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Longitudinal trajectories of sensation seeking, risk taking propensity, and impulsivity across early to middle adolescence

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Abstract

Adolescent substance use and abuse show associations with increases in disinhibitory constructs, including sensation seeking, risk taking propensity, and impulsivity. However, the longitudinal trajectories of these constructs from early to middle adolescence remain largely unknown. Thus, the current study examined these developmental trajectories in 277 adolescents (M_{age} = 11.00 at Wave 1), over five consecutive yearly waves. Controlling for age, Hierarchical Linear Modeling analyses showed that sensation seeking increased linearly, whereas risk taking propensity and impulsivity demonstrated curvilinear changes. Specifically, risk taking propensity increased in the first four waves of assessment but did not evidence changes at the last assessment wave. Impulsivity, on the other hand peaked at wave four before subsequently declining. A comparison between females and males and Black and White adolescents suggested that these groups' trajectories were similar. Black adolescents' sensation seeking trajectory differed from adolescents who belonged to the "Other" racial group (i.e., adolescents who neither self-identified as Black or White). Generally, the study findings replicate and extend earlier work indicating that these risk factors increase across early adolescence and begin to level-off during middle adolescence. The importance of understanding the natural course of these core constructs is of great importance for directing future relevant prevention and intervention work.

Keywords

Developmental trajectories; sensation seeking; impulsivity; risk taking propensity; adolescence

Adolescence is a developmental period that has received singular attention for presenting unique risk factors that contribute to the initiation, progression, and escalation of substance use. Substance use represents a significant public health concern among youth given strong associations between earlier initiation of use and worse mental and physical health outcomes, as well as increased likelihood of addiction in adulthood (e.g., Brook et al., 2004;

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Colman et al., 2007; Sourander et al., 2007). However, not all adolescents experiment with substances (Johnston et al., 2009a, 2009b), and of those who do, most do not proceed to develop long-term problematic consumption patterns (e.g., Bachman et al., 2002; Schulenberg & Maggs, 2002). The differential engagement in substance use and variability in developmental trajectories has resulted in a proliferation of models of the emergence of substance use, many rooted in a personality diatheses framework (Chassin, Flora, & King, 2004; MacPherson et al., 2011; Sher et al., 2000; Zuckerman, 1983). These models posit that individual differences in personality characteristics produce vulnerabilities that may lead to the development of substance use disorders (Krueger et al., 2002; Vanyukov et al., 2003; Sher & Trull, 1994). Moreover, personality-targeted interventions have demonstrated positive outcomes in preventing the onset and escalation of adolescent substance use (e.g., Conrod et al., 2010; Conrod et al., 2006; Watt, Stewart, Birch, & Berner, 2006). Understanding the trajectories of key personality risk variables associated with substance use in early adolescence is therefore critical to effectively targeting prevention efforts.

Associations between Facets of Adolescent Disinhibition and Substance Use

Disinhibitory-based traits have received particular attention as individual difference constructs associated with a range of substance use and other problem behaviors (e.g., Iacono et al., 2008; De Wit, 2008; Lejuez et al., 2002; 2010; Reynolds et al., 2013). The umbrella term of “disinhibition” encompasses broadly overlapping, but non-redundant constructs including sensation seeking, risk taking propensity, and impulsivity (Reynolds et al., 2013). A considerable body of literature has linked disinhibition more broadly to risk behavior, but there are several meaningful differences in the core focus of each construct.

Sensation seeking is a personality type that describes individuals’ tendency to seek out novel, complex, and intense sensations and experiences and a willingness to take risks to attain these experiences (Zuckerman, 1994; 2009). A robust construct, sensation seeking is also considered to have overlap with novelty-seeking and is consistent with the excitement seeking dimension of the five-factor model of personality specific to extraversion (Cloninger, 1986; Stautz & Cooper, 2013). Impulsivity is a multidimensional construct characterized by deficiencies in self-control or delayed gratification, oftentimes resulting in rash and hasty behaviors (Green et al. 1999; Mischel et al. 1989). While there are arguably multiple ways to define the construct, the most common definition describes impulsivity as a trait characterized by the tendency to act on the spur of the moment and to neglect planning for the future (Lejuez et al., 2010). Finally, risk taking propensity refers to the appetitive processes underlying a behavioral tendency to take risks in response to cues for potential reward with a probability for undesirable results (MacPherson et al., 2010; Lejuez et al., 2002; 2007).

For each of these personality risk variables, a large body of adolescent research supports their relationship with substance use. Specifically, research indicates consistent significant relationships between sensation seeking and adolescent alcohol use (Hittner & Swickert, 2006), cigarette smoking and marijuana use (Crawford, Pentz, Chou, Li, & Dwyer, 2003; Martin et al., 2002; Romer & Hennessy, 2007). Similar associations have been observed

between impulsivity and alcohol use (Dick et al., 2010), cigarette smoking, and illicit drug use (Elkins, King, McGue & Iacono, 2006) in adolescence. Although a more recent investigational target, risk taking propensity has also garnered strong support for its links to alcohol use, illicit substance use, and cigarette smoking in adolescence (e.g., Aklin et al. 2005; Lejuez et al. 2007; MacPherson et al., 2010). In general, the aforementioned facets of disinhibition are well-implicated in contributing to the initiation and progression of adolescent substance use (Sher, Bartholow, & Wood, 2000; Chassin, Flora, & King, 2004; Zuckerman & Kuhlman, 2000; MacPherson et al., 2010; Steinberg, Dahl, Keating, Kupfer, Masten & Pine, 2006). Research also suggests that adolescents' earlier development of neural pathways associated with disinhibition relative to cognitive control may be associated with the increase in reward-seeking behaviors, such as substance use (e.g., Casey, Jones & Hare, 2008; Galvan et al., 2006).

Trajectories of the Facets of Disinhibition across Adolescence and Relevant Extensions

Although earlier research regarded personality risk variables such as impulsivity, sensation seeking, and risk taking propensity as stable traits across time, emerging findings from longitudinal and cross-sectional research are beginning to provide evidence of their dynamic nature. Influential findings from cross-sectional cohort study conducted by Steinberg and colleagues (2008) indicated that between 10 and 30 years old, mean sensation seeking scores reflected a curvilinear pattern; scores were highest for individuals ages 10 to 15 but decreased or stabilized for older participants. Other cross-sectional research is consistent with Steinberg's findings for both impulsivity (Galvan, Hare, Voss, Glover, & Casey, 2007; Leshem & Glicksohn, 2007) and sensation seeking (Russo et al., 1993; Stephenson, Hoyle, Palmgreen, & Slater, 2003; Roth, Schumacher, & Brahler, 2005; Zuckerman, Eysenck, & Eysenck, 1978). Noticeably absent from these investigations are studies examining the developmental trajectory of risk taking propensity.

The existing literature provides initial evidence that sensation seeking and impulsivity may vary according to age, but the reliance on cross-sectional designs in the existing literature does not allow for examination of within-individual change over time. Using a longitudinal design is critical in light of reports of substantial intra-individual variability in adolescents' personality over time (Roberts & DelVecchio, 2000; Donnellan, Conger, & Burzette, 2007; Neyer & Lehnart, 2007; Vaidya, Gray, Haig, Mroczek, & Watson, 2008). As opposed to assessing disinhibitory constructs using mean-level data, longitudinal investigations are able to capture within-person variability over time. As a result, an important extension of the existing literature involves a longitudinal examination of the course of impulsivity, sensation seeking, and risk taking propensity beginning in early adolescence. Further, it is critical to examine rates of substance use from early to middle adolescence, as evidence suggests dramatic increases in substance use over this developmental period (e.g., Windle et al. 2008; Chen & Jacobson, 2012).

A second important avenue for research is the role of demographic factors in the developmental trajectories of these variables. This extension is particularly relevant given that data from the CDC indicates that boys and girls differ in their substance use

engagement, such that, on average, boys engage in significantly higher rates of use than their female peers (see CDC, 2011). Similarly, CDC statistics suggest that there is significant racial variability in substance use frequency, indicating that White adolescents evidence higher rates of substance use than non-White peers (see CDC, 2011). However, few investigations have examined individual differences on disinhibition variables as a function of gender or of race. An important exception is research by Romer and Hennesy (2007) who, using a national sample of youths 14 to 22 years old, found that sensation seeking peaks earlier in girls than in boys. Among adults, multiple studies indicate higher impulsivity, sensation seeking, and risk taking propensity scores for males compared to females (e.g., Lejuez et al., 2002). Among adolescents, Pedersen, Molina, Belendiuk, and Donovan (2012) found that boys (ages 9 to 15) scored higher than same-aged girls in impulsivity and sensation seeking. In contrast, MacPherson and colleagues (2010), analyzing three waves of data of the sample utilized in the current five-wave longitudinal study, found no gender difference in risk taking propensity in early adolescence. Racial and ethnic differences in the trajectories of disinhibited personality constructs have also been identified. In the Pedersen et al (2012) study referenced above, European Americans had higher initial levels and steeper growth in sensation seeking from ages 9 to 15 when compared to African Americans. In this same study, the authors noted that African American adolescents had higher levels of baseline impulsivity. In sum, these findings suggest the importance of examining the influence of gender and race, as each may predict differential divergent trajectories and resultant engagement in substance use.

Aims of the Current Research

Given the limitations of the extant literature on adolescent trajectories of disinhibition traits, the current study had two aims. The first aim was to provide a prospective investigation of the course of sensation seeking, impulsivity, and risk taking propensity from early to middle adolescence (a period ranging from 12 to 15 years of age) (Abela & Hankin, 2011). Consistent with longitudinal and cross-sectional studies on disinhibitory trajectories, we expected that sensation seeking, risk taking propensity, and impulsivity would increase across waves. The second aim was to examine factors that are potentially related to both initial levels and changes in these constructs across time, focusing here on the key demographic variables of race and gender. We hypothesized that boys would score higher in each of the facets of disinhibition examined. For race we did not have concrete hypotheses given the lack of research in this area (with the exception of Pedersen and colleagues' research (2012)).

Method

Participants

The study sample consisted of early adolescents participating in a larger prospective investigation assessing behavioral, environmental and genetic factors that contribute to youths' engagement in high-risk HIV behaviors. Participants and their parents were recruited from the greater metropolitan Washington D.C. area through media outreach and mailings with area schools, libraries, and Boys and Girls Clubs. The sole eligibility criterion to participate in the study was individuals' English proficiency. Recruitment had an

approximate duration of two years and was open to all community youths in the 5th and 6th grades. Follow-up assessments were conducted annually for 5 consecutive years. Data collection for additional waves is ongoing. Permission to conduct the current research was granted by the [Academic Institution Omitted]'s Institutional Review Board (IRB).

Upon arrival to the laboratory at [Academic Institution Omitted] for participants' initial session, research staff provided participants and their caregivers with information regarding study procedures. Informed consent and assent were obtained from the adolescent's parent/guardian and the adolescent, respectively. The youth and the parent/guardian were then accompanied to separate rooms to complete the assessments. According to participant confidentiality guidelines and IRB approval, parents did not have access to the responses provided by the participants. All measures were administered using standard instruction sets. These procedures were repeated across all waves of assessment.

The original study sample consisted of 277 adolescents (44% girls) between ages 9 and 13 (M_{age} = 11.00, SD_{age} = 0.81) at the first wave of assessment and 13 to 18 (M_{age} = 15.04, SD_{age} = 0.95) at the fifth wave of assessment. Forty-nine percent of the sample self-identified as White, 35% as Black, 3% as Latino/a, 1% as Asian, and 11% as "Other." Of the original participants in Wave 1, 89% participated in Wave 2, and 89%, 84% and 77% participated at Waves 3, 4, and 5 respectively. This attrition included participants who could not be located, or who did not respond to various efforts of study staff to contact the participant through multiple telephone calls and letter inquiries. Relative to those who remained in the study, participants who dropped out at each wave did not differ significantly on key study variables including any of the disinhibition variables as well as demographic characteristics including gender and race (all *p*'s >.10). Instruments to assess sensation seeking and risk taking propensity were administered at every wave. The assessment of impulsivity however, was administered beginning at the second wave of the study. All available data were included in the analyses (see Data Analytic Strategy).

Measures

Demographic Variables: To determine the impact of selected key demographic variables in their relationship to differential levels of disinhibited personality constructs, we extracted items from a demographics questionnaire also used in previous studies (MacPherson et al., 2010; Reynolds et al., 2011). Among these items were self-reported gender, age, and race.

Balloon Analogue Risk Task-Youth: (BART-Y; Lejuez et al., 2007). The BART-Y is a well-validated and widely-used behavioral measure of risk taking propensity for youth developed directly from the original BART (Lejuez et al., 2007). In the BART-Y, a computer-generated balloon is inflated by the adolescent, with each pump representing one point. If the balloon is pumped past its explosion point, all of the points accrued for that balloon are lost. Participants can stop pumping the balloon at any time prior to an explosion and allocate the accrued points to a permanent prize meter. After a balloon explodes or points are allocated to the permanent prize meter, a new balloon appears. After completing 30 balloon trials, the total points in the prize meter determines the participants' final prize value, ranging from small (a prize valued at $10) to bonus (a prize valued at $35). Modeling

previous studies that have used the task, the adjusted average, which equals the average number of pumps on balloons that did not explode, was used as the dependent variable (see Lejuez et al., 2002; 2007; Pleskac, Wallsten, Wang, & Lejuez, 2009 for computational and theoretical rationale for utilizing the BART-Y's adjusted average).

Eysenck Impulsivity Subscale, version 7: (EI-7 subscale; Eysenck, Pearson, Easting, & Allsopp, 1985): We utilized the Impulsiveness subscale from the Eysenck I-7 to measure self-reported trait impulsivity, as we have done in previous studies with adolescents (Lejuez et al., 2007). The subscale measures rash impulsivity, or the tendency to act without considering negative consequences or awareness of risk (Miller, et al., 2004). Example subscale items include questions such as "Do you generally do and say things without stopping to think?" The subscale consists of 19 items. Items are coded as 1 or 0 depending on whether the participant agrees or not with the statement. Possible scores for this scale range from 0 to 19, with higher scores reflecting higher impulsivity. Internal consistency was adequate across all waves, α = .67 to .74.

Brief Sensation Seeking Scale: (BSSS; Hoyle et al., 2002): This self-report measure was used to assess sensation seeking. It was chosen over the original version developed by Zuckerman (1979) because it was a) considerably fewer items, b) excluded several items directly querying about substance use and other risk behaviors, and c) excluded more dated and confusing items. The scale consists of 8-items that include statements such as "I would love to have new and exciting experiences, even if they are illegal." Participants are asked to rate each item according to the extent to which it accurately describes their experience using a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree). Research suggests that the BSSS is related to other well-established measures of disinhibition and is predictive of risky behaviors (Hoyle et al. 2002; Stephenson, Hoyle, Palmgreen, & Slater, 2003). All items were summed to create a composite score. The scale demonstrated adequate internal consistency, with α = .69 to .82 across waves.

Data Analytic Strategy

We utilized multi-level modeling (MLM) conducted with HLM 7 (Scientific Software International Inc., IL) to examine adolescents' individual trajectories of impulsivity, sensation seeking, risk taking propensity and predictors (i.e., gender and race) of individual differences in each of these trajectories. There are several advantages to utilizing MLM that make the data analytic method appropriate for the current investigation. One of these benefits includes the ability for data to be modeled at two different levels: Level 1 describes within-individual change over time (e.g., trajectory of sensation seeking), and Level 2 allows the prediction of between individual-level differences in this change (e.g., race). An additional advantage to using MLM is that the approach accounts for missing data at Level 1 (Singer and Willett, 2003) by estimating the trajectory using all existing data for that participant. This benefit is crucial in any longitudinal data analyses so as not to exclude participants with partial data on the dependent variables. Individuals with data missing at Level 2 were excluded during analysis (n=1 excluded for missing self-reported race). In addition to the approach's benefits, MLM allows to control for baseline scores of each measure when investigating change in each construct over time.

Prior to conducting the proposed MLM models, the appropriateness of using this analytic approach was examined by building three null models. Each null model separately tested each of our dependent variables (i.e., risk taking propensity, impulsivity and sensation seeking) to determine the potential for correlated error and the need for linear mixed modeling. In all cases, the intraclass correlation coefficient (ICC) and variance partition effect (VPC) were significant, indicating that a multilevel model was appropriate and necessary. For risk taking propensity, the correlation in the construct across time within participants was 0.50, for sensation seeking it was 0.56, and for impulsivity, it was 0.59.

We specified Level-1 intercepts and slopes as random given expected within-person variability in baseline scores and change in constructs over time. All independent variables, other than time, were centered on their grand mean. We tested a total of three models. In each, the disinhibition construct was individually treated as a dependent variable. The trajectory models were first estimated to evaluate systematic linear changes over time. Quadratic changes were examined in subsequent models. Given the reported links between age and the constructs of interest (e.g., Steinberg, 2008), all models included age at wave 1 as a covariate. Between-subject Level-2 variables, including race and gender, were incorporated individually as predictors of the course of these personality risk variables. As a result of the sample's greater representation of Black and White adolescents (altogether 84%), we grouped adolescents as "Black" (35%) "White" (49%) and "Other" (16%) and compared White to Black adolescents and Black adolescents to adolescents in the "Other" group. This was accomplished by sequentially coding groups so that we could compare one group to the subsequent group. Interaction terms were created by multiplying terms (gender and race variables) to create new terms reflecting the product of both Level 2 predictors (Aiken & West, 1991).

Results

Descriptive Statistics and Correlations between Variables of Interest

All variables of interest were checked for skewness. In all cases, the range of skew was acceptable (i.e., values ranged from -0.35 to 0.92). Mean score levels for each construct at each wave are presented in Table 1. Analyses indicated that sensation seeking scores did not change significantly from the first to the second wave ($t(243) = 1.14$, $p = .26$). Scores did increase however, from the second to the third wave ($t(233) = 4.89$, $p < .001$), from the third to the fourth wave ($t(227) = 4.88$, $p < .001$), and the fourth to the fifth wave ($t(199) = 2.00$, $p = .05$). Risk taking propensity scores on the other hand evidenced significant increases from the first to the second wave ($t(233) = 5.66$, $p < .001$), from the second to the third wave ($t(225) = 4.24$, $p < .001$), and from the third to the fourth wave ($t(212) = 2.34$, $p = .02$). There was not a significant change in risk taking propensity scores from the fourth to the fifth wave ($p = .96$). Finally, impulsivity did not evidence significant change between the second (i.e., the first wave at which the construct was assessed) to third wave and from the third to the fourth wave (p's > .10). Mean-level scores of impulsivity did demonstrate a decrease from the fourth to the fifth wave $t(199) = 4.28$, $p < .001$).

Zero-order correlations were also conducted to examine the relationships between each disinhibition risk variable at each wave of assessment (see Table 1). Risk taking propensity

was not correlated with sensation seeking at any of the assessment waves. Risk taking propensity at wave 2 was correlated with impulsivity at wave 3, and at wave 3 with impulsivity at wave 5. Sensation seeking and impulsivity exhibited moderate, significant correlations at all waves at which the constructs were assessed and ranged from *r's* = .34 - .41.

Trajectories of Sensation Seeking, Risk Taking Propensity, and Impulsivity

To examine systematic change over time for each of our variables of interest, we first evaluated models incorporating the linear effect of time. Subsequent models tested quadratic changes over time for each of the independent constructs. Key demographic variables were then entered into the models sequentially. Lastly, the interaction terms of race and gender were added to each of the models.

For every model that was tested, the intercepts for sensation seeking, risk taking propensity and impulsivity were significant, indicating that baseline scores for each of these disinhibitory constructs was different across individuals (see Tables 2-4). Age was only significantly associated with sensation seeking over time ($\beta = 1.62$, $SE = 0.46$, $p < .001$), with older individuals exhibiting higher scores of the construct over time.

While controlling for the effects of age at baseline, sensation seeking followed a linear trajectory with scores increasing over the course of time ($\beta = 0.83$, $SE = 0.37$, $p = 0.03$). There was no significant quadratic change over time for this construct (p = 0.76). Furthermore, gender was not significantly related to the construct's linear trajectory ($p = 0.37$). In contrast, race was associated significantly with sensation seeking ($\beta = 0.79$, $SE = 0.30$, $p = 0.01$). Specifically, this construct's trajectory showed steeper increases over time for youths who belonged to the "Other" race grouping relative to youths who self-reported as being Black. The interaction of race and gender was not significant in these analyses. See Table 2 for results and Figure 1 for a representation of the sensation seeking trajectory.

In contrast to sensation seeking, risk taking propensity showed a significant linear and quadratic change over time, above and beyond age ($\beta = 7.18$, $SE = 1.13$, $p < 0.001$ and $\beta = -0.80$, $SE = 0.18$, $p < 0.001$, respectively). Risk taking propensity showed acceleration within the first three waves of assessment and the scores tended to remain the same from years 4 to 5. Neither gender nor race had an influence on this quadratic trajectory of risk taking over time ($p's > 0.36$). Furthermore, adolescents showed no differences between baseline risk taking propensity scores as a function of either race or gender. The interaction of race and gender was not significant in this trajectory. Results are presented in Table 3. Figure 2 represents the trajectory of risk taking propensity.

Finally, impulsivity showed both a significant linear ($\beta = 1.52$, $SE = 0.41$, $p < .001$) and quadratic ($\beta = -0.32$, $SE = 0.08$, $p < .001$) change over time controlling for the effects of age at wave 1. Due to the presence of a quadratic effect of time, we focused on this finding. When entered separately into the model, race and gender did not impact the quadratic trajectory (p's < .17) nor did these youths exhibit differences in baseline impulsivity scores. The interaction between these demographic variables did not predict differential change in

the trajectory of impulsivity (*p's* =.19; see Table 4). Figure 3 represents the trajectory of impulsivity.

Discussion

The current study is the first to examine the developmental trajectory of three critical facets of disinhibition commonly linked to substance use. Three major findings emerged from this study. First, sensation seeking increased linearly from early- to middle-adolescence. Second, levels of impulsivity suggest a modest quadratic trend over time, indicating that levels of impulsivity may peak at wave 4 when youth are ages 13-17 before subsequently declining. Third, risk taking propensity also showed a quadratic effect of time, but one that includes a steeper increase followed by stabilization by the last assessment. Contrary to previous findings, with the exception of the relation between race and sensation seeking, race and gender did not appear to be significant predictors of any disinhibitory construct. We discuss the current findings and their clinical implications below.

Disinhibition and Development

Historically, personality traits associated with risky behaviors, including disinhibition, have been thought to be relatively stable and immutable constructs across development (Roberts, Walton, & Viechtbauer, 2006). For this reason, the majority of prevention efforts were targeted at older adolescents to coincide with the onset of risky behaviors themselves. More recent, developmentally-informed models have posited that some of these risk factors may exhibit normative changes across childhood. Specifically, emerging evidence suggests that sensation seeking and impulsivity peak during early adolescence and gradually level-off or decrease over time (e.g. Zuckerman, 2007). However, the preponderance of evidence of developmental changes in these variables has come from studies using cross-sectional designs and primarily White American samples.

Findings from the current study add to this literature both by examining these trajectories prospectively among a diverse adolescent sample, as well as by providing support for a more nuanced view of changes in these disinhibition-related factors during this dynamic period of development. Specifically, these results suggest that sensation seeking steadily increases across early to middle adolescence, consistent with earlier work demonstrating a linear increase in the construct in early adolescence (Harden & Tucker-Drob, 2011; Russo et al., 1993; Steinberg et al., 2008; Stephenson et al., 2003). These findings bolster support for the notion that the activation and arousal needs characteristic of sensation seeking increase across this period and, relative to other disinhibitory traits examined in the current study, may be less attenuated by maturation accompanying the transition to middle-adolescence.

Conversely, impulsivity and risk-taking propensity increase during early adolescence and level-off (or even decrease) during the transition to middle-adolescence. These differential trajectories may reflect fundamental differences between the constructs and their relation to the development of neurobiological and cognitive systems. For example, although sensation-seeking is associated with goal-directed behavior of identifying and seeking out arousing experiences, impulsivity and risk-taking propensity (as measured by a behavioral task) are more closely related to behavioral control. The stabilization of both impulsivity and risk-

taking propensity during middle-adolescence may coincide with notable increases in impulse control (Casey, Getz & Galvan, 2008). Specifically, Yurgelun-Todd (2007) suggests that these adolescent years are associated with the development of greater efficiency in the cognitive control system related to the maturation of the prefrontal cortex. This increase in cognitive control allows for the suppression of less adaptive behaviors and the concomittent increase in goal-directed actions (Casey, Galvan, & Hare, 2005).

Taken together, these findings are the first to demonstrate both the similarity in trajectories among these risk factors and the disparate ages at which these variables peak, a crucial component in targeting effective interventions (e.g., Conrod, Castellanos-Ryan, & Strang, 2010). Understanding the natural course of these core constructs is of great importance for directing future relevant intervention work. Our results support personality-based interventions that identify children with early elevations in level of sensation seeking, as well as youth who continue to struggle with impulse control or evidence elevated risk-taking propensity in middle and late adolescence. These children may be more prone to engage in risk behaviors (Casey et al., 2008) and likely represent a particularly vulnerable group.

Whereas there are clear interpretable findings regarding the trajectory analyses, our secondary aim examining the impact of key demographic variables produced few significant findings. As it relates to the current findings, our results suggested that there was a significant difference in the sensation seeking trajectory between adolescents who self-identified as Black and those belonging to the “Other” racial group (which consisted of adolescents who neither self-identified as Black or White). These findings are somewhat inconsistent with previous studies that noted both significant gender and ethnic differences between European-American and African-American youth on sensation seeking and impulsivity (e.g. Pederson et al., 2012). As a result, future studies should include a larger diverse racial sample to better explore these trajectories. Moreover, while it is important to consider that the transition through older adolescence might show greater impact of these demographic variables, it also is crucial to consider other conceptually relevant variables to be examined as predictors of developmental shifts in these disinhibitory traits in future work. These efforts will be most effective if tied to developmental models that are aimed at understanding biological and environmental factors.

Limitations

This study employed an adolescent sample followed over the course of four years. However, despite these and other methodological strengths (including the use of behavioral tasks), the following limitations should be considered when interpreting the results. First, as with many prospective studies, our results were limited by attrition between the first and fifth year of data collection. This resulted in a significantly smaller sample size by wave five which has the potential to affect parameter estimates. To address this potential limitation, we utilized a multilevel modeling approach which allowed us to include all cases in our analyses; however it will be important to replicate these results in larger samples.

Second, our sample included only children from early to middle adolescence. While this developmental period allowed us to detect the leveling-off of mean scores on measures of impulsivity and risk taking, we may have missed important changes in sensation seeking

that might happen in middle to late adolescence (e.g. Harden & Tucker-Drob, 2011). Future studies should examine the development of these variables from early childhood through the emergence of young adulthood.

Third, time constraints and the limitations of participant burden forced us to utilize a smaller set of measures than we would have liked and limited our ability to implement a multimethod approach for each construct (or at least for impulsivity and risk taking propensity where both behavioral and self-report assessments are available). We chose to use what we believed were among the most common and well supported measures for each construct which resulted in two self-report measures and one behavioral measure. Thus, it is unclear to what extent method bias may have impacted the results.

Finally, the current study did not examine these constructs in relation to actual substance use behaviors. While the goal of the current study was to examine the developmental trajectories of important risk factors of the onset of substance use, an important next step will be to look at the relation between these trajectories and substance use over time. As average rates of substance use tend to increase steadily from ages 14 to 18 (e.g. Johnston, O'Malley, Bachman, & Schulenberg, 2011), examination of the trajectory of these disinhibitory variables as predictors of late adolescent substance use will be important. Thus, although we observed a linear increase in sensation seeking and a curvilinear pattern for impulsivity and risk taking propensity between early to middle adolescence, the absence of an examination of substance use behavior precludes conclusions regarding the extent to which changing trajectories are problematic or pathological. In fact, increases in these disinhibitory variables have shown to predict a number of adaptive outcomes (Gullo & Dawe, 2008). As such, prospective studies that examine trajectories of disinhibitory variables with both problematic and adaptive outcomes across adolescence into young adulthood are warranted. Finally, although we observed general changes in the trajectories of risk taking propensity, sensation seeking, and impulsivity from early to middle adolescence, this investigation constitutes a first step in this examination. Future investigations should examine additional predictors of these trajectories.

Conclusion and Future Directions

Taken together, the current findings complement existing neurobiological and developmental frameworks that posit adolescence is a period of competing influences, with increases in appetitive motivations in early adolescence gradually modulated by the development of greater cognitive control during middle and late adolescence (e.g. Steinberg, 2008, 2010). However, while most research on the development of individual differences in disinhibitory constructs has come from cross-sectional studies (e.g. Steinberg et al., 2008), the current study is one of the first to look at behavioral and self-report measures of disinhibition across early to middle adolescence. Our findings replicate and extend earlier work indicating that these risk factors increase across early adolescence and begin to level-off during middle adolescence. These results suggest the importance of providing substance use preventions to early adolescents thereby effectively targeting a critical developmental period for risk factors in the onset and progression of substance use.

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Highlights

- The longitudinal trajectories of disinhibitory constructs including sensation seeking, risk taking propensity and impulsivity were examined across early to middle adolescence in five consecutive, longitudinal waves.
- Sensation seeking increased linearly.
- Risk taking propensity increased in the first four waves of assessment but did not evidence changes at the last assessment wave.
- Impulsivity peaked at wave four before subsequently declining.
- Females and males evidenced similar disinhibitory construct trajectories.
- There were no significant differences between White and Black adolescents' disinhibitory construct trajectories. Sensation seeking showed steeper decreases over time in Black adolescents relative to those who belonged to the "Other" racial group (i.e., adolescents who neither self-identified as Black or White).

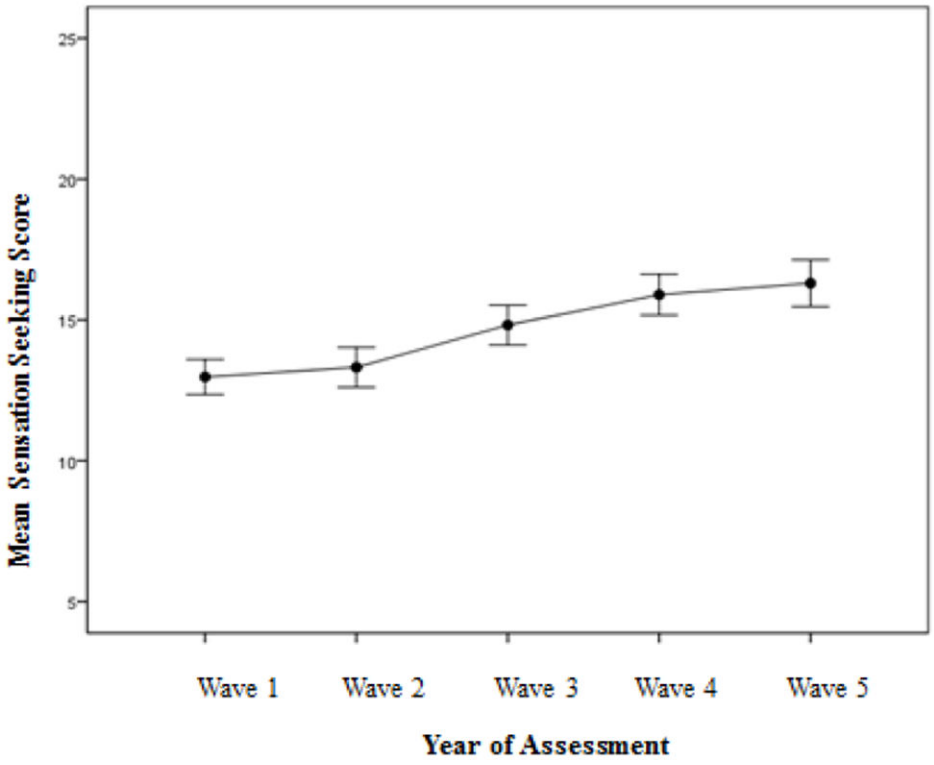

Figure 1.
Mean sensation seeking score as a function of assessment wave.

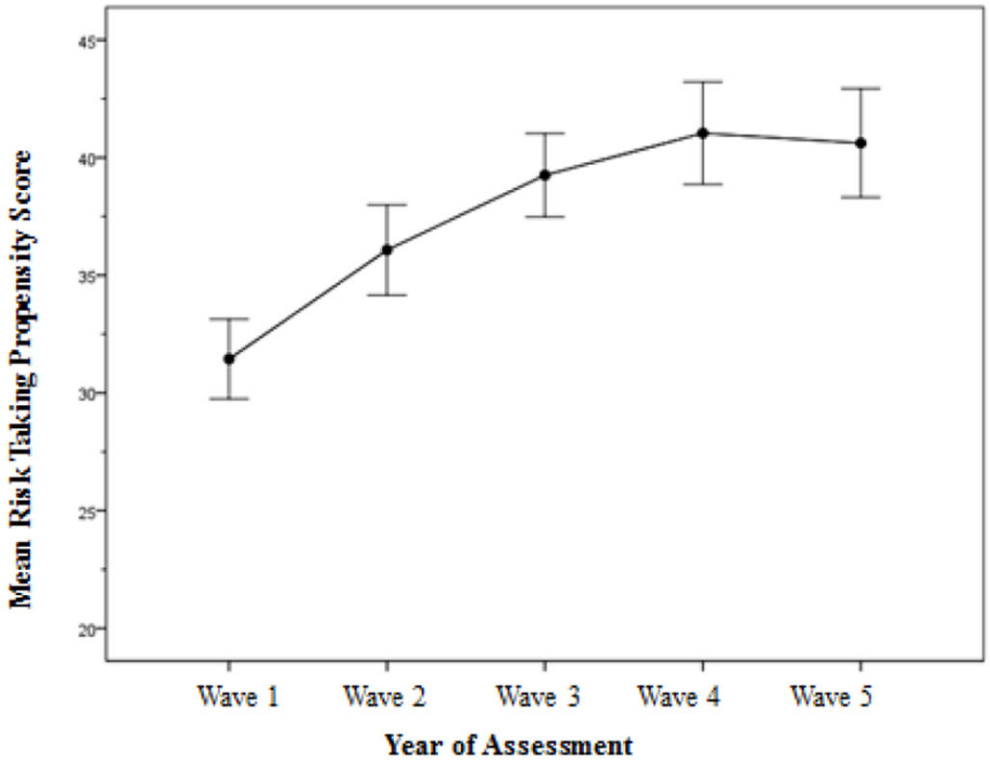

Figure 2.
Mean risk taking propensity score as a function of assessment wave.

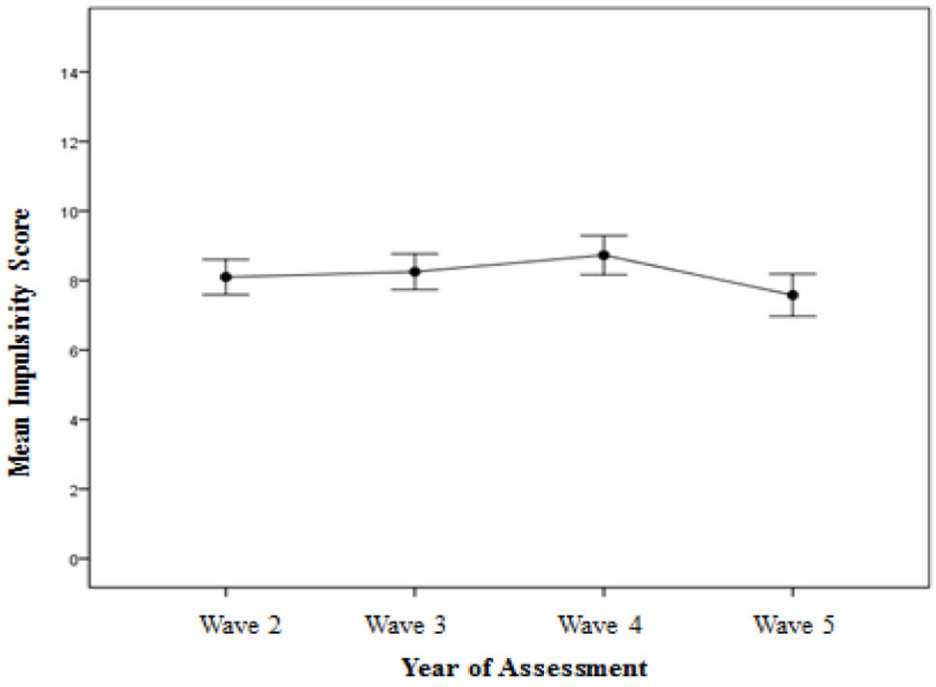

Figure 3.
Mean impulsivity score as a function of assessment wave.

Table 1

Descriptive Statistics and Intercorrelations of Risk Taking Propensity, Sensation Seeking, and Impulsivity

Measure	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Wave 1 BART	---									
2. Wave 2 BART	.49***	---								
3. Wave 3 BART	.38***	.67***	---							
4. Wave 4 BART	.35***	.60***	.75***	---						
5. Wave 5 BART	.33***	.58***	.65***	.73***	---					
6. Wave 1 BSSS	.11	.03	-.00	.01	-.05	---				
7. Wave 2 BSSS	.05	.06	.04	.12	.11	.53***	---			
8. Wave 3 BSSS	.12	.11	.10	.08	.12	.44***	.69***	---		
9. Wave 4 BSSS	.03	.04	.07	.08	.11	.39***	.67***	.79***	---	
10. Wave 5 BSS	.06	.06	.16*	.12	.09	.29***	.64***	.72***	.79***	---
11. Wave 2 EI-7	.01	.06	-.00	.03	.05	.33***	.36***	.36***	.34***	.23***
12. Wave 3 EI-7	-.05	.15*	.07	.03	.14	.23***	.32***	.41***	.38***	.37***
13. Wave 4 EI-7	.05	.07	-.01	-.03	-.02	.31***	.27***	.37***	.39***	.33***
14. Wave 5 EI-7	-.01	.07	.04	.03	.09	.17*	.24***	.33***	.37***	.40***
N	270	241	238	217	194	276	245	246	232	207
Mean	31.44	36.07	39.25	41.04	40.62	12.98	13.32	14.82	15.90	16.30
SD	14.14	15.10	13.88	16.26	16.30	5.25	5.65	5.62	5.59	6.06

Note. BART = Balloon Analogue Risk Taking, Youth Version; BSSS = Brief Sensation Seeking Scale; EI-7 = Eysenck Impulsivity Scale.

* $p < .05$,

** $p < .01$,

*** $p < .001$

Table 2

Results of Hierarchical Linear Models of Sensation Seeking

Fixed Effects	***B***	***SE***	***t***	***p*-value**	**Variance-Covariance Components Test**		
					Deviance	**χ^2 statistic**	***p*-value**
			Effects of Time				
Intercept	11.989	0.531	22.600	**<0.001**			
Age	-0.806	0.656	-1.228	0.221	7131.308	1696.718	**<0.001**
Linear Effect of Time	0.825	0.373	2.210	**0.027**			
Age	1.616	0.455	3.548	**<0.001**	6904.369	226.939	**<0.001**
Quadratic Effect of Time	0.017	0.057	0.300	0.764			
Age	-0.263	0.067	-3.918	**<0.001**	6869.128	35.242	**<0.001**
			Effects of Gender				
Intercept	11.871	0.355	34.051	**<0.001**			
Age	0.891	0.426	2.091	**0.037**			
Gender	1.190	0.702	1.694	0.091	7130.786	1689.568	**<0.001**
Linear Effect of Time	0.928	0.099	9.329	**<0.001**			
Age	0.071	0.122	0.582	0.561			
Gender	-0.177	0.197	-0.895	0.371	6902.158	228.628	**<0.001**
			Effects of Race				
Intercept	11.882	0.346	34.384	**<0.001**			
Age	0.946	0.419	2.260	**0.025**			
Contrast 1	-0.429	1.049	-0.409	0.683			
Contrast 2	-1.392	1.114	-1.249	0.213	7125.602	1663.536	**<0.001**
Linear Effect of Time	0.922	0.100	9.450	**<0.001**			
Age	0.062	0.117	0.526	0.599			
Contrast 1	0.047	0.260	0.182	0.856			

Fixed Effects	***B***	***SE***	***t***	***p*-value**	**Variance-Covariance Components Test**		
					Deviance	**χ^2 statistic**	***p*-value**
			Effects of Time				
Contrast 2	0.788	0.300	2.622	**0.009**	6889.902	235.700	<**0.001**

Note. Race Contrast 1 compared differences between White and Black adolescents. Race Contrast 2 compared Black adolescents to adolescents who belonged to the “Other” racial group.

Table 3

Results of Hierarchical Linear Models of Risk Taking Propensity

Fixed Effects	***B***	***SE***	***t***	***p*-value**	**Variance-Covariance Components Test**		
					Deviance	***χ²* statistic**	***p*-value**
			Effects of Time				
Intercept	25.035	1.526	16.409	<**0.001**			
Age	1.829	1.880	0.973	0.331	9242.512	1406.690	<**0.001**
Linear Effect of Time	7.183	1.129	6.363	<**0.001**			
Age	0.029	1.342	0.021	0.983	9051.538	190.974	<**0.001**
Quadratic Effect of Time	-0.796	0.178	-4.481	<**0.001**			
Age	-0.012	0.205	-0.057	0.954	9004.273	47.265	<**0.001**
			Effects of Gender				
Intercept	25.065	1.532	16.381	<**0.001**			
Age	1.780	1.910	0.932	0.352			
Gender	1.019	3.125	0.326	0.745	9241.426	1402.421	<**0.001**
Linear Effect of Time	7.143	1.237	6.281	<**0.001**			
Age	0.080	1.362	0.059	0.953			
Gender	-0.987	2.266	-0.436	0.663	9046.677	194.749	<**0.001**
Quadratic Effect of Time	-0.786	0.179	-4.381	<**0.001**			
Age	-0.026	0.208	-0.126	0.900			
Gender	0.281	0.355	0.792	0.429	9000.387	46.289	<**0.001**
			Effects of Race				
Intercept	25.005	1.529	16.353	<**0.001**			
Age	1.854	1.880	0.986	0.325			
Contrast 1	0.575	4.857	0.118	0.906			
Contrast 2	-0.002	5.116	0.000	1.000	9216.004	1281.564	<**0.001**

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Fixed Effects	*B*	*SE*	*t*	*p*-value	Variance-Covariance Components Test		
					Deviance	χ^2 *statistic*	*p*-value
			Effects of Time				
Linear Effect of Time	7.217	1.123	6.425	**<0.001**			
Age	0.080	1.334	0.060	0.952			
Contrast 1	-3.783	3.328	-1.137	0.257			
Contrast 2	0.701	3.556	0.197	0.844	9019.015	196.989	**<0.001**
Quadratic Effect of Time	-0.803	0.177	-4.534	<0.001			
Age	-0.021	0.204	-0.105	0.917			
Contrast 1	0.300	0.330	0.910	0.363			
Contrast 2	0.161	0.552	0.291	0.771	8969.452	49.563	**<0.001**

Note. Race Contrast 1 compared differences between White and Black adolescents. Race Contrast 2 compared Black adolescents to adolescents who belonged to the “Other” racial group.

Table 4

Results of Hierarchical Linear Models of Impulsivity

Fixed Effects	***B***	***SE***	***t***	***p*-value**	**Variance-Covariance Components Test**		
					Deviance	***χ²* statistic**	***p*-value**
			Effects of Time				
Intercept	6.746	0.473	14.270	**<0.001**			
Age	0.006	0.542	0.012	0.991	4918.315	1602.266	**<0.001**
Linear Effect of Time	1.520	0.409	3.718	**<0.001**			
Age	0.291	0.465	0.626	0.532	4894.309	23.691	**<0.001**
Quadratic Effect of Time	-0.323	0.080	-4.060	**<0.001**			
Age	-0.801	0.091	-0.891	0.374	4878.495	15.814	**0.002**
			Effects of Gender				
Intercept	6.750	0.473	14.281	**<0.001**			
Age	-0.027	0.540	-0.049	0.961			
Gender	0.923	0.942	0.980	0.328	4919.039	1599.520	**<0.001**
Linear Effect of Time	1.517	0.409	3.710	**<0.001**			
Age	0.305	0.461	0.662	0.509			
Gender	-0.474	0.817	-0.580	0.562	4894.508	24.531	**<0.001**
Quadratic Effect of Time	-0.323	0.080	-4.051	**<0.001**			
Age	-0.083	0.090	-0.922	0.357			
Gender	0.055	0.162	0.342	0.733	4882.176	12.332	**0.007**
			Effects of Race				
Intercept	6.762	0.473	14.295	**<0.001**			
Age	-0.027	0.540	-0.049	0.961			
Contrast 1	-0.796	1.261	-0.631	0.529			
Contrast 2	-2.144	1.417	-1.513	0.131	4915.883	1596.527	**<0.001**

Fixed Effects	*B*	*SE*	*t*	*p*-value	Variance-Covariance Components Test		
					Deviance	χ^2 *statistic*	*p*-value
			Effects of Time				
Linear Effect of Time	1.483	0.398	3.723	**<0.001**			
Age	0.305	0.462	0.662	0.509			
Contrast 1	0.654	1.069	0.612	0.541			
Contrast 2	1.629	1.174	1.387	0.167	4893.702	22.181	**<0.001**
Quadratic Effect of Time	-0.317	0.077	-4.107	**<0.001**			
Age	-0.083	0.09	-0.992	0.357			
Contrast 1	-0.098	0.205	-0.475	0.635			
Contrast 2	-0.308	0.223	-1.381	0.169	4878.387	15.315	**0.002**

Note. Race Contrast 1 compared differences between White and Black adolescents. Race Contrast 2 compared Black adolescents to adolescents who belonged to the “Other” racial group.