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Premeditation Moderates the Relation Between Sensation Seeking and Risky Substance Use Among Young Adults

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Abstract

Young adulthood is a peak period for externalizing behaviors such as substance abuse and antisocial conduct. Evidence from developmental neuroscience suggests that externalizing conduct within this time period may be associated with a "developmental asymmetry" characterized by an early peak in sensation seeking combined with a relatively immature impulse control system. Trait measures of impulsivity— sensation seeking and premeditation—are psychological manifestations of these respective systems, and multiple prior studies suggest that high sensation seeking and low premeditation independently confer risk for distinct forms of externalizing behaviors. The goal of the present study was to test this developmental asymmetry hypothesis, examining whether trait premeditation moderates the effect of sensation seeking on substance use and problems, aggression, and rule-breaking behavior. Using a cross-sectional sample of college-enrolled adults (n = 491), we applied zero-inflated modeling strategies to examine the likelihood and level of risky externalizing behaviors. Results indicated that lower premeditation enhanced the effect of higher sensation seeking on higher levels of positive and negative alcohol consequences, more frequent drug use, and more problematic drug use, but was unrelated to individual differences in antisocial behaviors. Our findings indicate that the developmental asymmetry between sensation seeking and a lack of premeditation is a risk factor for individual differences in problematic substance use among young adults, and may be less applicable for antisocial behaviors among high functioning individuals.

Keywords

sensation seeking; impulse control; substance use; externalizing behaviors; individual differences

Late adolescence and young adulthood is a developmental period characterized by the highest rates of externalizing behavior relative to any other period. Of those between 18 and 25 years of age, for instance, 40% are classified as binge drinkers (drinking 5 or more drinks in a single episode at least monthly), and 21% report current illicit drug use (U.S. Department of Health and Human Services, 2011). Aggression and delinquency—as well

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as more extreme forms of antisocial conduct such as violent criminal activity (Snyder, 2012)—also peak in adolescence and remain high in young adulthood (Loeber & Hay, 1997). Moreover, these are thought to presage more extreme antisocial behaviors and may serve as a marker for life-course-persistent antisocial conduct (Burt, Donnellan, Iacono, & McGue, 2011; Moffitt, 1993). Indeed, many—if not most—externalizing behaviors at all levels reach peak population prevalence between the ages of 16 and 25 (Steinberg, 2013).

Peaks in externalizing behavior in late adolescence and young adulthood may be explained by differential development of reward and control systems. Neurological studies suggest that reward sensitivity develops in a curvilinear pattern across puberty and young adulthood, generally peaking in midadolescence and declining through young adulthood (Galvan et al., 2006; Van Leijenhorst et al., 2010). Concurrently, structural magnetic resonance imaging (MRI) studies investigating the development of the prefrontal cortex (responsible for cognitive control over impulses) have shown that full maturation of this area follows a linear and protracted course through the third decade of life (Giedd, 2004; Gogtay et al., 2004; Paus, 2005; Somerville, Jones, & Casey, 2010). The disparate courses of development of these two systems produce a developmental asymmetry, and this asymmetry has been forwarded as an explanation for the high rates of risk behavior during adolescence (Casey, Jones, & Somerville, 2011; Steinberg, 2010). Specifically, adolescents may be particularly vulnerable to problematic engagement in externalizing behaviors because they have a higher propensity toward reward-driven behavior while their capacity to control such behavior is relatively immature.

Similar to neurological studies, studies using trait and behavioral measures suggest that adolescence reflects a time of increased sensation seeking and slowly developing impulse control. Increases in reward sensitivity are thought to increase trait sensation seeking, defined as the propensity to actively seek out novelty and excitement regardless of associated risks (Steinberg, 2013; Steinberg et al., 2008). Survey and behavioral measures of sensation seeking have shown similar patterns of development across the life span, peaking in midadolescence and generally declining after age 20 (Harden & Tucker-Drob, 2011; Romer, Duckworth, Sznitman, & Park, 2010; Steinberg et al., 2008). Evidence from cross-sectional and longitudinal studies suggest a similar course of development in survey and behavioral measures of impulse control, showing a linear increase across adolescence and young adulthood (Galvan, Hare, Voss, Glover, & Casey, 2007; Harden & Tucker-Drob, 2011; Romer & Hennessy, 2007; Steinberg, 2010).

However, it is also the case that a substantial proportion of individuals within this age range tend to abstain from externalizing behavior altogether (Romer, 2010), and that much externalizing behavior during this period may be driven by only a minority of individuals. For instance, National Household Survey (NHS) data report that among 12- to 20-year-olds, approximately 66% of drunk driving, 72% of criminal arrests, and 87% of all drug-related health problems were accounted for by only 18% of youths sampled (Romer, 2003; Biglan, Brennan, Foster, & Holder, 2004). This suggests that although adolescents and young adults do engage in problem behaviors more frequently on average, these figures may not reflect unilateral shifts in externalizing conduct, and a critical step is to translate the predictions of the developmental asymmetry model into predications about individual differences.

Specifically, this model implies that the individuals who are highest on sensation seeking and lowest on impulse control will exhibit the greatest level of multiple externalizing behaviors. That is, regardless of developmental level, asymmetry between systems may predict high risk behaviors. However, to our knowledge, few studies have tested this hypothesis.

Sensation Seeking and Risk Behavior

Sensation seeking has been a consistent predictor of externalizing behaviors in adolescent and young adult samples (Whiteside & Lynam, 2001, 2009; Zuckerman, 1979). Those high on sensation seeking may pursue risky activities as a result of a hedonic drive toward novel and rewarding activities, and measures of sensation seeking within this developmental period are indeed associated with engagement in multiple externalizing behaviors (Zuckerman & Kuhlman, 2000). Among young adults, sensation seeking is associated with greater drinking frequency (Coskunpinar, Dir, & Cyders, 2013; Stautz & Cooper, 2013), higher rates of drug use, aggression, and other forms of risky externalizing behaviors (see Roberti, 2004 for a review).

Although sensation seeking may reflect a broad propensity toward involvement in risky behavior, it is less clear whether sensation seeking confers direct vulnerability for *problematic* levels of risk behavior. For example, prior research has frequently demonstrated that there are often different predictors of substance use versus substance related problems (King, Karyadi, Luk, & Patock-Peckham, 2011; Simons, 2003; Stice, Barrera, & Chassin, 1998), particularly among young adults. Separately, relations between sensation seeking and problem behaviors may be confounded by a failure to disaggregate sensation seeking from other traits that confer risk (Whiteside & Lynam, 2009). For instance, trait measures of sensation seeking (such as the Zuckerman Sensation-Seeking Scale; Zuckerman et al., 1993) have frequently included items that reflect both a tendency toward novelty as well as a propensity toward acting on impulse, yet sensation seeking may reflect only one of a number of distinct, weakly correlated definitions of impulsivity (Cyders et al., 2007; Smith et al., 2007; Whiteside & Lynam, 2009). When controlling for these distinct factors in more recent studies, sensation seeking does independently predict risk behaviors such as the frequency of alcohol and drug use, count of sexual partners, and gambling frequency—but less consistently predicts problem levels of these activities per se (Cyders, Flory, Rainer, & Smith, 2009; Hawkins, Catalano, & Miller, 1992; Miller, Flory, Lynam, & Leukefeld, 2003; Quinn & Harden, 2013; Smith et al., 2007). This notion is supported by research that has observed no association between sensation seeking and problem behaviors above and beyond separate forms of trait impulsivity, such as urgency, lack of perseverance, and a lack of premeditation (Verdejo-García, Bechara, Recknor, & Pérez-García, 2007). Relatedly, in more recent meta analyses, sensation seeking was a moderate predictor of alcohol use (r values = 0.27 and 0.28), but was less strongly related to problem use (r values = 0.17 and .24; Coskunpinar et al., 2013; Stautz & Cooper, 2013). Whiteside and Lynam (2009) have further noted that sensation seeking may be associated with alcohol-related use and problems in adolescents (Bates & Labouvie, 1995; Wood, Cochran, Pfefferbaum, & Arneklev, 1995) but not in older adults (Lejoyeux, Feuché, Loi, Solomon, & Adès, 1998; Virkkunen et al., 1994), which may imply a potential role for psychological maturity to

buffer the risk of sensation seeking among adults relative to younger populations. Taken together, these observations suggest that although a relation between sensation seeking and problem externalizing behaviors may exist, the nature of this relation may be moderated by separate contextual and psychological risk factors.

Impulse Control as a Moderator

One potential moderator implied by the developmental asymmetry model—and a frequent predictor of risk behavior consequences—is trait impulse control. Impulse control has frequently been operationalized as the ability to think before acting and plan ahead (Whiteside & Lynam, 2001, 2009; Wills, Ainette, Stool-miller, Gibbons, & Shinar, 2008), and is commonly referred to as planning, premeditation, or "good self-control," with similar or identical items used as indicators of these parallel constructs (King, Patock-Peckham, Dager, Thimm, & Gates, 2014; Sharma, Markon, & Clark, 2014). A wide body of personality literature suggests a direct and inverse relation between impulse control and problem behaviors. For instance, low impulse control predicts higher rates of externalizing and conduct problems (Luengo, Carrillo-de-la-Peña, Otero, & Romero, 1994; Monahan, Steinberg, Cauffman, & Mulvey, 2009; Whiteside & Lynam, 2009); alcohol problems and heavy drinking (Coskunpinar et al., 2013; Stautz & Cooper, 2013); and drug use (Verdejo-García, Lawrence, & Clark, 2008), among others. These relations further persist above and beyond other known dispositional risk factors, such as sensation seeking, perseverance, and emotion-based impulsivity (i.e., urgency; Smith et al., 2007; Whiteside & Lynam, 2009).

More recent evidence suggests that impulse control (or a lack thereof) can also buffer (or enhance) the effects of other known risk factors for externalizing problems, though the construct has frequently been quantified heterogeneously. For instance, Wills and colleagues (2008) operationalized "good self-control" as a combined measure of planning and problem solving, and found that high levels of this trait reduced the effect of risk factors such as peer use and family events on frequency of cigarette, alcohol, and marijuana use in adolescents. Related findings have been observed in a daily diary study of college students (Neal & Carey, 2007), in which higher scores on the Eysenck Impulsiveness Scale (Eysenck, Pearson, Easting, & Allsopp, 1985)—a broad measure of acting without forethought and making hasty decisions—enhanced the relation between daily intoxication and the likelihood of experiencing consequences as a result of drinking. In a more recent study examining premeditation—or the tendency to think before acting—as a moderator, higher levels of the trait buffered the effect of depressive symptoms in predicting levels of alcohol problems, and enhanced this relation at low levels of premeditation (King et al., 2011).

Although numerous prior studies have tested the unique effects of impulse control and sensation seeking in the prediction of risk behaviors (e.g., Malmberg et al., 2010; Quinn & Harden, 2013; Roberts, Peters, Adams, Lynam, & Milich, 2014), few studies to date have tested interactions between these traits in predicting risk behaviors, and these studies have not reported evidence for the developmental asymmetry proposed in the present study (i.e., *high* sensation seeking and *poor* impulse control). For instance, in assessing levels of risky sexual behaviors, impulsive decision-making—a measure that encompasses aspects of

both negative urgency and planning—was less strongly associated with sexual activity while intoxicated at higher levels of sensation seeking, suggesting that being high on *either* trait is risky, though being high on *both* traits predicts no greater risk (Charnigo et al., 2013). A separate study using a measure of self-control that included items measuring "breaking habits, resisting temptation, and keeping good self-discipline" (Tangney, Baumeister, & Boone, 2004, p. 275) found that *good* self-control had a buffering effect on unprotected sex and with a monogamous partner, as well as on alcohol problems among heavy drinkers, at *lower* levels of sensation seeking, but this study did not report whether the co-occurrence of poor self-control and high sensation seeking conversely predicted higher risk (Quinn & Fromme, 2010). By using measures of sensation seeking and impulse control that are clearer analogues of reward and control systems proposed by the developmental asymmetry model that also have well-established psychometric properties (e.g., Whiteside & Lynam, 2001), we aim to test whether the co-occurrence of high sensation seeking and poor impulse control characterizes synergistic risk for externalizing behaviors across multiple forms of externalizing conduct.

In the present study, we examined the moderating role of impulse control—operationalized in the present study as premeditation—on sensation seeking in predicting indicators of high risk substance use and delinquent behavior in a cross-sectional cohort of college-age young adults. Based on prior studies of known trait predictors of externalizing behavior, we expected that sensation seeking would likely predict externalizing behavior engagement (Magid & Colder, 2007), and a lack of premeditation would be associated with both engagement and more problematic levels of such behaviors (Smith et al., 2007; Stautz & Cooper, 2013). However, a lack of premeditation may additionally reflect a deficit in regulating reward drive, and may further have an enhancing effect on sensation seeking in predicting both frequency and problem levels of externalizing behavior. As such, we hypothesized that the co-occurrence of risk levels of these traits—that is, high sensation seeking and a lack of premeditation—would further characterize those with the most problematic levels of externalizing behavior.

Method

Participants

Participants (n = 491) were undergraduate students in Psychology at the University of Washington who received course credit for survey participation. Participants completed the study in a single in person computer assisted interview session. A total of 34 participants were removed from antisocial behavior analyses due to missing data in criterion variables. Excluded participants did not significantly differ from retained participants in age (b =−.37, p = .08), gender, $\chi^2(1\ df) = .55$, p = .46, or Asian American versus non-Asian American ethnicity, $\chi^2(1\ df) = .31$, p = .57. A total of 56.6% of the participants were female. Approximately 55% were of Caucasian ethnicity, 33% of Asian or Pacific Islander ethnicity, and the remaining 12% reported being of other ethnicities. Participant age ranged from 18 to 24 with a median age of 19; 86% of participants were between 18 and 20.

Measures

Covariates.—Gender, Asian/Asian American ethnicity, and age and were entered into the models as covariates to control for potential demographic differences in risk behavior outcomes. Gender was coded 0 for females and 1 for males. Because of the relatively high proportion of Asian American participants in our sample, and the lower mean prevalence rates of alcohol and drug use among Asian American populations, we included Asian American ethnicity as a covariate, coded as 1 = Asian/Pacific Islander ethnicity, and 0 for all other ethnicities. Although prevalence rates of substance use and risk behavior may be similarly lower for other minority groups, only a small proportion of participants reported minority status (e.g., 1.8% of the sample were African American, 4.9% were Hispanic/Latino) and meaningful comparisons for these groups could not be made. Current age was measured with a single self-report item.

Sensation seeking and premeditation.—Premeditation (11 items) and sensation seeking (12 items) were measured via self-report from the Urgency, Premeditation, Perseverance and Sensation Seeking (UPPS) Impulsive Behavior Scale (Whiteside & Lynam, 2001). Participants were instructed to rate how well each statement described them. Response options for all facets were on a 5-point Likert scale ranging from *not at all* to *very much*. Sample premeditation items included “My thinking is usually careful and purposeful” and “I don’t like to start a project until I know exactly how to proceed.” Sample sensation seeking items included “I like sports and games in which you have to choose your next move very quickly” and “I would enjoy fast driving.” Facet scores were computed by taking the mean of the items for that facet. Internal consistency coefficients were high for both premeditation and sensation seeking (α =.87, α = .91, respectively). We coded premeditation such that higher scores reflected higher levels of premeditation, and higher sensation seeking scores reflected higher sensation seeking. Consistent with previous findings (e.g., Cyders et al., 2009), sensation seeking and premeditation were only modestly correlated in the present sample (r =−.26).

Substance Use

Alcohol use.—Participants self-reported their frequency and quantity of alcohol consumption in the past year with four items. Frequency was assessed using two items (one for beer/wine and one for hard liquor) with responses ranging from *never* to *every day*. Quantity was assessed with two items (one for beer/wine, one for hard liquor) asking how much the participant drank in the past year on a “typical” occasion, ranging from 1 to 9 or more drinks per occasion. A single alcohol use variable was computed as the sum of the products of the beer/wine quantity *frequency and the hard liquor quantity*frequency variables.

Alcohol consequences.—We assessed the consequences of alcohol use in two ways. First, to assess the immediate risk posed by alcohol use, participants self-reported on 39 negative consequences related to alcohol use in the past year. A total of 27 items were from the Young Adult Alcohol Problems Screening Test (YAAPST; Hurlbut & Sher, 1992), including items such as “Have you ever been arrested for drunk driving, driving while intoxicated, or driving under the influence of alcohol?,” “Have you ever felt like you

needed a drink just after you'd gotten up?," and "Have you ever had "the shakes" after stopping or cutting down on drinking?," reflecting traditional symptoms of alcohol abuse and dependence. Twelve negative consequences were taken from Mallett, Bachrach, and Turrisi (2008) to reflect alcohol consequences that may be common to young adults, but may or may not be traditionally represented in indices of alcohol disorders. These items include "Have you ever urinated on yourself because of your drinking?," "Have you ever been embar-rassed socially because of your drinking?," or "Have you ever lost personal items because of your drinking?"

We also measured positive alcohol-related consequences, to assess for potentially reinforcing effects of alcohol use that might presage later escalations in drinking (Logan, Henry, Vaughn, Luk, & King, 2012; Park, Kim, & Sori, 2013). We used 14 items from the Positive Drinking Consequences Questionnaire (PDCQ; Corbin, Morean, & Benedict, 2008), and included items such as "Have you ever stood up for a friend or confronted someone who was in the wrong while drinking?" and "Have you ever felt especially confident that other people found you attractive while you were drinking?"

For both scales, 10 response options ranged from *never or not in the past year* to *1 time in the past year* to *40 or more times in the past year*. We computed pseudocounts for negative and positive alcohol consequences, reflecting the sum of past year perceived frequency of these alcohol-related consequences. We computed coefficient alphas as a measure of consistency among items for each of these scales in order to assess whether items for each reflect an underlying construct of alcohol dyscontrol (e.g., Hurlbut & Sher, 1992; Read, Merrill, Kahler, & Strong, 2007); alphas for these scales were .94 and .92, respectively.

Drug use.—Illicit drug use was self-reported using 11 items measuring the frequency of using marijuana, inhalants, cocaine, stimulants, club drugs, hallucinogens, opiates, and steroids within the past year. The seven response options for past year consumption ranged from *not at all* to *everyday*. Total past year drug use was computed as a sum of drug use frequency across all the items. Reliability for this measure was .62. Because 31.4% of all participants reported marijuana use, and few reported use of illicit substances other than marijuana (17.1%), we also examined the single-item frequency of past year marijuana use as a separate risk outcome.

Drug consequences.—Participants self-reported the frequency of negative drug consequences experienced within the past year. A total of 39 items assessed the number of times a consequence occurred in the past year, with 10 categories ranging from *never or not in the past year* to *1 time in the past year* to *40 or more times in the past year*. Items were derived from the YAAPST (Hurlbut & Sher, 1992) and Mallett et al. (2008), and were modified to apply to drug use outcomes. Sample items included "Have you gotten into physical fights when using drugs?" and "Have you ever been arrested for driving under the influence of drugs (besides alcohol)?" Similar to the alcohol consequences variable, we computed a pseudocount variable by summing across all 39 consequence items. Reliability for this scale was .88.

Antisocial Behavior

Aggression and rule-breaking behavior.—Aggression and rule-breaking behaviors were measured using the Achenbach Adult Self Report (ASR; Achenbach & Rescorla, 2003). These subscales consisted of 15 and 14 self-reported items, respectively, ranging on a 3-point scale from *not true* to *very true or often true*. Sample aggressive behavior items included “I get along badly with my family” and “I get in many fights.” Sample rule-breaking behavior items included “I hang around people who get in trouble” and “my behavior is irresponsible.” Subscale scores were computed as means, and were transformed into *T* scores based on national norms (Achenbach & Rescorla, 2003). Reliability for these scales were .79 and .77, respectively.

Results

Analytic Strategy

Our outcome measures of annual drug and alcohol use frequency, drug and alcohol consequences, and externalizing behavior scores were highly overdispersed, with a substantial proportion of the sample reporting no occurrence of many risk-taking behaviors and few reporting at or near the maxima of these outcomes (see Table 1 for summary). As such, we explored a variety of analytic methods for modeling nonnormally distributed data. Although sum scores of ordinal data (such as self-report frequency of past year alcohol-related consequences collected on an ordered categorical scale) do not reflect true counts, their distributions behaved very much like zero-inflated count distributions, in that there were excessive zeroes, many participants with low scores, and very high skew with very few high-scoring participants. Although modeling approaches for treating ordinal data as counts exist for single-item indicators (McGinley, Curran, & Hedekr, n.d.), these methods have not yet been extended to sums of ordinal items (McGinley, personal communication). Thus, we modeled these data treating outcomes as “pseudocount” data (e.g., counts of past year alcohol and drug use and consequences), analyzed using zero-inflated Poisson (ZIP), zero-inflated negative binomial (ZINB), and negative binomial hurdle modeling (NBH) for highly zero-inflated count data (Atkins, Baldwin, Zheng, Gallop, & Neighbors, 2013; Bandyopadhyay, DeSantis, Korte, & Brady, 2011). These zero-inflated strategies are used to analyze outcome variables in two separate regression models: a logistic regression predicting the logged-odds of a binary zero versus nonzero value of the outcome, and a separate model predicting counts among those reporting nonzero values of the outcome variable. In the present context, this allowed us to predict the relative likelihood of experiencing any risk behavior compared with experiencing none at all, and separately, the “count” of these outcomes among those engaging in these behaviors. We tested all substance use and substance-related problem outcomes assuming a normal (Gaussian) distribution as a baseline model, then specified models using ZIP, ZINB, and NBH. Final model selection was determined by comparing Akaike information criteria (AIC) and Bayesian information criteria (BIC), and were tested formally using likelihood ratio tests for nested models and Vuong tests for non-nested models (Vuong, 1989). Models with lower information criteria were selected when likelihood tests were nonsignificant. Based on these results, NBH was selected for models of past year alcohol, drug, and marijuana use, and ZINB was used to model negative and positive drinking consequences as well

as drug use consequences. For highly skewed continuous measures of aggression and rule-breaking behavior, semicontinuous (or two-part) regression was used for analysis (Gottard, Stanghellini, & Capobianco, 2013), and coefficients produced by this modelling strategy are interpreted similarly to NBH. Comparisons of model fit using likelihood ratio and Vuong tests for each outcome are provided in Table 2.

We included age, Asian American ethnicity, and gender as covariates to control for expected group differences in problem risk behaviors. We probed significant interactions using the pick-a-point approach (Aiken & West, 1991). Probing interactions between sensation seeking and premeditation were conducted at high (+1 *SD*), mean, and low (−1 *SD*) levels of premeditation. All main predictors within the models were centered at zero to simplify the interpretation of regression coefficients (Cohen, Cohen, West, & Aiken, 2003). Effect sizes are reported as odds ratios (OR) in the likelihood portions of our models and rate ratios (RR) in the count portions, which refer to factor increases in the odds of a dichotomous outcome, and factor increases in the predicted count outcome resulting from single-unit increases in predictor values, respectively (Atkins et al., 2013). Descriptive data analyses were performed using Statistical Packages for the Social Sciences (SPSS) 20.0, and all other analyses were performed using R (R Development Core Team, 2014). Zero-inflated count models were estimated using package “pscl” (Zeileis, Kleiber, & Jackman, 2008), and semicontinuous outcomes using “mhurdle” (Carlevaro, Croissant, & Hoareau, 2012).

Premeditation as a Moderator of Sensation Seeking on Alcohol Use and Consequences

We first examined the effects of sensation seeking, premeditation, and their interaction on the quantity and frequency of past year alcohol use, negative alcohol consequences, and positive alcohol consequences. Results from these models are reported below and summarized in Table 3.

Higher sensation seeking increased the likelihood of past year alcohol use, while premeditation decreased in the likelihood of use. In the count portion of our model, premeditation was associated with lower levels of use among alcohol-using participants. No other effects were significant.

Similar to alcohol use, sensation seeking increased the likelihood of experiencing negative alcohol consequences, and premeditation decreased the likelihood of consequences. The effects on positive alcohol consequences were similar: higher sensation seeking was associated with a higher likelihood of positive consequences, and higher premeditation decreased the likelihood.

Moreover, we observed a significant interaction between sensation seeking and premeditation predicting the counts of both negative and positive alcohol consequences. At mean levels of sensation seeking, premeditation was associated with fewer positive and negative consequences in the count portion of our model. Further, sensation seeking was associated with alcohol consequences when premeditation was low, but was unrelated to consequences when premeditation was at mean or high levels. When premeditation was low, a unit increase in sensation seeking was associated with a nearly significant 15% increase in negative consequences, $RR = 1.15$, $p = .057$, 95% CI [1.00, 1.34], and a 12% increase in

positive consequences, *RR* = 1.12, *p* = .036, 95% CI [1.01, 1.25]. Figure 1 illustrates these effects.

Premeditation as a Moderator of Sensation Seeking on Drug Use and Consequences

We next tested premeditation as a moderator of the effects of sensation seeking on drug use and consequences. Results are reported below and in Table 4.

Similar to the effects of alcohol outcomes reported above, sensation seeking was associated with a higher likelihood of drug use, while premeditation was associated with a lower likelihood. Results for the likelihood of marijuana use were similar for both sensation seeking and premeditation. Although neither sensation seeking nor premeditation predicted the level of drug use alone, we found evidence of an interaction. When premeditation was low, a unit increase in sensation seeking was associated with a 69% increase in the predicted count of past year drug use, *RR* = 1.69, *p* = .002, 95% CI [1.21, 2.38], but predicted no change in drug use when premeditation was at mean and high levels. These effects are shown in Figure 1. We did not observe this interaction when marijuana was a sole outcome.

For our drug consequences outcome, results largely mirrored those reported for drug use. Higher sensation seeking was associated with a higher likelihood of consequences, and premeditation was associated with a lower likelihood, and we observed an interaction predicting levels of drug consequences. At mean and high levels of premeditation, sensation seeking was unrelated to the level of drug consequences; however, when premeditation was low, sensation seeking trended toward an association with drug consequences, predicting a 28% increase in the count for every unit change, *RR* = 1.28, *p* = .058, 95% CI [0.99, 1.65], but this pattern was not significant—and in fact trended toward the reverse—at higher levels of premeditation, *RR* = 0.75, *p* = .096, 95% CI [0.54, 1.05]. That is, sensation seeking trended toward being protective against higher drug consequences when premeditation was high, but was a risk factor when premeditation was low. Figure 1 illustrates these effects.

Premeditation as a Moderator of Aggression and Rule-Breaking Behaviors

Finally, we tested the effects of sensation seeking, premeditation, and their interaction on aggression and rule-breaking behavior (see Table 5 for summary). Unlike our substance use outcomes, we found no main effects or interactions for aggression. Sensation seeking was a risk factor for higher levels of rule-breaking behavior, and similarly predicted a greater likelihood of reporting any rule-breaking behavior. Premeditation was unrelated to rule-breaking behavior among those reporting any rule-breaking behavior, but was protective against the likelihood of exhibiting such behavior. The interaction between sensation seeking and premeditation was not significant.

Discussion

The goal of the present study was to test whether the interaction between sensation seeking and premeditation was associated with externalizing behaviors in young adulthood. Our main effect findings yielded consistent results: higher sensation seeking characterized individuals who were more likely to be alcohol and drug users within the past year, while premeditation characterized those who were less likely to use alcohol and drugs

and those who drank less among alcohol-initiated participants. Moreover, our results provided moderate support for the developmental asymmetry hypothesis among substance use outcomes: a combination of high sensation seeking and a lack of premeditation characterized those with the highest rates of drinking consequences, drug use, and drug consequences, suggesting that an asymmetry between high sensation seeking and a lack of premeditation may be a critical risk indicator for heightened substance abuse among young adults.

Although previous findings have reported mixed or weak relations between sensation seeking and problematic drinking (Coskunpinar et al., 2013; Smith et al., 2007; Stautz & Cooper, 2013), our findings clarified and extended these results: the relation between sensation seeking and problem levels of drinking may be stronger among individuals who also lack premeditation. Importantly, the effects were similar whether we examined negative alcohol consequences, which likely reflect risky behavior that directly results from alcohol use, or positive alcohol-related consequences, which may serve as a marker of those at higher risk for heavier alcohol involvement (Park et al., 2013). The present findings were the first to provide direct evidence for these synergistic associations. One prior study failed to detect this interaction (Quinn & Fromme, 2010). It may be that using modeling strategies that address zero inflation and overdispersion in outcomes provided increased sensitivity to detect these effects. Second, we used trait predictors designed to measure orthogonal constructs of impulsivity (Whiteside & Lynam, 2009) that may be more appropriate psychological analogues to the neurobiological dual systems model proposed by Steinberg (2010). Third, we did not covary for drinking quantity/frequency to avoid the concern of collinearity between drinking levels and drinking consequences.[1] Although some research suggested that sensation seeking increased the risk of substance related problems merely by increasing substance use frequency (Magid & Colder, 2007; Quinn & Fromme, 2010), our previous work suggested that high sensation seekers experience more consequences for a given level of alcohol use (King et al., 2011). Future research should attempt to disaggregate the mediating/moderating role of alcohol use more directly.

The present study was also, to our knowledge, the first to test this interaction predicting drug use. Multiple prior studies have reported relations between multidimensional constructs of trait impulsivity and multiple forms of drug use, including heavy ecstasy use (Parrott, Milani, Parmar, & Turner, 2001), cocaine use (Coffey, Gudleski, Saladin, & Brady, 2003; Moeller et al., 2002), and heroin use (Kirby, Petry, & Bickel, 1999; Madden, Petry, Badger, & Bickel, 1997), while sensation seeking has been previously associated with stimulant use (Leland & Paulus, 2005) and heroin dependence (Dissabandara et al., 2014). The present findings add to this literature: risk levels of both traits predicted a higher probability of drug use engagement, and their co-occurrence was synergistically associated with more polydrug use and problems. Moreover, although marijuana use was the single most commonly used illicit substance in our sample and both sensation seeking and premeditation predicted

[1]Negative and positive drinking consequences were highly correlated with alcohol use in the present sample (r values = 0.83 and 0.81, respectively). When use was included as a covariate, fitted probabilities for consequences were numerically 0 or 1 in the zero inflation portion due to perfect collinearity between use and consequences, and reliable estimates for predictors of interest could not be obtained.

higher likelihoods of having used marijuana, we did not find evidence of significant main or interactive effects among marijuana-using college students. Although some previous findings have observed main effects of trait impulsivity on problematic marijuana use (e.g., Day, Metrik, Spillane, & Kahler, 2013), still others have failed to observe these relations (Butler & Montgomery, 2004; Dvorak & Day, 2014; Simons, Neal, & Gaher, 2006; Verdejo-García et al., 2008). It is possible that these and the present results may be confounded by distinctions in motivations toward marijuana use versus other illicit substances. Although young adults may use certain substances primarily to seek stimulation (e.g., MDMA; Peters, Kok, & Abraham, 2008), a proportion of marijuana users may separately use to cope with negative emotional states such as anxiety (Bonn-Miller, Zvolensky, & Bernstein, 2007); thus, the relation between marijuana use, sensation seeking, and premeditation may be particularly attenuated by separate predictors of use such as coping motives, and we encourage future studies to address these relations. Moreover, we encourage others to address transactions and interactions between sensation seeking and premeditation predicting patterns of drug use in a longitudinal sample; some prior research suggests that impulsivity may be an earlier marker for drug abuse while sensation seeking a product of abuse (Ersche, Turton, Pradhan, Bullmore, & Robbins, 2010), yet the precise nature of these relations has yet to be investigated.

The present dual systems framework hypothesizes that the developmental asymmetry explains the relative peak in criminal and antisocial conduct such as robbery, burglary, and forcible rape among young adults (Steinberg, 2013), among other risky behaviors. Although relations between aggressive behavior and poor impulse control and sensation seeking have been reported previously (Monahan et al., 2009; Wilson & Scarpa, 2011), we did not observe a synergistic interaction between these traits. There may be two reasons why we did not observe this result. First, the present data was drawn from a community sample of college-enrolled young adults, with very few respondents reporting clinically relevant levels of aggression (3.1%) or rule-breaking behavior (7.7%). Future research investigating this developmental asymmetry in more vulnerable populations, such as among incarcerated samples, may find evidence among “riskier” young adults exhibiting higher rates of antisocial conduct. Second, our measures of self-reported aggression and rule-breaking behavior may not have been sufficiently sensitive constructs to properly measure “antisocial” behavior in this population. Although these measures are considered ecologically valid (Achenbach et al., 2003), they may not capture the range of subthreshold antisocial behavior that may be observed in non- or preclinical populations. Relatedly, measures separate from antisocial conduct that are more relevant to lower-level risky behavior in college may yield more promising results, such as risky sexual conduct (Charnigo et al., 2013) and risky driving (Pharo, Sim, Graham, Gross, & Hayne, 2011).

Our findings indicate that sensation seeking increases the likelihood of engaging in multiple forms of externalizing behaviors and is also a *conditioned* risk indicator of externalizing problems (i.e., is unrelated directly to levels of substance use unless coupled with a lack of premeditation). These findings are consistent with a more nuanced perspective of the trait (e.g., Ravert et al., 2013): sensation seeking may confer risk for engaging in novel (and sometimes risky) behaviors, but may not be a direct indicator of risk for consistent and problematic engagement in itself. Moreover, some prior research has observed positive

developmental outcomes among sensation-seekers, such as higher IQ (Bayard, Raffard, & Gely-Nargeot, 2011; Raine, Reynolds, Venables, & Mednick, 2002), psychological well-being (Ravert et al., 2013), and age-related improvements in the ability to delay gratification (Romer, 2010), suggesting that a propensity toward novelty may be adaptive and yield positive results in certain environments. We found marginal evidence of this in the present study among those experiencing drug consequences: the nature of the interaction between sensation seeking and premeditation was such that the effect of sensation seeking on drug consequences reversed in its direction depending on level of premeditation, implying that high levels of these traits might constitute protection in the context of problematic drug use. It may be the case that separate contextual factors drive sensation-seekers toward more adaptive forms of reward-driven behaviors (Romer & Hennessy, 2007); this interpretation warrants caution given that this effect was not the focus of the present analyses, though we encourage this question be addressed directly in future research.

Our results reflect an estimate of the associations between developmental asymmetry and externalizing behaviors during young adulthood. It may be that this interaction differs across development. Several factors highlight the importance of considering development in predicting externalizing behaviors from asymmetry. First, although longitudinal reports indicated that sensation seeking remains high through the mid-twenties (Harden & Tucker-Drob, 2011), studies suggested that sensation seeking peaks earlier in development, specifically during midadolescence (Romer et al., 2010; Steinberg et al., 2008). Given the protracted and linear development of impulse control, asymmetry between these two systems might therefore be greatest on average during this developmental period. Second, engaging in substance use earlier in development is less normative than drinking at older ages and may reflect greater propensity toward delinquency than college-age drinking. Evidence has indicated that earlier initiation and problematic use within adolescence were markers for substance disorder throughout the life span (King & Chassin, 2007; McGue & Iacono, 2005), and we might expect that asymmetry within this period is a particularly critical indicator of delinquency both within the period and in later life. Third, although we did not find evidence of an association between developmental asymmetry and antisocial behavior among young adults, developmental asymmetry may capture antisocial behavior that is limited to adolescence (Moffitt, 1993) and largely desists by young adulthood (Steinberg, 2013). Taken together, the effect of the developmental asymmetry on multiple forms of delinquency may be stronger during adolescence on average and may predict other period-specific externalizing behaviors, though translation of these population-level predictions to examining individual differences within adolescence remains unexplored.

The present study provides evidence that the dual systems framework does predict individual differences in problematic substance use among college-enrolled adults (Strang, Chein, & Steinberg, 2013). The present study has a number of strengths, including the application of advanced quantitative methods to appropriately specify models for low base-rate risk behavior and the application of psychometrically validated measures of trait impulsivity. The present study also has a number of limitations that should be considered. First, our results are cross-sectional, and precise causal inferences between trait impulsivity and risk behavior cannot be made. For instance, substance use may result in an increase in impulsiveness or sensation seeking over time (Ersche et al., 2011; Littlefield, Vergés, Wood, & Sher,

2012), and correlational data in either cross-sectional or longitudinal designs is not sufficient for ensuring causal precedence of impulsive traits. Second, as mentioned previously, these results represent findings among a community sample of college-enrolled young adults; two critical future directions include extending these findings to younger adolescent populations—among whom the developmental asymmetry is theoretically paramount in predicting externalizing and other risk behavior—as well as vulnerable populations such as clinical samples and incarcerated youth. Third, the present study sought to test the specific interaction between trait measures of sensation seeking and premeditation, but other dispositions toward impulsive behavior may explain additional variance in substance abuse outcomes, or may buffer or enhance the effects observed in the present study. For instance, positive and negative urgency— which reflect dispositions toward positive and negative emotion-based rash action—are critical and independent determinants of problem behaviors in themselves (Cyders & Smith, 2007) and may similarly interact with impulsive traits specified in the present study. Relatedly, we encourage future research to examine the developmental asymmetry model using behavioral measures of these constructs as well. Although support for direct overlap between laboratory-based behavioral measures and self-reported trait measures is modest, both methods of measuring these constructs have independently predicted externalizing behavior outcomes (Cyders & Coskunpinar, 2011; Sharma et al., 2014). Thus, examining interactions between reward sensitivity and impulse control measured using laboratory tasks may provide additional support for the developmental asymmetry model. Our findings underscore that dispositions toward impulsive behavior are critical in the assessment, prevention, and intervention of risk-taking behavior, and that examining the synergistic impact of these traits can provide additional insight in understanding individual differences in problem behaviors.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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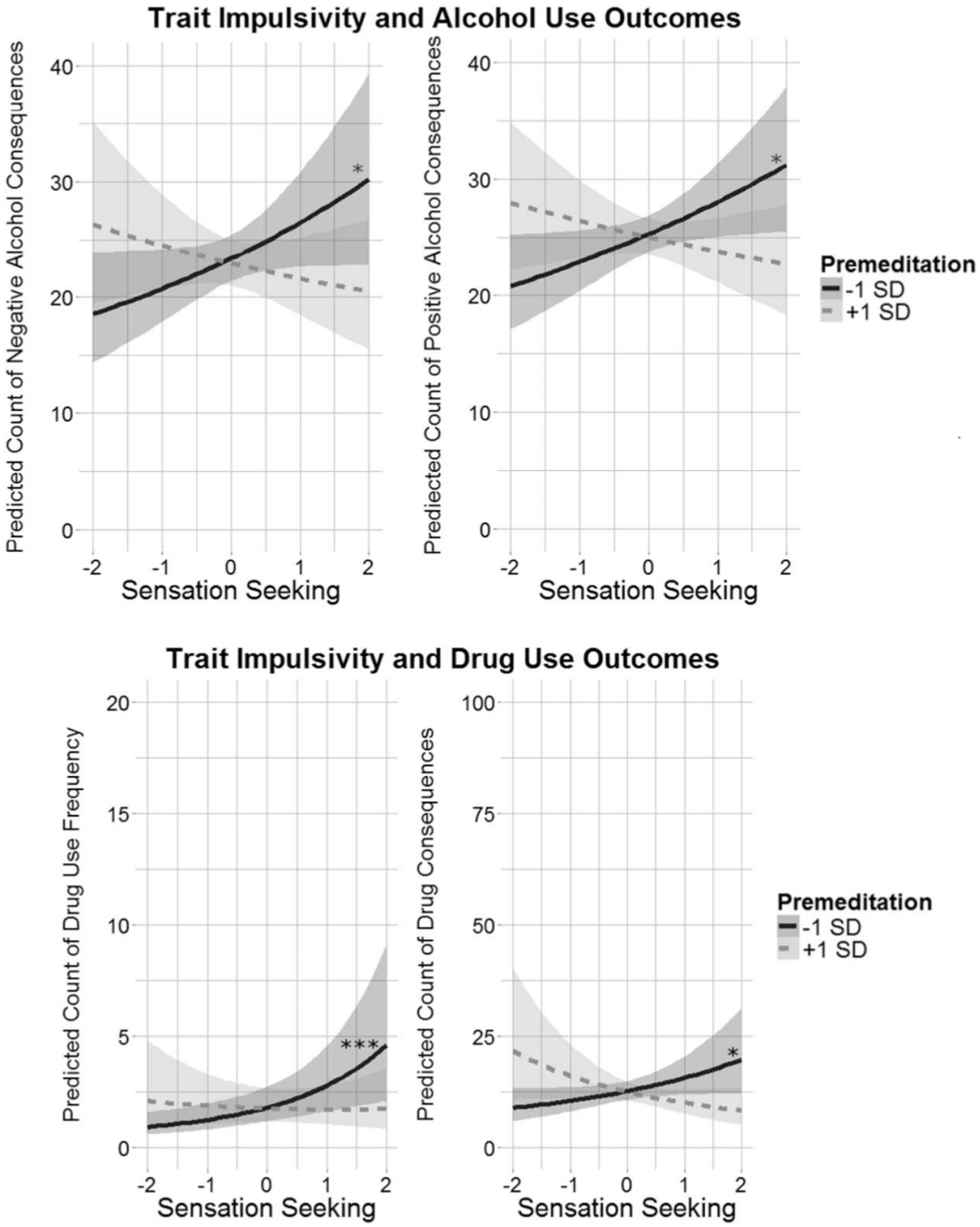

Figure 1.

The synergistic effects of sensation seeking and premeditation on substance use outcomes. Lines represent relations between sensation seeking and alcohol consequences at low (−1 *SD*) and high (+1 *SD*) levels of premeditation. Shaded regions represent simulated 95% confidence intervals. *$p \leq .05$. **$p \leq .01$. **$p \leq .001$.

Table 1

Sample Descriptive Statistics

Variable	Mean/*n*	SD/%	% Zero	Min.	Max.	Skew	Kurtosis
Covariates							
Age	19.26	1.21	—	—	—	—	—
Gender (Male)	*216*	*44%*	—	—	—	—	—
Asian-American ethnicity	*162*	*33%*	—	—	—	—	—
Predictors							
Premeditation	3.51	0.63	—	—	—	−0.09	0.09
Sensation seeking	3.21	0.94	—	—	—	−0.24	−0.70
Risk behaviors Alcohol use	22.11	21.07	18.5%	0	106	1.08	0.84
Negative alcohol consequences	18.03	22.82	25.7%	0	129	1.87	4.05
Positive alcohol consequences	18.56	17.59	23.6%	0	79	0.82	0.14
Drug use	1.25	2.70	64.1%	0	17	3.30	13.36
Negative drug consequences	4.17	10.31	69.6%	0	99	4.12	23.28
Aggressive behavior	52.70	4.10	44.9%	50	70	1.92	3.11
Rule-Breaking behavior	53.19	5.17	43.1%	50	76	2.13	4.49

Table 2

Model Selection Criteria

		Alcohol consequences		Past year		
	Quantity/frequency of alcohol use	**Negative**	**Positive**	**Drug**	**Marijuana**	**Past year drug consequences**
$Gaussian_{LL}$	−2,133.96	−2,175.23	−2,041.80	−1,137.04	−763.85	−1,800.50
ZIP_{LL}	−3,423.92	−3,832.57	−2,799.88	−705.40***	−488.37***	−1,315.88***
$ZINB_{LL}$	−1,867.92***	**−1,738.28*****	**−1,747.55*****	−628.81***	−480.24**	**−794.94*****
NBH_{LL}	**−1,867.91**	−1,738.42	−1,747.62	**−627.54**	**−479.18**	−795.01

Note. Table 2 presents model selection criteria, conducted formally using likelihood ratio tests and Vuong tests for nonnested models (Vuong, 1989). For each outcome, log-likelihood (LL) values are shown in the top row for base models assuming a Gaussian-distributed outcome, and the log-likelihood values are shown in rows below these for subsequent models, specified stepwise by row to account for zero inflation and overdispersion. Asterisks indicate significant improvements in fit at each step. Log-likelihood values closer to zero indicate better-fitting models. Bolded values indicate models selected for each outcome. ZIP = zero-inflated Poisson; ZINB = zero-inflated negative binomial; NBH = negative binomial hurdle.

** $p < .01$.

*** $p < .001$.

Table 3

Sensation Seeking, Premeditation, and Drinking Behavior

	Likelihood			Drinking behavior count		
	OR	**[95% CI]**	***p***	***RR***	**[95% CI]**	***p***
Quantity/frequency of alcohol use						
Age	**1.29**	**[1.07, 1.51]**	**.022**	0.98	[0.92, 1.03]	.406
Male	0.73	[0.21, 1.25]	.244	**1.31**	**[1.12, 1.53]**	**.001**
Asian-American ethnicity	**0.51**	**[0.03, 1.00]**	**.007**	**0.55**	**[0.47, 0.65]**	**<.001**
Sensation seeking	**1.55**	**[1.25, 1.84]**	**.004**	1.04	[0.95, 1.13]	.400
Premeditation	**0.49**	**[0.07, 0.91]**	**<.001**	**0.77**	**[0.69, 0.87]**	**<.001**
Sensation seeking × Premeditation	1.06	[0.66, 1.45]	.776	0.98	[0.88, 1.09]	.712
Negative alcohol consequences						
Age	**1.13**	**[0.93, 1.33]**	.237	1.01	[0.94, 1.09]	.774
Male	0.68	[0.16, 1.20]	.141	1.24	[0.94, 1.09]	.047
Asian-American ethnicity	**0.43**	**[−0.06, 0.91]**	**.001**	**0.46**	**[0.37, 0.57]**	**<.001**
Sensation seeking	**1.39**	**[1.09, 1.69]**	**.030**	1.04	[0.92, 1.16]	.545
Premeditation	**0.50**	**[0.08, 0.93]**	**.002**	**0.73**	**[0.62, 0.86]**	**<.001**
Sensation seeking × Premeditation	1.21	[0.80, 1.61]	.362	**0.84**	**[0.72, 0.99]**	**.035**
Positive alcohol consequences						
Age	1.15	[0.96, 1.34]	.157	0.99	[0.93, 1.04]	.700
Male	0.71	[0.22, 1.20]	.171	1.11	[0.96, 1.30]	.168
Asian-American ethnicity	**0.42**	**[−0.04 0.87]**	**<.001**	**0.55**	**[0.47, 0.64]**	**<.001**
Sensation seeking	**1.54**	**[1.27, 1.82]**	**.002**	1.03	[0.94, 1.12]	.520
Premeditation	**0.52**	**[0.13, 0.91]**	**.001**	**0.81**	**[0.72, 0.92]**	**<.001**
Sensation seeking × Premeditation	1.13	[0.75, 1.50]	.532	**0.87**	**[0.77, 0.98]**	**.021**

Note. Coefficients in bold are significant. OR = odds ratio; RR = rate ratio.

Table 4

Sensation Seeking, Premeditation, and Drug Behavior

	Likelihood			Drinking behavior count		
	OR	**[95% CI]**	***p***	***RR***	**[95% CI]**	***p***
Past year drug use						
Age	0.91	[0.75, 1.08]	.278	1.01	[0.83, 1.23]	.913
Male	1.46	[1.03, 1.89]	.085	1.18	[0.73, 1.92]	.429
Asian-American ethnicity	**0.41**	**[−0.05, 0.87]**	**<.001**	**0.46**	**[0.26, 0.83]**	**.005**
Sensation seeking	**1.72**	**[1.45, 1.99]**	**<.001**	1.27	[0.95, 1.69]	.103
Premeditation	**0.44**	**[0.08, 0.81]**	**<.001**	0.98	[0.63, 1.51]	.913
Sensation seeking × Premeditation	1.27	[0.89, 1.65]	.219	**0.63**	**[0.42, 0.95]**	**.017**
Marijuana use						
Age	**0.82**	**[0.65, 0.99]**	**.020**	0.94	[0.75, 1.18]	.583
Male	1.52	[1.09, 1.96]	.060	1.05	[0.62, 1.80]	.813
Asian-American ethnicity	**0.39**	**[−0.08, 0.87]**	**<.001**	0.71	[0.37, 1.35]	.263
Sensation seeking	**1.57**	**[1.30, 1.84]**	**.001**	1.23	[0.88, 1.74]	.184
Premeditation	**0.44**	**[0.05, 0.82]**	**<.001**	0.92	[0.59, 1.44]	.702
Sensation seeking × Premeditation	1.27	[0.89, 1.65]	.212	0.83	[0.55, 1.26]	.343
Drug consequences						
Age	0.88	[0.70, 1.07]	.198	0.93	[0.80, 1.08]	.198
Male	1.51	[1.05, 1.97]	.081	1.37	[0.94, 1.98]	.097
Asian-American ethnicity	**0.51**	**[0.02, 1.00]**	**.008**	0.72	[0.47, 1.11]	.110
Sensation seeking	**1.56**	**[1.28, 1.83]**	**.002**	0.98	[0.78, 1.23]	.872
Premeditation	**0.47**	**[0.08, 0.86]**	**<.001**	0.88	[0.64, 1.21]	.408
Sensation seeking × Premeditation	1.18	[0.79, 1.57]	.409	**0.66**	**[0.48, 0.89]**	**.007**

Note. Coefficients in bold are significant. OR odds ratio; RR rate ratio.

Table 5

Sensation Seeking, Premeditation, and Antisocial Behavior

	Likelihood			Antisocial behavior level			
	OR	**[95% CI]**	***p***	***b***	***SE***	**β**	***p***
Aggression							
Age	1.03	[0.94, 1.13]	.515	0.028	0.043	0.004	.519
Male	0.96	[0.71, 1.21]	.729	0.027	0.119	0.006	.819
Asian-American ethnicity	**1.34**	**[1.08, 1.59]**	**.024**	**0.309**	**0.114**	**0.092**	**.006**
Sensation seeking	1.05	[0.91, 1.19]	.498	−0.087	0.067	−0.010	.192
Premeditation	1.15	[0.96, 1.35]	.160	−0.008	0.093	−0.001	.928
Sensation seeking × Premeditation	0.97	[0.79, 1.15]	.772	−0.061	0.085	−0.010	.470
Rule-Breaking behavior							
Age	0.99	[0.89, 1.09]	.850	−0.007	0.049	−0.001	.886
Male	**0.68**	**[0.42, 0.94]**	**.004**	**0.400**	**0.013**	**0.072**	**.003**
Asian-American ethnicity	0.92	[0.66, 1.18]	.519	0.108	0.012	0.026	.429
Sensation seeking	**1.38**	**[1.23, 1.52]**	**<.001**	**0.262**	**0.008**	**0.024**	**<.001**
Premeditation	**0.65**	**[0.45, 0.86]**	**<.001**	−0.152	0.011	−0.01	.171
Sensation seeking × Premeditation	0.92	[0.72, 1.12]	.426	−0.075	0.011	−0.009	.466

Note. Coefficients in bold are significant. OR = odds ratio.