamer-Loeber M, & Green SM. (1993). A sensation seeking scale for children: Further refinement and psychometric development. Journal of Psychopathology and Behavioral Assessment, 15(2), 69–86. 10.1007/BF00960609

Ryan SR, Acheson A, Charles NE, Lake SL, Hernandez DL, Mathias CW, & Dougherty DM. (2016). Clinical and social/environmental characteristics in a community sample of children with and without family histories of substance use disorder in the San Antonio area: A descriptive study. Journal of Child and Adolescent Substance Abuse, 25(4), 327–339. 10.1080/1067828X.2014.999202 [PubMed: 28936105]

Scaramella LV, Conger RD, & Simons RL. (1999). Parental protective influences and gender-specific increases in adolescent internalizing and externalizing problems. Journal of Research on Adolescence, 9(2), 111–141. 10.1207/s15327795jra0902_1

Schuster RM, Hoeppner SS, Evins AE, & Gilman JM. (2016). Early onset marijuana use is associated with learning inefficiencies. Neuropsychology, 30(4), 405–415. 10.1037/neu0000281 [PubMed: 26986749]

Schwartz CE, Snidman N, & Kagan J. (1999). Adolescent social anxiety as an outcome of inhibited temperament in childhood. Journal of the American Academy of Child and Adolescent Psychiatry, 38(8), 1008–1015. 10.1097/00004583-199908000-00017 [PubMed: 10434493]

Sharma L, Markon KE, & Clark LA. (2014). Toward a theory of distinct types of “impulsive” behaviors: A meta-analysis of self-report and behavioral measures. Psychological Bulletin, 140(2), 374–408. 10.1037/a0034418 [PubMed: 24099400]

Sobell LC, Kwan E, & Sobell MB. (1995). Reliability of a drug history questionnaire (DHQ). Addictive Behaviors, 20(2), 233–241. 10.1016/0306-4603(94)00071-9 [PubMed: 7484317]

Sobell LC, & Sobell MB. (1992). Timeline follow-back. In Litten RZ& Allen JP(Eds.), Measuring alcohol consumption (pp. 41–72). Humana Press. 10.1007/978-1-4612-0357-5_3

Sonon K, Richardson GA, Cornelius J, Kim KH, & Day NL. (2016). Developmental pathways from prenatal marijuana exposure to Cannabis Use Disorder in young adulthood. Neurotoxicology and Teratology, 58, 46–52. 10.1016/j.ntt.2016.05.004 [PubMed: 27208888]

Stanford MS, Mathias CW, Dougherty DM, Lake SL, Anderson NE, & Patton JH. (2009). Fifty years of the Barratt Impulsiveness Scale: An update and review. Personality and Individual Differences, 47(5), 385–395. 10.1016/j.paid.2009.04.008

Steinberg L. (2010). A dual systems model of adolescent risk-taking. Developmental Psychobiology, 52(3), 216–224. 10.1002/dev.20445 [PubMed: 20213754]

Stice E, Rohde P, Seeley JR, & Gau JM. (2008). Brief cognitive-behavioral depression prevention program for high-risk adolescents outperforms two alternative interventions: A randomized efficacy trial. Journal of Consulting and Clinical Psychology, 76(4), 595–606. 10.1037/a0012645 [PubMed: 18665688]

Tarter RE, Kirisci L, Habeych M, Reynolds M, & Vanyukov M. (2004). Neurobehavior disinhibition in childhood predisposes boys to substance use disorder by young adulthood: Direct and mediated etiologic pathways. Drug and Alcohol Dependence, 73(2), 121–132. 10.1016/j.drugalcdep.2003.07.004 [PubMed: 14725951]

Telzer EH. (2016). Dopaminergic reward sensitivity can promote adolescent health: A new perspective on the mechanism of ventral striatum activation. Developmental Cognitive Neuroscience, 17, 57–67. 10.1016/j.dcn.2015.10.010 [PubMed: 26708774]

Terry-McElrath YM, O’Malley PM, & Johnston LD. (2020). The growing transition from lifetime marijuana use to frequent use among 12th grade students: U.S. National data from 1976 to 2019. Drug and Alcohol Dependence, 212(February), 108064. 10.1016/j.drugalcdep.2020.108064

Trucco EM, Hicks BM, Villafuerte S, Nigg JT, Burmeister M, & Zucker RA. (2016). Temperament and externalizing behavior as mediators of genetic risk on adolescent substance use. Journal of Abnormal Psychology, 125(4), 565–575. 10.1037/abn0000143 [PubMed: 26845260]

Trucco EM, Villafuerte S, Hussong A, Burmeister M, & Zucker RA. (2018). Biological underpinnings of an internalizing pathway to alcohol, cigarette, and marijuana use. Journal of Abnormal Psychology, 127(1), 79–91. 10.1037/abn0000310 [PubMed: 29172598]

Wang FL, Chassin L, Eisenberg N, & Spinrad TL. (2015). Effortful control predicts adolescent antisocial-aggressive behaviors and depressive symptoms: Co-occurrence and moderation by impulsivity. Child Development, 86(6), 1812–1829. 10.1111/cdev.12406 [PubMed: 26286709]

Wang M, & Liu L. (2018). Reciprocal relations between harsh discipline and children's externalizing behavior in China: A 5-year longitudinal study. Child Development, 89(1), 174–187. 10.1111/cdev.12724 [PubMed: 28146336]

Wasserman AM, Crockett LJ, & Hoffman L. (2017). Reward seeking and cognitive control: Using the dual systems model to predict adolescent sexual behavior. Journal of Research on Adolescence, 27(4), 907–913. 10.1111/jora.12321 [PubMed: 29152861]

Wasserman AM, Mathias CW, Hill-Kapturczak N, Karns-Wright TE, & Dougherty DM. (2020). The development of impulsivity and sensation seeking: associations with substance use among at-risk adolescents. Journal of Research on Adolescence, 30(4), 1051–1066. 10.1111/jora.12579 [PubMed: 32951266]

Weidman AC, Augustine AA, Murayama K, & Elliot AJ. (2015). Internalizing symptomatology and academic achievement: Bi-directional prospective relations in adolescence. Journal of Research in Personality, 58, 106–114. 10.1016/j.jrp.2015.07.005

Weiland BJ, Welsh RC, Yau WW, Zucker RA, Zubieta J, & Heitzeg MM. (2013). Accumbens functional connectivity during reward mediates sensation-seeking and alcohol use in high-risk youth ☙. Drug and Alcohol Dependence, 128(1–2), 130–139. 10.1016/j.drugalcdep.2012.08.019 [PubMed: 22958950]

White JL, Moffitt TE, Caspi A, Bartusch DJ, Needles DJ, & Stouthamer-Loeber M. (1994). Measuring impulsivity and examining its relationship to delinquency. Journal of Abnormal Psychology, 103(2), 192–205. 10.1037/0021-843X.103.2.192 [PubMed: 8040489]

Whiteside SP, & Lynam DR. (2001). The Five Factor Model and impulsivity: using a structural model of personality to understand impulsivity. Personality and Individual Differences, 30(4), 669–689. 10.1016/S0191-8869(00)00064-7

Wills Thomas A., Simons JS, Sussman S, & Knight R. (2016). Emotional self-control and dysregulation: A dual-process analysis of pathways to externalizing/internalizing symptomatology and positive well-being in younger adolescents. Drug and Alcohol Dependence, 163, S37–S45. 10.1016/j.drugalcdep.2015.08.039 [PubMed: 27306730]

Wills Thomas Ashby, & Dishion TJ. (2004). Temperament and adolescent substance use: A transactional analysis of emerging self-control. Journal of Clinical Child & Adolescent Psychology, 33(1), 69–81. 10.1207/S15374424JCCP3301_7

Wilson LC, & Scarpa A. (2011). The link between sensation seeking and aggression: A meta-analytic review. Aggressive Behavior, 37(1), 81–90. 10.1002/ab.20369 [PubMed: 20973087]

Yoneda T, Ames ME, & Leadbeater BJ. (2019). Is there a positive side to sensation seeking? Trajectories of sensation seeking and impulsivity may have unique outcomes in young adulthood. Journal of Adolescence, 73(March), 42–52. 10.1016/j.adolescence.2019.03.009 [PubMed: 30978586]

Yu J, & Williford WR. (1992). The age of alcohol onset and alcohol, cigarette, and marijuana use patterns: An analysis of drug use progression of Young adults in new york state. Substance Use and Misuse, 27(11), 1313–1323. 10.3109/10826089209047353

Zucker RA, Heitzeg MM, & Nigg JT. (2011). Parsing the undercontrol-disinhibition pathway to substance use disorders: A multilevel developmental problem. Child Development Perspectives, 5(4), 248–255. 10.1111/j.1750-8606.2011.00172.x [PubMed: 22116786]

Zuckerman M. (2007). Sensation seeking and risky behavior. In Sensation seeking and risky behavior. American Psychological Association. 10.1037/11555-000

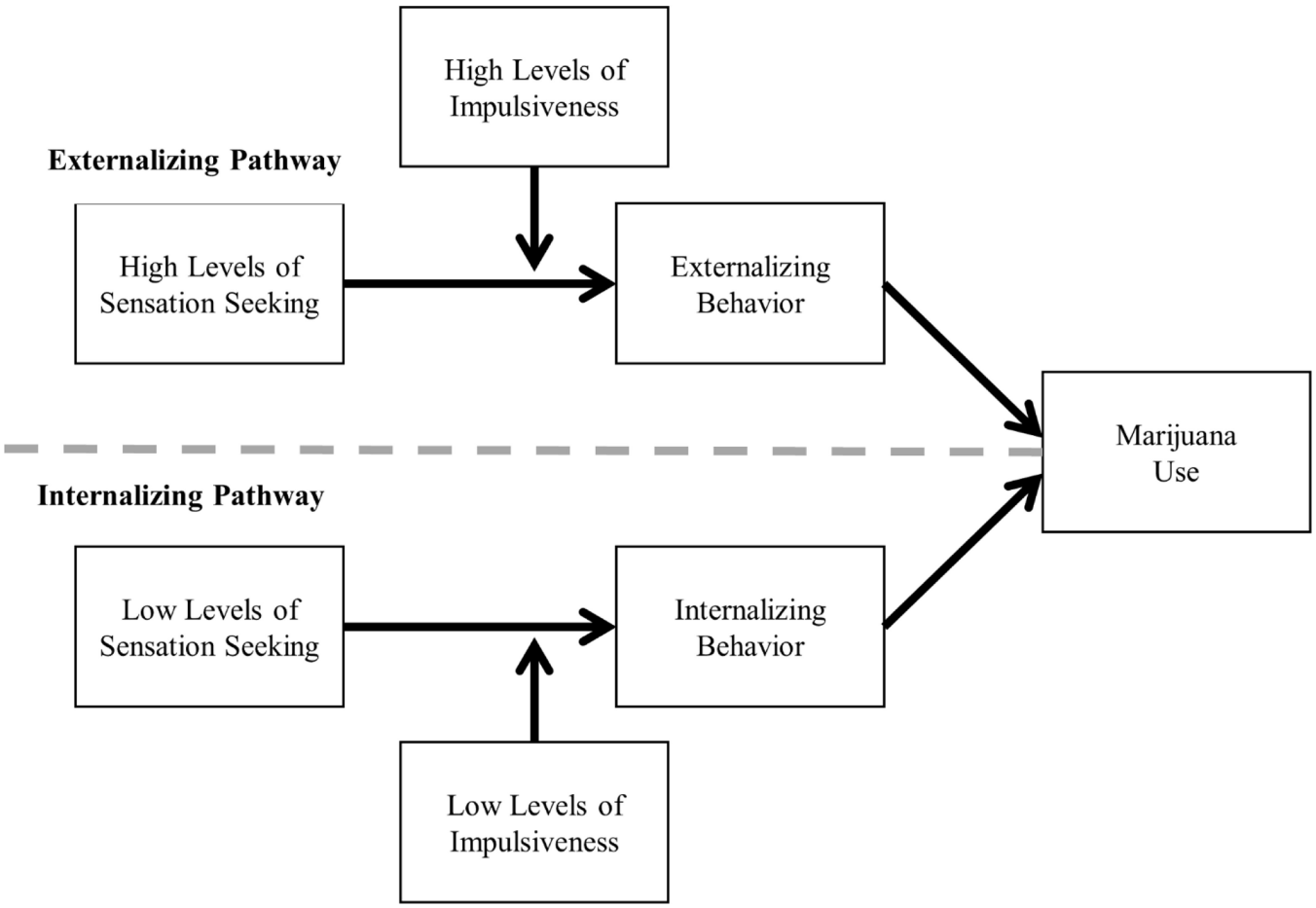

Figure 1.
Hypothetical Model

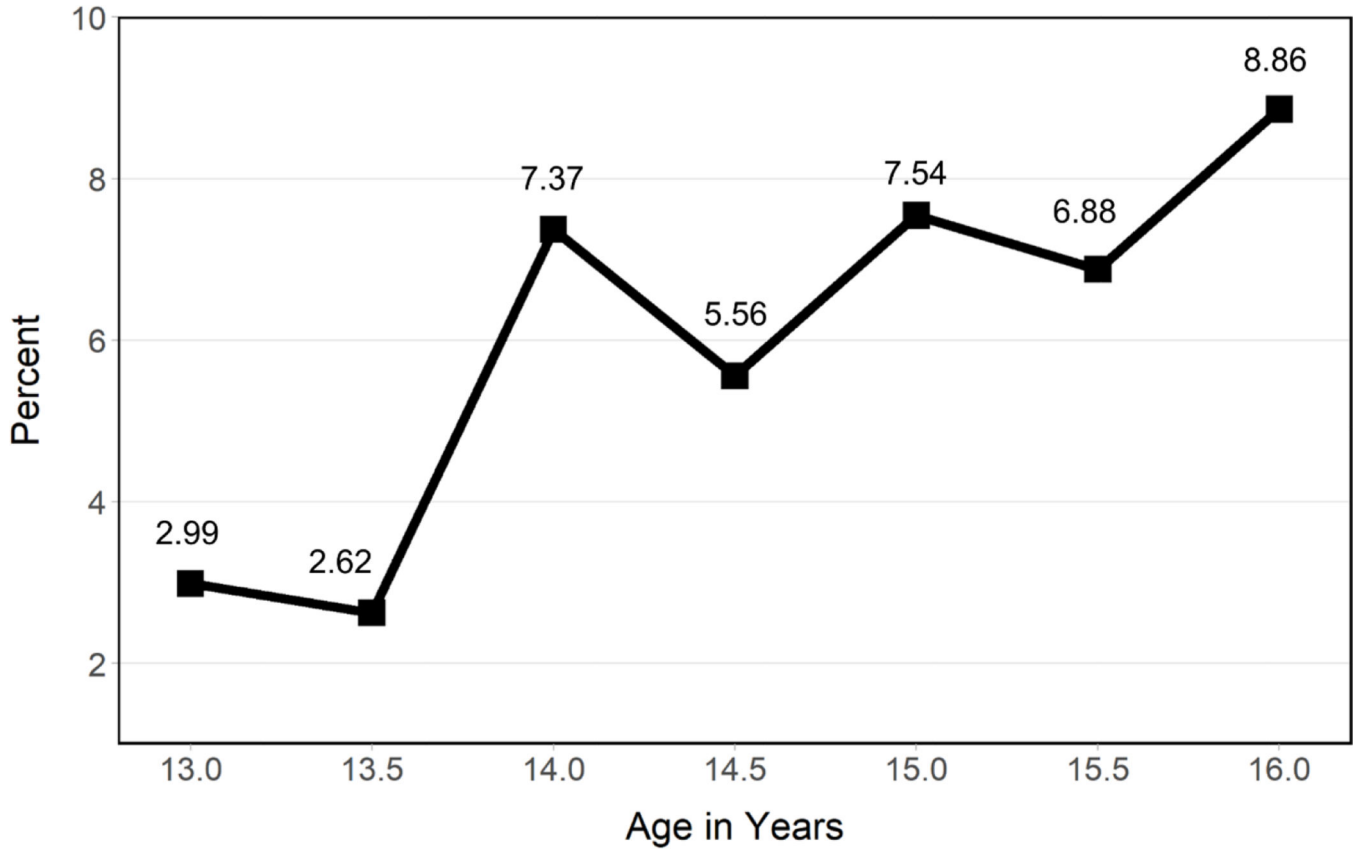

Figure 2. Unconditional Survival Curve for Marijuana Use Initiation between the Ages of 13–16

Note. Numbers can be interpreted as the percent likelihood of marijuana use initiation between the ages of 13 to 16 years old, given that use was not initiated at an earlier age. Of the 343 participants, 99 (28.9%) initiated marijuana use by age 16.

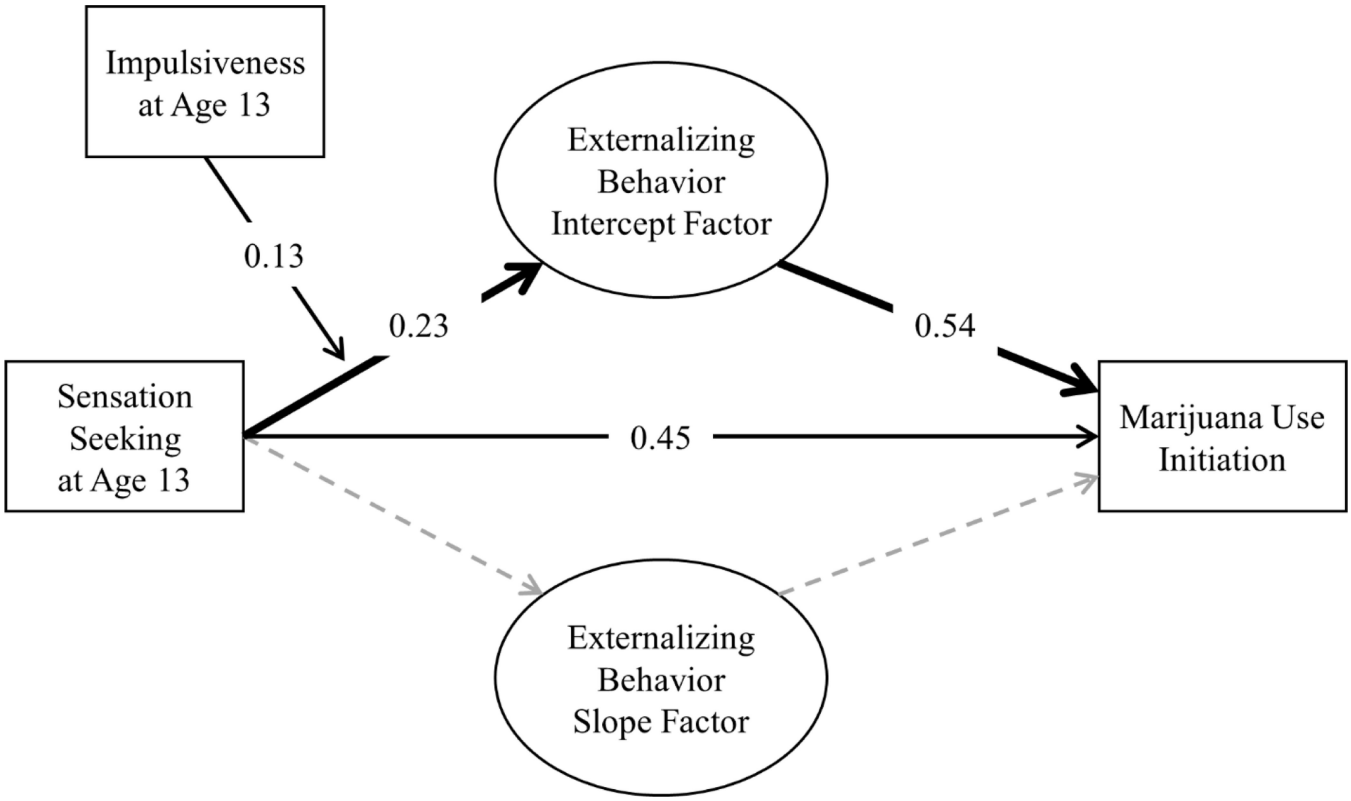

Figure 3. Moderated Mediation Model for Externalizing Behavior

Note. Unstandardized estimates shown. Thin black lines indicate significant relationships at $p < .05$; dashed grayed lines indicate non-significant relationships. Thick black lines indicate a significant indirect effect. Some paths not shown for parsimony. Impulsiveness was centered at one standard deviation above the mean and sensation seeking was mean centered. Gender was included as a covariate.

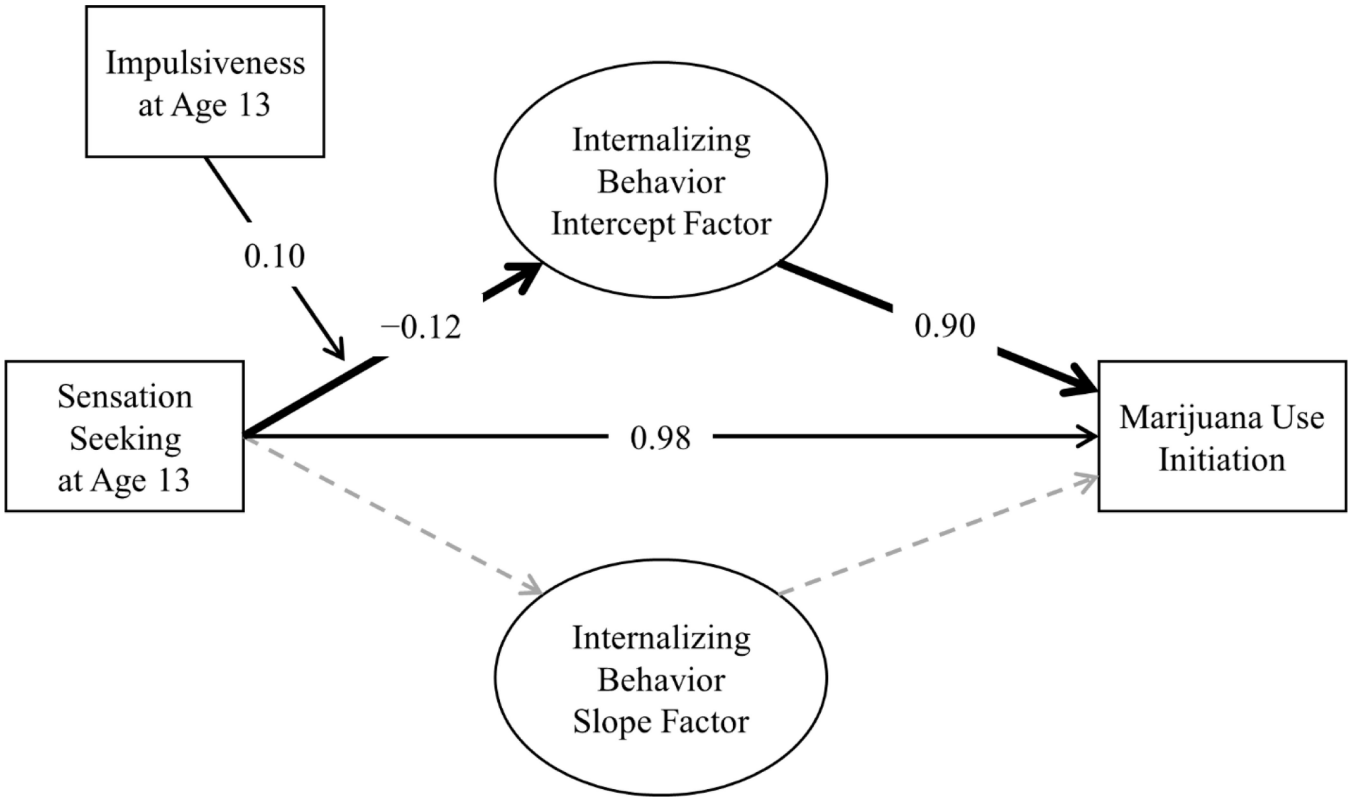

Figure 4. Moderated Mediation Model for Internalizing Behavior

Note. Unstandardized estimates shown. Thin black lines indicate significant relationships at $p < .05$; dashed grayed lines indicate non-significant relationships. Thick black lines indicate a significant indirect effect. Some paths not shown for parsimony. Impulsiveness was centered at one SD below the mean and sensation seeking was mean centered. Gender was included as a covariate.

Table 1.

Descriptive statistics and bivariate correlations of study variables

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
1. Impulsiveness at Age 13	62.16	10.46	–																	
2. Sensation Seeking at Age 13	12.72	5.14	**.28**																	
Externalizing Behavior																				
3. Age 13.0	4.41	4.97	**.26**	**.17**																
4. Age 13.5	4.27	4.98	**.23**	**.15**	**.76**															
5. Age 14.0	3.87	4.67	**.26**	**.12**	**.75**	**.78**														
6. Age 14.5	3.69	4.95	**.22**	**.18**	**.75**	**.76**	**.78**													
7. Age 15.0	4.17	5.06	**.21**	**.19**	**.75**	**.76**	**.79**	**.79**												
8. Age 15.5	3.88	5.24	**.16**	.09	**.70**	**.67**	**.75**	**.75**	**.80**											
9. Age 16.0	4.42	7.02	**.22**	**.17**	**.66**	**.64**	**.72**	**.71**	**.79**	**.82**										
Internalizing Behavior																				
10. Age 13.0	1.96	2.82	**.22**	.01	**.45**	**.37**	**.39**	**.39**	**.38**	**.37**	**.27**									
11. Age 13.5	1.83	2.93	**.17**	−.03	**.34**	**.49**	**.44**	**.36**	**.34**	**.31**	**.27**	**.62**								
12. Age 14.0	1.81	2.79	**.20**	.05	**.35**	**.36**	**.46**	**.32**	**.35**	**.27**	**.24**	**.63**	**.70**							
13. Age 14.5	1.92	3.01	**.17**	.01	**.33**	**.33**	**.37**	**.44**	**.39**	**.32**	**.36**	**.59**	**.61**	**.64**						
14. Age 15.0	2.38	3.31	**.14**	−.02	**.45**	**.40**	**.45**	**.46**	**.58**	**.46**	**.42**	**.60**	**.55**	**.56**	**.65**					
15. Age 15.5	2.02	2.84	**.17**	.02	**.44**	**.42**	**.44**	**.44**	**.51**	**.52**	**.52**	**.64**	**.59**	**.50**	**.60**	**.70**				
16. Age 16.0	2.59	4.62	**.17**	.09	**.43**	**.42**	**.44**	**.40**	**.50**	**.46**	**.60**	**.50**	**.50**	**.50**	**.61**	**.65**	**.74**			
17. Marijuana Use Initiation	29%	N/A	**.18**	**.28**	**.25**	**.26**	**.28**	**.25**	**.29**	**.25**	**.34**	**.21**	**.30**	**.22**	**.27**	**.20**	**.26**	**.26**		
19. Marijuana Use Frequency	N/A	N/A	.11	**.26**	**.24**	**.23**	**.23**	**.20**	**.21**	**.27**	**.29**	**.13**	**.20**	**.14**	**.19**	**.16**	**.22**	**.23**	**.70**	
21. Gender (0 = girl, 1 = boy)	49%	N/A	.01	**.19**	.01	−.03	−.04	−.05	−.08	.03	−.01	−.05	**−.15**	**−.16**	**−.17**	**−.21**	−.13	**−.14**	.01	.09

Note. Estimates in bold are significant at $p < .05$. For marijuana use initiation, 0 = “Did not initiate by age 16” and 1 = “Initiated by age 16.” Raw scores are reported for impulsiveness, sensation seeking, externalizing behavior, and internalizing behavior instead of transformed scores.

Table 2.

Externalizing Behavior Moderated Mediation Model

Effects for Externalizing Behavior (EB) Intercept Factor	**EST**	**SE**	**STD**	***P*<**
Intercept Factor				
Mean	1.45	0.08	1.69	.01
Variance	0.66	0.04	0.89	.01
Covariance with Slope Factor	−0.09	0.04	−0.22	.02
Direct Effects				
Impulsiveness (IMP)	0.23	0.05	0.27	.01
Sensation Seeking (SS)	0.23	0.06	0.27	.01
IMP x SS	0.13	0.05	0.21	.01
Gender (Girl = 0, Boy = 1)	−0.06	0.10	−0.04	.53
Effects for Externalizing Behavior (EB) Slope Factor	**EST**	**SE**	**STD**	***P*<**
Slope Factor				
Slope Factor Mean	−0.17	0.09	−0.32	.05
Slope Factor Variance	0.26	0.07	0.96	.01
Direct Effects				
Impulsiveness (IMP)	−0.08	0.05	−0.16	.09
Sensation Seeking (SS)	−0.08	0.07	−0.15	.27
IMP x SS	−0.08	0.06	−0.22	.14
Gender (Girl = 0, Boy = 1)	−0.01	0.08	−0.01	.97
Effects for Marijuana Use Initiation	**EST**	**SE**	**STD**	***P*<**
Impulsiveness (IMP)	0.15	0.12	0.16	.20
Sensation Seeking (SS)	0.45	0.19	0.49	.02
IMP x SS	−0.20	0.14	−0.30	.17
EB Intercept Factor	0.54	0.14	0.50	.01
EB Slope Factor	0.20	0.30	0.12	.49
Gender (Girl = 0, Boy = 1)	−0.09	0.22	−0.05	.67

Note. EST = unstandardized estimate; SE = standard error; STD = standardized estimate. Impulsiveness was centered at one SD above the mean and sensation seeking was centered at the mean.

Table 3.

Internalizing Behavior Moderated Mediation Model

Effects for Internalizing Behavior (IB) Intercept Factor	**EST**	**SE**	**STD**	***P*<**
Intercept Factor				
Mean	0.63	0.06	1.03	.01
Variance	0.33	0.03	0.89	.01
Covariance with Slope Factor	−0.02	0.03	−0.09	.41
Direct Effects				
Impulsiveness (IMP)	0.17	0.03	0.27	.01
Sensation Seeking (SS)	−0.12	0.05	−0.19	.02
IMP x SS	0.10	0.04	0.23	.01
Gender (Girl = 0, Boy = 1)	−0.18	0.07	−0.15	.01
Effects for Internalizing Behavior (IB) Slope Factor	**EST**	**SE**	**STD**	***P*<**
Slope Factor				
Slope Factor Mean	0.15	0.09	0.38	.08
Slope Factor Variance	0.16	0.08	0.99	.05
Direct Effects				
Impulsiveness (IMP)	−0.04	0.04	−0.10	.31
Sensation Seeking (SS)	0.04	0.05	0.10	.46
IMP x SS	−0.02	0.04	−0.06	.66
Gender (Girl = 0, Boy = 1)	−0.02	0.08	−0.03	.77
Effects for Marijuana Use Initiation	**EST**	**SE**	**STD**	***P*<**
Impulsiveness (IMP)	0.12	0.12	0.12	.32
Sensation Seeking (SS)	0.98	0.22	0.98	.01
IMP x SS	−0.23	0.14	−0.32	.08
IB Intercept Factor	0.90	0.20	0.55	.01
IB Slope Factor	−0.03	0.44	−0.01	.95
Gender (Girl = 0, Boy = 1)	0.03	0.23	0.02	.89

Note. EST = unstandardized estimate; SE = standard error; STD = standardized estimate. Impulsiveness was centered at one SD below the mean and sensation seeking was centered at the mean.