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Altered Developmental Trajectories for Impulsivity and Sensation Seeking among Adolescent Substance Users

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Abstract

A number of studies have associated impulsivity and sensation seeking with level of substance use and risk for developing a substance use disorder. These relationships may be particularly apparent during adolescence, when developmental changes in impulsivity and sensation seeking occur at the same time as increased opportunities for substance use. To examine this, the current study measured impulsivity and sensation seeking from pre-adolescence to mid-adolescence in a sample of youth, the majority of whom were identified as being at risk for developing a substance use disorder based on their family history of substance use disorders. Youth were separated into those who did ($n = 117$) and did not ($n = 269$) initiate substance use by mid-adolescence. Results showed that substance users were more impulsive and more sensation seeking during pre-adolescence, prior to any significant substance use, and that greater sensation seeking in pre-adolescence was related to heavier substance use by mid-adolescence. In addition, developmental trajectories for substance-using youth showed a greater increase in sensation seeking but a more modest decrease in impulsivity from pre-adolescence to mid-adolescence. Taken together, these results indicate that increased impulsivity and sensation seeking is apparent in adolescent substance users as early as pre-adolescence, that the difference between substance users and non-users becomes larger across early adolescence as their developmental trajectories diverge, and that

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greater sensation seeking in pre-adolescence may predict increased substance use by mid-adolescence.

Keywords

Adolescence; Impulsivity; Sensation Seeking; Substance Abuse

1. Introduction

Substance abuse often begins during adolescence and is influenced by many aspects of an individual's personality and environment. Two traits that have frequently been associated with substance abuse are impulsivity and sensation seeking (e.g., Bjork, Hommer, Grant, & Danube, 2004; Coffey, Gudleski, Saladin, & Brady, 2003; Fischer & Smith, 2008; Gerra et al., 2004; La Grange, Jones, Erb, & Reyes, 1995; Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). Impulsivity can be conceptualized as a tendency to act in unplanned ways without considering the potential negative consequences of one's actions (Moeller et al., 2001). Sensation seeking is a related but distinct trait that is defined as interest in varied, novel, and intense experiences, as well as a willingness to take risks to have such experiences (Zuckerman, 1994). Factor analysis suggests that sensation seeking and impulsivity are distinct factors (Whiteside & Lynam, 2001), but that both contribute to behavioral outcomes (Steinberg, Albert, Cauffman, Banich, Graham, & Woolard, 2008). The relationship between these two factors and negative outcomes such as substance abuse may be particularly apparent during adolescence, when there are normative changes in impulsivity and sensation seeking at the same time that the risk for initiating substance use increases sharply. Research on the developmental trajectories of impulsivity and sensation seeking during adolescence has shown that sensation seeking increases from late childhood to mid-adolescence (Galvan, Hare, Voss, Glover, & Casey, 2007; Spear, 2000; Steinberg et al., 2008; Timpop, Kerr, & Kirkcaldy, 1999; Zuckerman, 1994;), whereas impulsivity declines from late childhood through adolescence (Casey, Jones, & Hare, 2008; Leshem & Glicksohn, 2007; Steinberg et al., 2008). However, there is limited empirical research investigating how these two traits develop across adolescence and in relation to substance use.

Much of the evidence relating impulsivity and sensation seeking to problematic substance use is from cross-sectional studies of substance users and non-users. For example, individuals with substance use disorders are more impulsive (Bjork et al., 2004; Coffey et al., 2003; Dom, D'haene, Hulstijn, & Sabbe, 2006; Li, Milivojevic, Kemp, Hong, & Sinha, 2006; Moeller et al., 2001; 2002) than are individuals with no history of substance use disorder. In addition, sensation seeking has been positively correlated with amount of alcohol and illicit drug use in adolescents and young adults (Fischer & Smith, 2008; Gerra et al., 2004; La Grange et al., 1995). However, these studies only provide evidence of differences that are present among individuals who are already substance users. They are unable to provide insight into whether substance users differ on these traits prior to substance use, or how developmental trajectories of impulsivity and sensation seeking differ between those who use substances and those who do not. Further research is needed to better

understand how developmental trajectories for impulsivity and sensation seeking relate to substance use during adolescence.

The dual systems model of adolescent development provides a framework for understanding why the developmental trajectories of impulsivity and sensation seeking may relate to adolescent substance use. According to this theory, changes related to brain maturation from childhood to adulthood lead to an increase in sensation seeking tendencies during adolescence that combines with still-immature impulse control abilities (Steinberg, 2008). It is thought that this elevated sensation seeking increases an adolescent's interest in potentially rewarding behaviors such as substance use, while poorer impulse control increases the likelihood of acting on these desires. This is supported by the general finding that adolescents engage in more risky behaviors, including substance use, than do other age groups (Gardner & Steinberg, 2005; Spear, 2000). The dual systems model was developed as a general model of developmental processes that occur in all individuals from childhood through adulthood. However, there is individual variation in the timing and degree of changes between individuals (e.g., Harden & Tucker-Drob, 2011), such as having an earlier age at which changes begin or a greater amount of total change. These differences may relate to risk for substance use involvement.

To test whether variability in the development of impulsivity and sensation seeking from pre-adolescence to mid-adolescence relates to risk for developing a substance use disorder, we previously examined changes in these traits in a longitudinal study of youth with high (FH+) and low (FH-) risk for developing a substance use disorder based on their family history. One aim of this study was to determine whether differences in developmental trajectories for impulsivity and sensation seeking might explain the higher risk for developing a substance use disorder among FH+ individuals. Another aim was to investigate whether FH+ youth who initiated substance use before age 15 differed from non-using FH+ and FH- youth. This group of youth was selected because they possess two characteristics that increase their risk for developing a substance use disorder: they are FH+ and they initiated substance use prior to age 15, which has previously been associated with increased risk of developing a substance use disorders (SAMHSA 2012). We found that FH+ youth were more impulsive in pre-adolescence than were FH- youth, and that this difference remained across development. When FH+ youth with early substance use initiation were compared to FH+ and FH- youth with no substance use, we found that FH+ youth with early substance use initiation had the smallest decreases in impulsivity and greatest increases in sensation-seeking across development (Redacted for review, 2015). These findings suggest that youth with early substance use initiation and familial histories of substance use disorders display altered developmental trajectories that involve higher levels of impulsivity and sensation seeking during early to mid-adolescence. However, it is not known whether this result is specific to very high-risk users (i.e., FH+ youth with early substance use initiation), or whether a similar result can be found when looking at substance-using adolescents more generally (i.e., including FH- substance users and users with later onset of use). Additionally, the previous study focused on initiation rather than amount of substance use. Therefore, it is not known whether adolescents with relatively heavier substance use (i.e., 5 times) differ from those who have simply initiated use. This is an important distinction because the overall amount of substance use, experiencing negative consequences

of substance use, and binge drinking during adolescence have been related to poorer outcomes longitudinally (D'Amico, Ellickson, Collins, Martino, & Klein, 2005; Hill, White, Chung, Hawkins, & Catalano, 2000). Specifically, youth in previous research who displayed these behaviors were more likely to experience short-term consequences such as commit crimes, less likely to graduate from high school or be gainfully employed, less likely to be close with their family, and more likely to be diagnosed with a substance use disorder in adulthood. In addition, substance use during adolescence is associated with a range of short-term negative outcomes, such as auto accidents, overdoses, risky sexual behavior, and suicide (Toumbourou, Stockwell, Neighbors, Marlatt, Sturge, & Rehm, 2007). If developmental trajectories for impulsivity and sensation seeking differ in a broader sample of adolescent substance users vs. non-users, or distinguish those who engage in more problematic substance use vs. those who only try a substance once or twice, then interventions could be developed to identify altered trajectories early on and to target the youth most at risk.

To address the gap of limited research on developmental trajectories of impulsivity and sensation seeking among adolescent substance users and non-users, and to extend our previous findings relating altered developmental trajectories to early-onset substance use in at-risk youth, the current study was designed to examine impulsivity and sensation seeking from pre-adolescence to mid-adolescence in substance-using and non-using youth. The first aim of this study was to extend our previous work on developmental trajectories of impulsivity and sensation seeking to determine whether our findings regarding FH+ youth with early substance use initiation can be replicated in a more general sample of adolescent substance users. A second aim was to examine whether these patterns differed between adolescents with relatively higher and lower levels of substance use. It was hypothesized that heavier substance users (i.e., 5 uses) would show altered developmental trajectories in impulsivity and sensation seeking compared to lighter users, and that non-users would show developmental trajectories that most closely resemble the typical developmental pattern suggested by the dual systems model.

2. Method

2.1 Participants

Three hundred and eighty six youth (187 boys, 199 girls), initially ages 10-12 years old, who were enrolled in a longitudinal study of adolescent development and substance use were included in this study. Details about sample characteristics and recruitment are described elsewhere (Redacted for review, In Press). Briefly, families were initially recruited between 2010 and early 2013 using radio and online advertisements in a large southwestern U.S. city. Following initial enrollment, participants were tested at 6-month intervals and this testing is still ongoing. At the time of the current analyses, families had been followed for a maximum of 54 months (Median = 36.0 mo). Participants in this study are compensated for an initial assessment (\$120 each for youth and parent) and follow-up visits (\$120 for youth, \$75 for parents). Recruitment was designed to create a sample at relatively high risk for developing substance abuse, so children with a family history of substance use disorders (FH+) were oversampled (Sher, Grekin, & Williams, 2004; Tarter et al., 2003). Four-fifths of the sample

(305 youth) was FH+ and one fifth (81) had no parents or grandparents who met lifetime criteria for any substance use disorder (FH-). The Institutional Review Board approved all study procedures, including the provision of informed consent/assent by participants, and participant data were further protected by a Certificate of Confidentiality from the Department of Health and Human Services.

2.2 Screening and Study Procedures

One parent or guardian participated with each child. Upon arrival at the laboratory, parents and children were placed in separate rooms to complete interviews, tasks, and measures. Parents provided information about demographic characteristics, family socioeconomic status (using the Four Factor Index of Socioeconomic Status; Hollingshead, 1975), family history of psychiatric and substance use disorders, children's developmental history, and current and lifetime psychiatric symptoms in children. Children reported on their substance use and psychiatric symptoms.

Family history of substance use and psychiatric disorders was assessed using parent responses regarding lifetime history of substance use disorder symptoms in parents and grandparents on the Family History Assessment Module (FHAM; Janca, Bucholz, Janca, & Jabos-Laster, 1991). All FH+ participants had at least a biological father with a past or present substance use disorder; additional diagnoses in parents or other relatives were not exclusionary. The criterion of a biological father with a substance use disorder has been used in previous research of this type (e.g., Clark, Cornelius, Kirisci, & Tarter, 2005; Tarter, Kirisci, Habeych, Reynolds, & Vanyukov, 2004), and this is done because of the elevated risk for developing an SUD that has been documented among the biological offspring of men with substance use disorders (Vanyukov & Tarter, 2000). Exclusion criteria were: low IQ (< 70; Wechsler Abbreviated Scale of Intelligence; Psychological Corporation, 1999); or physical/developmental disabilities that would interfere with the ability to understand or complete study procedures. At study entry only, regular substance use reported by the child (defined as use at least once per month for 6 consecutive months; Clark, Cornelius, Kirisci, & Tarter, 2005) and positive urine drug test or breath alcohol test were exclusionary. Psychiatric disorder symptoms were evaluated using the Schedule for Affective Disorders and Schizophrenia for School-Age Children—Present and Lifetime Version (K-SADS-PL; Kaufman, Birmaher, Brent, Rao, Flynn, Moreci et al., 1997). Lifetime history of Major Depressive, Bipolar, or Psychotic disorders were exclusionary for all children, FH- children with any current psychiatric diagnoses at study entry were also excluded but current Oppositional Defiant Disorder, Conduct Disorder, ADHD, Dysthymia, and Anxiety Disorders were not exclusionary for the FH+ group because these disorders are commonly co-morbid with substance use involvement (Iacono et al, 2008). Study procedures were identical at study entry and each longitudinal follow-up appointment, which were scheduled at 6-month intervals.

2.3 Measures

2.3.1 Substance Use—Adolescents were interviewed using a drug history interview modified from the procedures of Sobell, Kwan and Sobell (1995). This interview queries about patterns of use for a number of drug classes: alcohol, cannabis, hallucinogens,

depressants, inhalants, narcotics, stimulants, tranquilizers, caffeine, nicotine, and other drugs. Age of initial use and time since most recent use are also recorded. These data were self-reported and answers were not shared with the parent/legal guardian. Youth also provided expired-air samples to screen for recent alcohol use (AlcoTest® 7110 MKIII C, Draeger Safety Inc., Durango, CO) and urine samples to screen for recent drug use (THC, cocaine, benzodiazepines, opiates, and amphetamines; Panel/Dip Drugs of Abuse Testing Device, Redwood Biotech, Santa Rosa, CA). Either self-reported use of a substance other than caffeine or a positive urine/breath test at any study visit was considered sufficient for classification as a substance user.

Group Classification

Participants were classified into two groups: Substance Use and No Use. The Substance Use group were those who reported or tested positive for substance use at any point during the ages being examined. Fifteen youth (12.8%) reported use at study entry, all of this use was infrequent (i.e., less than once per month) and at a light level (i.e., less than 5 uses total) at study entry, though all of the youth reported additional use at later ages. The remainder of the Substance Use group consists of youth whose use began between ages 11 and 15. Youth who denied use throughout this time period and also never tested positive for alcohol or other drugs were classified into the No Use group. To further test the effects of effects of frequency of substance use, follow-up analyses were conducting subdividing the Substance Use group to Regular and Nonregular Use group; defined by at least five times, a criterion that has been used previously in adolescent samples (e.g., Wittchen et al., 2008; Perkonig, Lieb, & Wittchen, 1998; Niethammer & Frank, 2007), or less than five uses, respectively.

2.3.2 Impulsivity—Adolescents were assessed on self-reported impulsivity using the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995). The frequency of impulsive (e.g., “I do things without thinking”) or non-impulsive (“I am self-controlled”) behavioral traits are rated on a scale from 1 (rarely/never) to 4 (almost always/always). Responses were summed across 30 items to provide a total impulsivity score that can range from 30 to 120, with higher scores indicating more impulsivity. The BIS-11 is established as a reliable and valid measure in adolescents and substance-using populations (e.g., Soloff et al., 2000; Stanford et al., 2009).

2.3.3 Sensation Seeking—The Sensation Seeking Scale for Children (SSSC; Russo et al., 1993) is a self-report measure of sensation seeking, or a preference for varied, novel, complex, and intense experiences and a willingness to take risks for the sake of such experiences (Zuckerman, 1994). Responses were summed across 26 items to produce a total sensation seeking score that can range from 0 to 26; with higher total scores indicating more sensation seeking. This measure has established reliability and validity in adolescents (Donohew et al., 1999; Russo et al., 1993).

2.4 Data Analysis

Differences between the substance use groups on demographic characteristics, impulsivity, and sensation seeking at age 11 were analyzed with independent samples t-tests or chi-square tests as appropriate. Changes in impulsivity and sensation seeking from ages 11 to 15

were analyzed using hierarchical linear modeling (HLM; Bryk & Raudenbush, 1987, 1992). This age range was chosen to capture developmental changes in the traits of interest in the years leading up to the typical age of substance use initiation (i.e., mid- to late-adolescence). HLM extends multiple linear regression modeling to repeated-measures data, provides a framework for analyzing individual change over time, and can accommodate time-invariant and time-varying predictors to determine whether individual characteristics are related to initial status or change over time. Two separate sets of models were created. First, substance use group (Use =1, No Use =0) was the primary independent variable. Changes in impulsivity and sensation seeking were modeled as functions of age in half-year increments from 11 to 15 years; group membership (Use, No Use) was then added as a predictor of initial status and change over time. Second, follow-up analyses were conducted looking at regular and nonregular substance users separately. Group (Regular Use =2, Nonregular Use = 1, No Use =0) was the primary independent variable. We examined whether including the covariates for gender ratios and prevalence of FH+ in each group affected our results and found that they did not so these variables were not retained. Changes in impulsivity and sensation seeking were modeled as functions of age in half-year increments from 11 to 15 years; group membership (Regular Use, Nonregular Use, or No Use) was then added as a predictor of initial status and change over time. Demographic and group comparison analyses were conducted using SPSS (version 21; IBM Corp., Armonk, NY), HLM was conducted using SAS (SAS Institute, Inc., Cary, North Carolina). HLM models were fit using a compound symmetry covariance structure for the repeated-measures; SAS PROC MIXED was used to fit all models.

3. Results

3.1 Participant Characteristics

3.1.1 Demographics—Group demographic characteristics are presented in Table 1. The overall characteristics of the participants at the initial assessment were as follows: their mean age was 11.9 years, they were of average IQ, and were predominantly Hispanic. See Table 2 for a depiction of the number of participants with data available from study entry through age 15. During this time, 18 youth in the No Use group (6.7%) dropped out of the study (voluntary withdrawal $n = 7$; moved out of the area $n = 5$), were dropped from the study due to loss of contact ($n = 4$), were withdrawn by the study's PI for noncompliance with study procedures ($n = 1$) or left the study due to a change in guardianship ($n = 1$). In the Substance Use group, 2 youth dropped out of the study (1.7%): 1 chose to withdraw and the other was dropped due to loss of contact. Youth in the Use ($n = 117$) and No Use ($n = 269$) groups did not differ in sex ratios, race, ethnicity, or SES. Youth in the Use group had lower IQs than did those in the No Use group, though both were within the average range. Youth in the Use group were also older at the initial assessment, though this difference was less than 6 months. A higher proportion of youth in the Use group, relative to the No Use group, had a family history of substance use disorders. Youth in the Use group also had higher rates of Attention-Deficit/Hyperactivity Disorder (ADHD) than did youth in the No Use group. Other than ADHD, the most common diagnoses in the sample were Anxiety disorders (14.8%), and Oppositional Defiant Disorder (ODD; 7.8%). The prevalence of these diagnoses did not vary between groups.

3.1.2 Substance use—Participants' self-reported substance use was recorded using the drug history interview at each study visit. Very few participants reported any substance use at study entry ($n = 15$, 3.9% of total sample), and all of this use was at a low level (i.e., fewer than 5 uses, frequency of not more than once per month). Mean age of substance use initiation across the whole sample was 13.8 years ($SD = 1.2$). From age 11 to age 15, the most commonly used substance was alcohol (70.1%), marijuana was second most common (60.7%), and tobacco was third (35.0%). Nearly half of youth reported using only one substance (46.2%); the use of two (27.4%) and three (16.2%) different substances was also relatively common. Of those who used more than one substance, most (85.2%) had used both alcohol and marijuana. The median number of uses reported by the Regular Use ($n = 41$) group was 29, and the most common peak pattern of use during the timeframe of interest was at least once per week but less than once per day (46.3%) followed by at least once per month but less than once per week (31.7%). Youth in the Nonregular Use group either reported substance use on fewer than five occasions ($n = 70$) or denied any substance use but had positive drug test results ($n = 6$).

3.2 Impulsivity and sensation seeking at initial assessment

Scores on the measures of impulsivity and sensation seeking at initial assessment for the Use and No Use groups were compared. Youth in the Use group were more impulsive at initial assessment ($M = 63.54$, $SD = 9.52$) than were youth in the No Use group ($M = 60.08$, $SD = 9.40$), ($\beta = 3.02$, $SE = 1.08$, $p < .01$; $d = .36$). Youth in the Use group also reported more sensation seeking at initial assessment ($M = 11.12$, $SD = 5.61$) than did youth in the No Use group ($M = 9.61$, $SD = 4.02$), though this difference did not reach statistical significance ($\beta = .82$, $SE = 0.54$, $p = .13$; $d = .30$).

3.3 Trajectories of impulsivity and sensation seeking

A growth curve model was tested to determine whether there were nonlinear changes in impulsivity and sensation seeking over time. Across all participants, there was a significant linear increase in impulsivity ($\beta = 0.63$, $SE = 0.21$, $p < .01$), though the relationship can be best characterized as quadratic ($\beta = -0.11$, $SE = 0.02$, $p < .001$). A similar pattern was found for sensation seeking: there was a significant linear increase ($\beta = 0.86$, $SE = 0.09$, $p < .001$), which is also best characterized as quadratic ($\beta = -0.04$, $SE = 0.01$, $p < .01$), from age 11 to age 15. When the trajectories for the substance use groups were compared, there were group by time interactions. Specifically, we observed a greater decrease in impulsivity for youth in the No Use group (9.3% decrease), relative to those in the Use group (7.4% decrease), between ages 11 and 15 ($\beta = 0.50$, $SE = 0.14$, $p < .01$). There was also a greater increase in sensation seeking for youth in the Use group (42.4% increase), compared to those in the No Use group (31.4% increase), during this same time period ($\beta = 0.40$, $SE = 0.06$, $p < .001$). Trajectories of change for impulsivity and sensation seeking among youth in the Use and No Use groups are presented in Figures 1-2.

3.4 Differences Related to Frequency of Use

Scores on the measures of impulsivity and sensation seeking at initial assessment in the Regular Use (i.e., use ≥ 5 times), Nonregular Use (i.e., < 5 times), and No Use (i.e., use = 0

times) groups were compared. Youth in both the Regular Use group ($M = 64.27$, $SD = 9.45$) ($\beta = 4.65$, $SE = 1.75$, $p < .01$) and the Nonregular Use group ($M = 62.88$, $SD = 9.64$) ($\beta = 2.78$, $SE = 1.37$, $p < .05$) were more impulsive at initial assessment than were youth in the No Use group ($M = 60.08$, $SD = 9.40$). There was not a significant group by time interaction between the Regular Use and Nonregular Use groups in the trajectories of impulsivity between ages 11 and 15 ($\beta = 1.88$, $SE = 2.04$, ns), though the trend was for a smaller decrease in impulsivity in the Regular Use group. Youth in the Regular Use group reported more sensation seeking at initial assessment ($M = 12.06$, $SD = 5.55$) than did youth in the Nonregular Use ($M = 10.31$, $SD = 4.30$) ($\beta = 1.18$, $SE = 1.00$, $p < .001$) and No Use groups ($M = 9.61$, $SD = 4.02$), ($\beta = 2.22$, $SE = 0.86$, $p < .05$). There was not a group by time interaction between the Regular Use and Nonregular Use groups in their trajectories of sensation seeking from ages 11 to 15 ($\beta = 0.09$, $SE = 0.096$, ns), though the trend was for a larger increase among youth in the Regular Use group.

4. Discussion

This study examined the developmental trajectories of impulsivity and sensation seeking from pre-adolescence to mid-adolescence in substance-using and non-using youth. Results showed that substance-using youth were more impulsive and more sensation seeking in pre-adolescence, prior to any significant substance use. In addition, substance-using youth displayed different patterns of change for both impulsivity and sensation seeking from age 11 to age 15. Specifically, self-reported impulsivity declined more modestly among substance-using youth than non-using youth during this time period. The opposite pattern was found for sensation seeking, with substance-using youth showing a greater increase in sensation seeking than did non-using youth. Analyses comparing the subset of youth who were regular substance users to those who were non-regular users also showed that regular users reported more sensation seeking in pre-adolescence and a non-significant tendency towards higher levels of impulsivity and sensation seeking across ages 11 to 15. Taken together, these results indicate that adolescent substance users differ from non-using peers in their levels of impulsivity and sensation seeking in pre-adolescence, that the magnitudes of these differences become larger over time as the developmental trajectory for substance users diverges from the trajectory for non-users, and that sensation seeking in pre-adolescence may be particularly related to the development of more regular substance use during adolescence, given that sensation seeking at age 11 differentiated youth in the Regular and Nonregular groups.

The current results are consistent with previous research on impulsivity and sensation seeking, and also provide new evidence of how the developmental trajectories for these traits may relate to substance use during adolescence. The overall developmental trajectories observed in this study are consistent with previous research documenting decreases in impulsivity (Casey et al. 2008; Leshem & Glicksohn, 2007; Steinberg et al., 2008) and increases in sensation seeking (Galvan et al. 2007; Spear 2000; Steinberg et al., 2008; Trimpop et al. 1999; Zuckerman, 1994) as youth mature from childhood through adolescence. In addition, these results extend our previous work documenting altered developmental trajectories for impulsivity and sensation-seeking among FH+ youth, regardless of substance use status, and for a subset of FH+ youth with early substance use

initiation. Here, we show that differences in the development of impulsivity and sensation seeking from pre-adolescence to mid-adolescence can be seen in youth with a later age of onset of substance use, as well. Finally, we provide evidence that the elevations in impulsivity and sensation seeking from age 11 to age 15 that are observed among heavier-using youth are more extreme than are those of lighter-using youth.

In addition, the present study complements cross-sectional research on impulsivity and sensation seeking by providing information about the how impulsivity and sensation seeking develop during the period that precedes many previously reported group differences. Previous research has found elevated impulsivity and sensation seeking among individuals with substance use disorders (e.g., Bjork et al., 2004; Coffey et al., 2003; Gerra et al., 2004; La Grange et al., 1995; Moeller et al., 2001). The results of the present study suggest that these differences may begin as early as pre-adolescence, when the differences in impulsivity and sensation seeking can be observed between youth who will go on to develop heavy substance use from those who do not. One explanation for this association is that substance use by mid-adolescence, an established risk factor for the development of a substance use disorder (SAMHSA, 2012), may alter the developmental trajectories for impulsivity and sensation seeking prospectively. It is difficult to test this in the present analyses, given the short follow-up period since substance use initiation for many individuals, but future research with this cohort will examine this possibility. Alternatively, it may be that the relationship between these variables is in the opposite direction, such that differences in the developmental trajectories for impulsivity and sensation seeking contribute to the likelihood of substance use. This is supported by the group differences seen at earlier ages in this study (e.g., age 11), when very few participants had initiated substance use, and it is consistent with the notion that individual differences in the development of these traits during adolescence may contribute to problem behaviors.

Further, this study makes an important contribution to the literature by providing an empirical test of the dual systems model of adolescent development. According to the model, increases in sensation seeking during adolescence, coupled with impulsivity that has not yet decreased to adult levels, contribute to risky and problem behaviors during adolescence (Steinberg, 2008). Much of the research supporting this model has focused on the development of two neurobiological systems: the first is associated with cognitive and emotional regulation and is most closely related to impulsivity; the second involves emotional expression and reward-seeking and is more associated with sensation seeking tendencies. The dual systems model suggests that these systems mature on different schedules, resulting in adolescents experiencing increased responsiveness to rewarding and exciting stimuli before their abilities to control their impulses are fully mature (Somerville, Jones, & Casey, 2010). Relatively less research has examined the behavioral correlates of these neurobiological processes or considered individual differences in development, though there is evidence of variability in the amount of change in self-reported impulsivity and sensation seeking during adolescence (Harden & Tucker-Drob, 2011). The current study provides additional evidence of differences in the developmental trajectories of impulsivity and sensation seeking between substance users and non-users from early to mid-adolescence.

4.1 Limitations and Future Directions

This study provides new evidence of differences in the developmental trajectories of impulsivity and sensation seeking in substance-using and non-using youth. However, it also has some limitations. The results reported here were from a convenience sample of youth in an ongoing study, many of whom are at elevated risk for developing a substance use disorder because of their family history, and much of the adolescents' substance use has occurred in the most recent visits. As a result, results may not be representative of all youth in this age range, and there is limited follow-up data that can be used to determine any effects of substance use on subsequent impulsivity and sensation seeking. Another limitation of this study is that most substance users in this sample have been using for a short period of time and at relatively low levels. Although the results of the analyses comparing lighter and heavier users suggest an association between frequency of use and increased sensation seeking, it is likely that some of the adolescents who will ultimately become heavier substance users have not yet displayed this behavior and thus may be misclassified in the current analyses. A third limitation is that the major measures of interest were self-reported, and that many of the questions required recall of information from several months in the past. Thus, our results may have been subject to biases related to social desirability and/or recall. Despite these limitations, this study has a number of strengths, including the use of a large sample that was followed longitudinally through an important developmental period. From the results obtained in this study, we can conclude that developmental trajectories for impulsivity and sensation seeking vary between substance-using and non-using adolescents, and that this may be especially pronounced for adolescents with greater substance use. This supports the dual systems model of adolescent development but also highlights the importance of considering individual differences when applying this model. Future research with this cohort will track developmental trajectories for impulsivity and sensation seeking during mid- to late-adolescence and examine how the trajectories relate to substance use over time. Ultimately, this work can help clarify how developmental trajectories for these traits contribute to the development of problem substance use and substance use disorders, which in turn will suggest targets for interventions.

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Highlights

- We model the development of impulsivity and sensation seeking in youth age 11-15.
- Sensation seeking increased and impulsivity decreased as youth matured.
- Preadolescent impulsivity and sensation seeking were higher among substance users.
- Developmental trajectories for substance users and non-users differed.

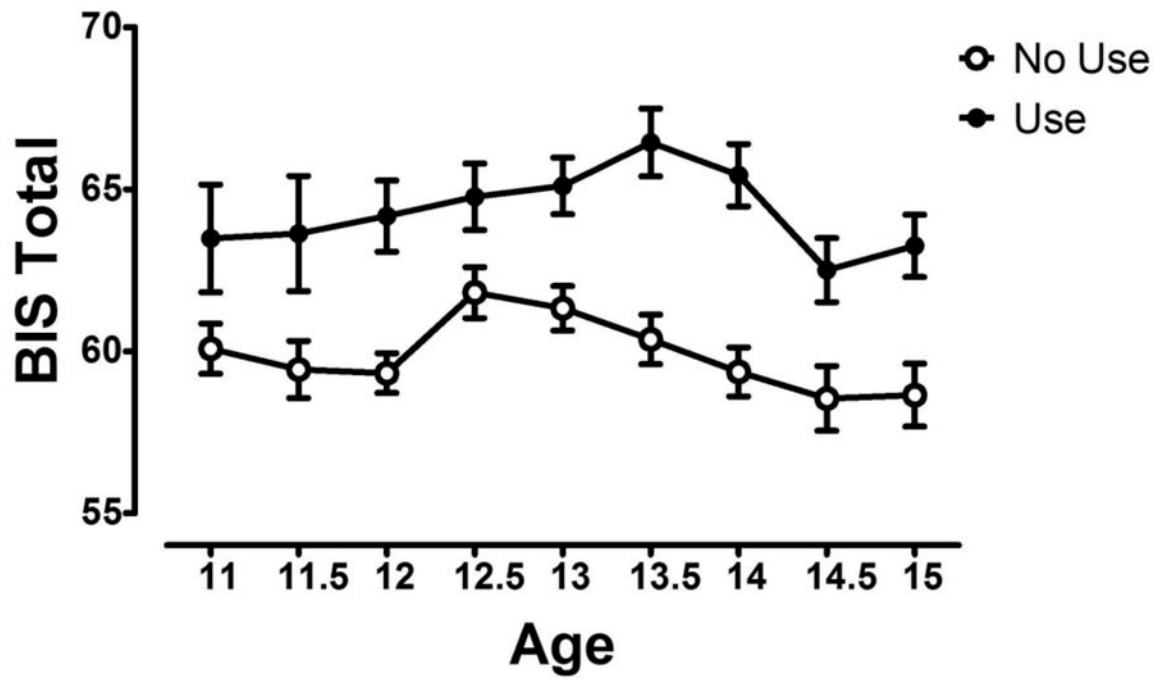


Figure 1.
Trajectories of impulsivity from age 11 to age 15.

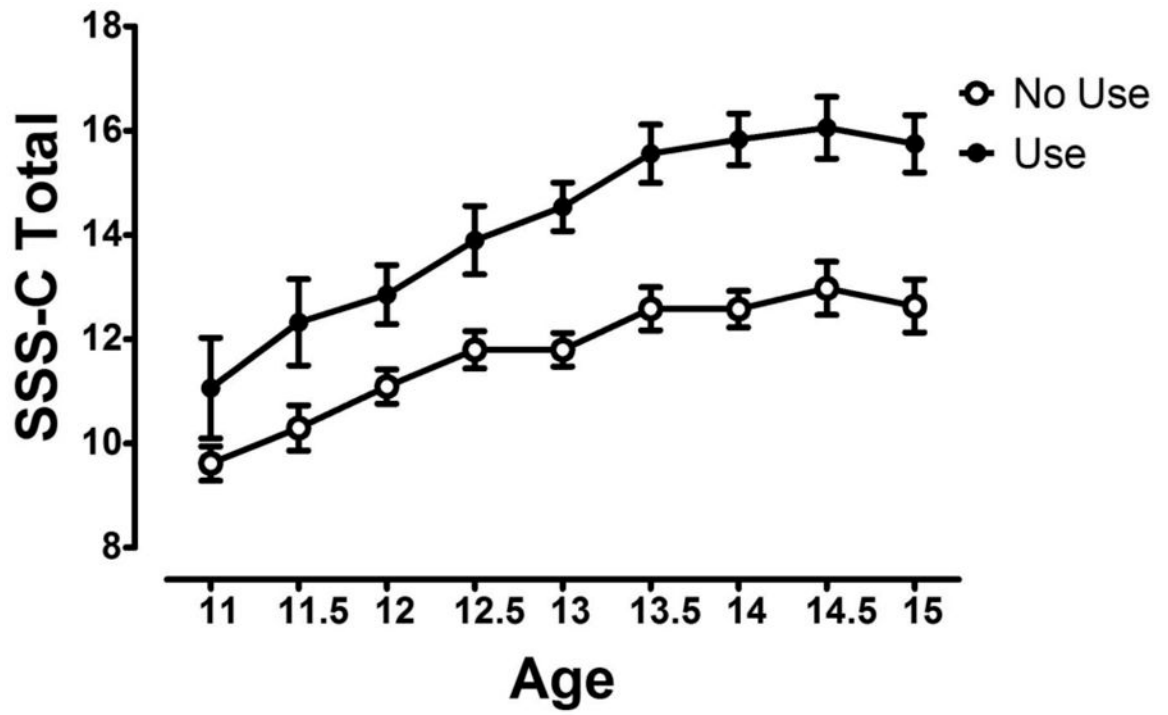


Figure 2.
Trajectories of sensation seeking from age 11 to age 15.

Table 1
Demographic Characteristics at Study Entry

	Substance Use <i>n</i> = 117	No Use <i>n</i> = 269
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
Age (in years)	11.9 (0.8)	11.4 (0.9)*
Total IQ Score	94.2 (11.4)	97.4 (11.8)*
Socioeconomic Status	33.0 (12.0)	35.3 (12.1)
	<i>n</i> (%)	<i>n</i> (%)
Family History ^{<i>l</i>}	101 (86.3)	204 (75.8)*
Sex		
Male	55 (47.0)	132 (49.1)
Female	62 (53.0)	137 (50.9)
Race		
African-American	12 (10.3)	30 (11.2)
Caucasian	102 (87.2)	233 (86.6)
Other	3 (2.6)	6 (2.2)
Ethnicity		
Hispanic/Latino	93 (79.5)	210 (78.0)
Not Hispanic/Latino	24 (20.5)	59 (21.9)
Psychiatric Disorders		
ADHD	35 (29.9)	55 (20.4)*
Oppositional Defiant Disorder	13 (11.1)	17 (6.3)
Anxiety Disorder	15 (12.8)	42 (15.6)

Note.

* $p < .05$;

^{*l*}Family history = having at least a father with a substance use disorder

Table 2

Sample size at each age

Group/Inclusion	Age									
	11	11.5	12	12.5	13	13.5	14	14.5	15	15
Substance Use										
Included	35	56	80	104	110	105	100	102	90	90
No Data	82	58	37	8	3	8	10	10	22	22
Missed Visit	0	0	0	4	3	3	5	3	3	3
Discontinued	0	0	0	1	1	1	2	2	2	2
No Use										
Included	142	170	204	231	221	214	190	169	121	121
No Data	127	90	49	12	18	30	56	78	120	120
Missed Visit	0	0	7	17	16	10	7	4	10	10
Discontinued	0	9	9	9	14	15	16	18	18	18

Note: No Data= cases that, because of the rolling recruitment, either 1) enrolled in the study after this age or 2) have not yet reached that age; Missed Visit= missed that particular wave of data collection but remain active in the study; Discontinued = withdrawn from study.