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BRIEF REPORT

Individual Differences in the Development of Sensation Seeking and Impulsivity During Adolescence: Further Evidence for a Dual Systems Model

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Consistent with social neuroscience perspectives on adolescent development, previous cross-sectional research has found diverging mean age-related trends for sensation seeking and impulsivity during adolescence. The present study uses longitudinal data on 7,640 youth from the National Longitudinal Study of Youth Children and Young Adults, a nationally representative sample assessed biennially from 1994 to 2006. Latent growth curve models were used to investigate mean age-related changes in self-reports of impulsivity and sensation seeking from ages 12 to 24 years, as well individual differences in these changes. Three novel findings are reported. First, impulsivity and sensation seeking showed diverging patterns of longitudinal change at the population level. Second, there was substantial person-to-person variation in the magnitudes of developmental change in both impulsivity and sensation seeking, with some teenagers showing rapid changes as they matured and others maintaining relatively constant levels with age. Finally, the correlation between age-related changes in impulsivity and sensation seeking was modest and not significant. Together, these results constitute the first support for the dual systems model of adolescent development to derive from longitudinal behavioral data.

Keywords: adolescence, impulsivity, sensation seeking, personality, individual differences

Adolescence is a developmental period characterized by sweeping biological, emotional, cognitive, and social changes. Emerging research in social neuroscience has resulted in a new theoretical paradigm for understanding how these developmental changes may produce a unique window of vulnerability for risk-taking behavior and psychopathology: the *dual systems model* (Casey, Getz, & Galvan, 2008; Steinberg, 2008, 2010; Somerville, Jones, & Casey, 2010). The dual systems model posits that adolescent behavior is shaped by a developmental imbalance between two neurobiological systems. The subcortical *socioemotional system*, which includes the ventral striatum and the amygdala, is responsive to emotion, novelty, and reward (Cardinal, Parkinson, Hall, & Everitt, 2002; Delgado, 2007; LeDoux, 2000; Schultz, Dayan, & Montague, 1997), whereas the *cognitive control system,* which includes the prefrontal cortex, is critical for impulse control, emotion regulation, and decision making (Miller & Cohen, 2001; Ochsner & Gross, 2005). The central premise of the dual systems model is that these neurobiological systems develop according to different time courses and thus reach structural and functional maturity at different ages (Somerville et al., 2010). The socioemotional system appears to become more sensitive in early adolescence, coincident with the changes of puberty (Galvan et al., 2006; Hare et al., 2008), whereas the cognitive control system matures more gradually through the end of early adulthood (Casey, Galvan, & Hare, 2005; Giedd et al., 1999). Thus adolescents are thought to experience an increased responsiveness to rewards, affective cues, and novelty while still having immature capacities for impulse control and inhibition.

Evidence to support the dual systems model of adolescent development has primarily come from neuroscience research conducted with both humans and animal models, but an emerging body of behavioral research specifically focuses on understanding the implications of the dual systems model for adolescent development in humans. One important area in which the neurobiological perspective on adolescence has informed behavioral research is the domain of personality development, specifically, the personality traits of impulsivity and sensation seeking. Guided by previous empirical and theoretical work on this topic (e.g., Steinberg et al., 2008), we define impulsivity as the tendency to act on behavioral impulses without planning or without considering potential consequences, and we define sensation seeking as the tendency to seek out experiences and situations that are novel, exciting, or rewarding. Historically, some personality theorists have seen impulsivity and sensation seeking as facets of the same underlying personality dimension (Buss & Plomin, 1975; Cloninger, Przybeck, & Svrakic, 1991; Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993). However, factor analytic results have indicated that items measuring sensation seeking (e.g., "I quite enjoy taking risks") and items measuring the ability to inhibit behavioral im-

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pulses ("I like to stop and think things over before I do them") measure independent personality constructs (Whiteside & Lynam, 2001). These results are consistent with the predictions of the dual systems model, which posits that impulsivity and sensation seeking are distinct traits influenced by qualitatively distinct developmental processes in adolescence (Steinberg et al., 2008). Specifically, impulsivity is thought to stem from failures to exert cognitive control, which is mediated by prefrontal cortical structures. Therefore, adolescents are predicted to demonstrate monotonic declines in impulsivity as their neurological capacity for response inhibition and self-regulation improves. In contrast, it has been suggested that sensation seeking stems from sensitivity of subcortical structures to motivational and affective cues (Steinberg, 2007, 2008). Thus adolescents are predicted to demonstrate an initial increase in sensation seeking during early adolescence, as these subcortical structures rapidly mature, followed by a leveling off or decline into adulthood.

Previous cross-sectional research on impulsivity and sensation seeking has found patterns of age-related change that are consistent with the predictions of the dual systems model. Impulsivity has generally been found to be negatively associated with age across childhood, adolescence, and early adulthood (Galvan, Hare, Voss, Glover, & Casey, 2007; Leshem & Glicksohn, 2007). In contrast, sensation seeking has been found to be positively associated with age (Russo et al., 1991, 1993; Stephenson, Hoyle, Palmgreen, & Slater, 2003) among early adolescents but negatively associated with age in adult samples (Giambra, Camp, & Grodsky, 1992; Roth, Schumacher, & Brahler, 2005; Zuckerman, Eysenck, & Eysenck, 1978). Only one previous study appears to report the age trends for both impulsivity and sensation seeking in a sample that spanned childhood to adulthood. In a sample of participants ranging in age from 10 to 30 years, Steinberg et al. (2008) found that impulsivity was negatively and linearly associated with age, whereas the association between sensation seeking and age was curvilinear, with middle adolescents (ages 14–15 years) showing more sensation seeking than both preadolescent participants (ages 10–11 years) and late-adolescent and adult participants. These results were interpreted as evidence that developmental change in sensation seeking and impulsivity are "distinct phenomena that are subserved by different brain systems and follow different developmental trajectories" (Steinberg et al., 2008, p. 1766).

Goals of the Current Project

We undertook the current project to test the predictions of the dual systems model of adolescent development with respect to population-level longitudinal changes in impulsivity and sensation seeking, as well as individual differences in these developmental changes. Data on impulsivity and sensation seeking were drawn from the National Longitudinal Study of Youth (NLSY79) Children and Young Adults (CNLSY), a longitudinal, nationally representative survey of over 7,000 children and young adults ranging in age from 12 to 24 years. We used latent growth curve modeling to answer three specific questions not previously addressed in the literature on adolescent personality development.

First, at the population level, do impulsivity and sensation seeking show divergent longitudinal age trends during adolescence? Previous research using cross-sectional data (e.g., Steinberg, 2008) has found evidence for distinct age trends in sensation seeking and impulsivity; however, cross-sectional age trends are based on comparisons of individuals of different ages to one another rather than comparisons of the same individuals at different ages to themselves. Research using longitudinal data is necessary to validate the results from previous cross-sectional samples.

Second, to what extent do population-level age trends in impulsivity and sensation seeking generalize to specific individuals within the population, and to what extent are there individual differences in these age-related changes? To date, research on age-related changes in impulsivity and sensation seeking, as well as research on the neurobiological changes thought to underlie impulsivity and sensation seeking, has focused on mean differences between age groups. In contrast, research has been relatively silent regarding the extent to which there are individual differences in age-related changes in impulsivity and sensation seeking.

Finally, what is the relation between individual differences in changes in impulsivity and sensation seeking over time? Although there is emerging evidence for the discriminant validity of individual differences in impulsivity and sensation seeking in the personality literature, there is no existing longitudinal evidence on whether impulsivity and sensation seeking change together over time. Neurobiological perspectives on adolescent development predict that because these personality dimensions have different neurological underpinnings that are themselves governed by different developmental time courses, impulsivity and sensation seeking will develop largely independently of each other. Accordingly, individual differences in longitudinal change in the two outcomes are expected to correlate only modestly.

Method

Mother Generation: The NLSY79

The Bureau of Labor Statistics designed and funded the NLSY79 survey to study workforce participation in the United States. A complex survey design was used to select a nationally representative sample of 3,000 households containing 6,111 youth, plus an additional oversample of 3,652 African American and Hispanic youth that were 14–21 years old as of December 31, 1978. The response rate for the initial NLSY79 survey was over 90% of the eligible sample, and participants have been reinterviewed annually from 1979 to 1994 and biennially since 1994. Retention rates for follow-up assessments of the NLSY79 sample were greater than 90% for the first 16 waves and greater than 80% for subsequent waves.

Adolescent Generation: The CNLSY

Beginning in 1986, the biological children of the NLSY79 women were assessed biennially (Chase-Lansdale, Mott, Brooks-Gunn, & Phillips, 1991). The initial participation rate was 95%, and the average retention rate through 2006 was approximately 90%. Beginning in 1988, children over the age of 10 years completed individual supplemental interviews that assessed their attitudes and behaviors. Finally, beginning in 1994, older children who were 15 years old by the end of the survey calendar year (*young adults*) were administered a separate interview. As of 2006, 11,466 children were identified as having been born to 6,283 NLSY79 women.

The current project uses data from a subsample of 7,640 youth who reported on their impulsivity and sensation seeking at least once between the ages of 12 and 24 years. This CNLSY sample is ethnically diverse: 1,681 youth (22%) were Hispanic, 2,598 (34%) were African American, and the remaining 3,361 (44%) were non-Hispanic White. Because children were assessed biennially, all data were analyzed using 2-year age groups: 12- to 13-year-olds, 14- to 15-year-olds, 16- to 17-year-olds, 18- to 19-year-olds, 20- to 21-year-olds, 22- to 23-year-olds, and 24- to 25-year-olds. Of the 7,640 youth used in the current study, 953 have data on personality at only one time point, 1,478 at two time points, 2,067 at three time points, 2,682 at four time points, and 460 at five time points between the ages of 12 and 24 years. Less data are available for younger participants, who have had fewer opportunities to be assessed since the age of 12 years; the median date of birth for participants who have data at one time point is 1992, versus 1984 for participants who have data for five time points.

The current CNLSY data overrepresent the oldest participants, who were born to relatively young mothers (Turley, 2003). To correct for this well-documented source of sampling bias, all analyses controlled for maternal age at first birth, as well as sociodemographic factors (including maternal education, family income, and race/ethnicity) that differ between older and younger mothers. This correction has been successfully implemented in multiple previous studies using the CNLSY data (e.g., D'Onofrio et al., 2008; Harden et al., 2009; Mendle et al., 2009).

Measures

Maternal characteristics. *Socioeconomic status* was measured using self-reported total family income, including government support and food stamps but excluding income received by unmarried cohabitating partners, when the mother was 30 years old (median = \$22,500 per year). *Maternal cognitive ability* was measured in the 1980 assessment using composite scores on the word knowledge, paragraph comprehension, math knowledge, and arithmetic reasoning subtests of the Armed Services Vocational Aptitude Battery. *Maternal education* was measured using maternal report of the number of years of school they had completed (M = 13.4 years, SD = 2.50 years; approximately 9% of the sample reported 11 years or less). Finally, maternal age at first birth was calculated using the date of birth for the mother and her first child (M = 21.9 years, SD = 4.52, range = 11.7–38.3 years).

Personality. *Impulsivity* was measured by youth self-report on three items: (a) "I often get in a jam because I do things without thinking," (b) "I think that planning takes the fun out of things," and (c) "I have to use a lot of self-control to keep out of trouble." *Sensation seeking* was measured by youth self-report on the following three items: (a) "I enjoy taking risks"; (b) "I enjoy new and exciting experiences, even if they are a little frightening or unusual"; and (c) "Life with no danger in it would be too dull for me." These six items made up a scale intended to measure propensity for risk taking, and items were drawn from multiple inventories (NLSY79 Children & Young Adults, 2009). All items were rated on a 4-point scale ranging from 1 = *strongly disagree* to 4 = *strongly agree*. Impulsivity and sensation-seeking sum scores were residualized for all demographic and maternal characteristics and then standardized to z scores (M = 0, SD = 1).

The correlation between impulsivity and sensation seeking was significant but small ($r = .27$, $p < .01$), supporting the conceptualization of these as distinct dimensions of personality. Furthermore, confirmatory factor analysis of the six items indicated that a single-factor model fit the data poorly, $\chi^2(8) = 869.63$, comparative fit index (CFI) = .80, root-mean-square error of approximation ($RMSEA$) = .17, whereas a two-factor model fit the data significantly better, $\Delta\chi^2 = 702.91$, $p < .001$, CFI = .96, $RMSEA$ = .07. Consistent with previous theoretical and empirical research (Costa & McCrae, 1992; Eysenck & Eysenck, 1985; Whiteside & Lynam, 2001), sensation seeking was significantly positively correlated with concurrent measures of the Big Five personality traits of Extraversion ($r = .19$) and Openness ($r = .23$), whereas impulsivity was significantly negatively correlated with Conscientiouness ($r = -.28$) and Emotional Stability ($r = -.32$). Big Five personality traits were measured during the 2006 assessment using the Ten-Item Personality Inventory (Gosling, Rentfrow, & Swann, 2003). Both sensation seeking and impulsivity were significantly correlated with youths' report at ages 15–16 years of delinquent acts (e.g., hitting someone, stealing, fighting, skipping school) in the last 12 months (range = 0–4; $r = .24$ for sensation seeking and $r = .26$ for impulsivity).

Analytic Methods

Longitudinal data on self-reported impulsivity and sensation seeking were analyzed using a series of latent growth curve models (LGMs; McArdle & Nesselroade, 2002; Meredith & Tiskak, 1990) in the software program Mplus. All models were estimated using full information maximum likelihood, which has been recommended as the preferred method for accounting for missing data (Schafer & Graham, 2002). In addition, standard errors and model fit statistics were adjusted for nonindependence of data from children from the same family (i.e., sibling clusters; Asparouhov & Muthén, 2006). Model fit was evaluated using the chi-square and RMSEA. RMSEA measures error in approximating data from the model per model parameter (Steiger, 1990). RMSEA values of less than .05 indicate a close fit, and values up to .08 represent reasonable errors of approximation.

Results

Do Impulsivity and Sensation Seeking Have Diverging Mean Trends?

We first calculated the mean levels of impulsivity and sensation seeking for each age group, which are illustrated in Figure 1. Consistent with previous cross-sectional research, impulsivity and sensation seeking had diverging mean trends in adolescence. Impulsivity declined linearly from ages 12 to 24 years, whereas sensation seeking initially increased until mid-adolescence (from ages 12 to 16 years) but was followed by a more gradual decline through the age of 24 years.

Are There Individual Differences in Change in Impulsivity and Sensation Seeking?

Next, we fit a series of univariate LGMs of impulsivity and sensation seeking to determine the most parsimonious representa-

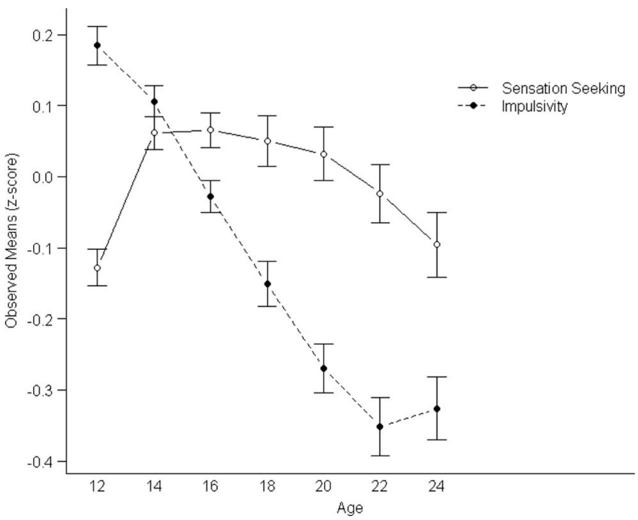

Figure 1. Age-related mean trends in impulsivity and sensation seeking from 12 to 24 years. Scores for impulsivity and sensation seeking are corrected for demographic and maternal characteristics and standardized.

tion of the mean age trends and also to estimate the extent of individual differences in change. The basic LGM can be written as follows (McArdle & Nesselroade, 2003):

$$Y[t] = y_L + \mathbf{A}[\boldsymbol{t}] \times y_{S1}(+\mathbf{B}[t] \times y_{S2}) + \mathbf{e}[\boldsymbol{t}],$$

where $Y[t]$ is the impulsivity or sensation-seeking z scores for person n at each age t, y_L is a latent score representing the overall level (centered at age 16 years), y_{S1} is a latent score representing the magnitude of linear change over time, $\boldsymbol{A}[\boldsymbol{t}]$ is a vector of time-specific basis coefficients representing the shape of change over time, and $\boldsymbol{e}[\boldsymbol{t}]$ is a vector of time-specific residual errors. The latent scores, y_L and y_{S1}, in turn, are assumed to be multivariate normal. Constraining the values of $\boldsymbol{A}[\boldsymbol{t}]$ constitutes a test of specific hypotheses regarding the shape of change. Further complexity may be incorporated with additional latent slope variables (e.g., the y_{S2} in parentheses above).

Changes in impulsivity and sensation seeking from ages 12 to 24 years were analyzed using a series of four LGMs: linear, quadratic, dual linear segments, and latent basis. The algebraic formulas for each of these models are written in Figure 2. The central goal in comparing these models was to determine which growth curve best captured the observed shape of changes in impulsivity and sensation seeking (McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002).

Model fit comparisons for the univariate LGMs of impulsivity and sensation seeking are summarized in Table 1. For impulsivity, a quadratic model was clearly the best fit to the data, $\chi^2(23) = 21.73$, $p = .54$, $CFI = 1.00$, $RMSEA = .00$. The parameters of the quadratic model for impulsivity are summarized in the column labeled *Model 1: Impulsivity* of Table 2. The mean of the Linear Change factor was negative, whereas the mean of the Quadratic Change (or *curvature*) factor was positive (but very small), implying that impulsivity declines through adolescence and then flattens out in the early 20s. In addition, there were significant individual differences in the Level, Linear Change, and Quadratic Change growth factors of impulsivity, indicating that some adolescents experience more rapid decreases in their impulsivity than other adolescents do. This is illustrated on the left side of Figure 3, which shows age-related change in impulsivity, as implied by model parameters. (Although analyses were conducted on the full sample, we limited Figure 3 to only 500 randomly chosen adolescents to maintain illustrative clarity.)

For sensation seeking, a quadratic model was the best overall fit to the data, $\chi^2(23) = 35.10$, $p = .051$, $CFI = .985$, $RMSEA = .01$. The parameters of the quadratic model for sensation seeking are summarized in the column labeled *Model 2: Sensation seeking* in Table 2. In contrast to results for impulsivity, the mean of the Linear Change factor for sensation seeking was positive, whereas the mean of the Quadratic Change factor was negative, implying that sensation seeking initially increases in adolescence and then begins to decline in late adolescence. In addition, there were significant individual differences in the Level, Linear Change, and Quadratic Change growth factors of sensation seeking, indicating that some adolescents experience more pronounced increases in sensation seeking than other adolescents do. This is illustrated in the right side of Figure 3, which shows age-related change in sensation seeking, as implied by model parameters, for 500 randomly chosen adolescents.

Are Changes in Impulsivity and Sensation Seeking Linked?

Our final analysis tested the relation between age-related changes in impulsivity and sensation seeking using a bivariate LGM. This model is illustrated in Figure 4.

The overall fit of the bivariate LGM model was good, $\chi^2(79) = 106.09$, $p = .02$, $CFI = .985$, $RMSEA = .007$. The means and variances of the growth factors estimated from the bivariate LGM are summarized in the right-hand column of Table 2, and the correlations among the growth factors for impulsivity and sensation seeking are summarized in Table 3. The Level–Level, Linear

Model	Equation
Linear	$Y[t]_n = y_{Ln} + A[t]*y_{Sn} + e[t]_n$ y_{Ln} = latent Level score of person n y_{Sn} = latent Linear Change score of person n $A[t]$ = age group – 16 e_n = time-specific error score of person n
Quadratic	$Y[t]_n = y_{Ln} + A[t]*y_{Sn} + B[t]*y_{Qn} + e[t]_n$ y_{Ln} = latent Level score of person n y_{Sn} = latent Linear Change score of person n y_{Qn} = latent Quadratic Change score of person n $A[t]$ = age group – 16 $B[t]$ = (age group – 16)^2 e_n = time-specific error score of person n
Latent Basis	$Y[t]_n = y_{Ln} + A[t]*y_{Sn} + e[t]_n$ y_{Ln} = latent Level score of person n y_{Sn} = latent Linear Change score of person n $A[t]$ = latent basis coefficient (fixed at 0 and 1 for age groups 16–17 years and 18–19 years) e_n = time-specific error score of person n
Dual Linear Segments	$Y[t]_n = y_{Ln} + A[t]*y_{S1n} + B[t]*y_{S2n} + e[t]_n$ y_{Ln} = latent Level score of person n $y_{S1\,n}$ = latent Linear Change score of person n before age 16 years $y_{S2\,n}$ = latent Linear Change score of person n after age 16 years $A[t]$ = 0, if age group > 16 (age group – 16)*–1, if age group ≤ 16 $B[t]$ = 0, if age group ≤ 16 age group – 16, if age group > 16 e_n = time-specific error score of person n

Figure 2. Algebraic equations for univariate latent growth curve models of impulsivity and sensation seeking.

Table 1
Model Fit Comparisons for Latent Growth Curve Models of Impulsivity and Sensation Seeking

	Impulsivity models						Sensation-seeking models					
Model	χ^2	*df*	*p*	*CFI*	*RMSEA*	*BIC*	χ^2	*df*	*p*	*CFI*	*RMSEA*	*BIC*
Linear	53.11	28	.003	.95	.01	30980.2	103.25	28	.00	.91	.02	30939.5
Quadratic	**21.73**	**23**	**.54**	**1.00**	**.00**	**30976.5**	**35.10**	**23**	**.05**	**.99**	**.01**	**30896.4**
Latent basis	41.83	23	.01	.96	.01	30996.9	70.60	23	.00	.94	.02	30934.4
Dual linear	34.49	23	.06	.98	.01	30988.9	35.88	23	.04	.94	.01	30897.0

Note. Best-fitting model is highlighted in boldface type.

Change–Linear Change, and Quadratic Change–Quadratic Change correlations are of the greatest theoretical relevance and are therefore shown in bold. Overall, the associations between age-related changes in impulsivity and sensation seeking, although positive, were small to medium in magnitude (based on guidelines of $r =$ .10 as small, .30 as medium, and .50 as large; Cohen, 1992). Adolescents with higher overall levels of impulsivity also showed higher overall levels of sensation seeking ($r = .35$), but the relation between linear changes was more modest ($r = .21$) and was not significantly different than zero, 95% confidence interval [−0.01, 0.44]. Put differently, only 4% of the variance in linear changes in sensation seeking could be accounted for by changes in impulsivity. Finally, adolescents who had more curvature in impulsivity tended to also have more curvature in sensation seeking (*r* between quadratic changes = .41). Thus the results from the bivariate LGMs were consistent with the prediction of the dual systems model that age-related changes in impulsivity and sensation seeking are largely distinct.

Discussion

This article reports three findings, each consistent with the dual systems model of adolescent development. Our first major finding concerns the average population-level age trends in impulsivity and sensation seeking. Mean levels of impulsivity were found to decline through adolescence and then level off as youth reached their mid-20s, which is consistent with neurobiological research indicating that cortical regions involved in impulse control and planning continue to mature through early adulthood. In contrast, mean levels of sensation seeking were found to sharply increase until mid-adolescence, peaking around age 16 years, and then slowly decline through the mid-20s. This age trend is consistent with neurobiological research indicating that subcortical regions that respond to emotion, novelty, and reward are more responsive in middle adolescents than in either children or adults. To our knowledge, this is the first report of such age trends from longitudinal data.

Table 2
Parameter Estimates for Univariate and Bivariate Latent Growth Curve Models of Sensation Seeking (SS) and Impulsivity (IMP)

Parameter	Model 1: Impulsivity	Model 2: Sensation seeking	Model 3: Impulsivity and sensation seeking
		Means	
IMP Level	−.10 [−.15, −.06]		−.10 [−.14, −.06]
IMP Linear Change	−.12 [−.14, −.10]		−.12 [−.14, −.10]
IMP Quadratic Change	.00 [−.01, .01]		.00 [−.01, .01]
SS Level		−.04 [−.08, .01]	−.04 [−.09, .01]
SS Linear Change		.03 [.01, .05]	.03 [.01, .05]
SS Quadratic Change		−.02 [−.03, −.02]	−.02 [−.03, −.01]
		Variances	
IMP Level	.26 [.22, .30]		.26 [.02, .05]
IMP Linear Change	.04 [.02, .05]		.03 [.02, .05]
IMP Quadratic Change	.01 [.002, .01]		.004 [.002, .007]
SS Level		.36 [.31, .40]	.35 [.03, .40]
SS Linear Change		.04 [.02, .05]	.04 [.03, .05]
SS Quadratic Change		.003 [.001, .005]	.003 [.001, .005]
		R^2	
IMP (ages 12–24 years)	.27–.79	—	.28–.72
SS (ages 12–24 years)		.36–.69	.35–.67

Note. The 95% confidence intervals are in brackets.

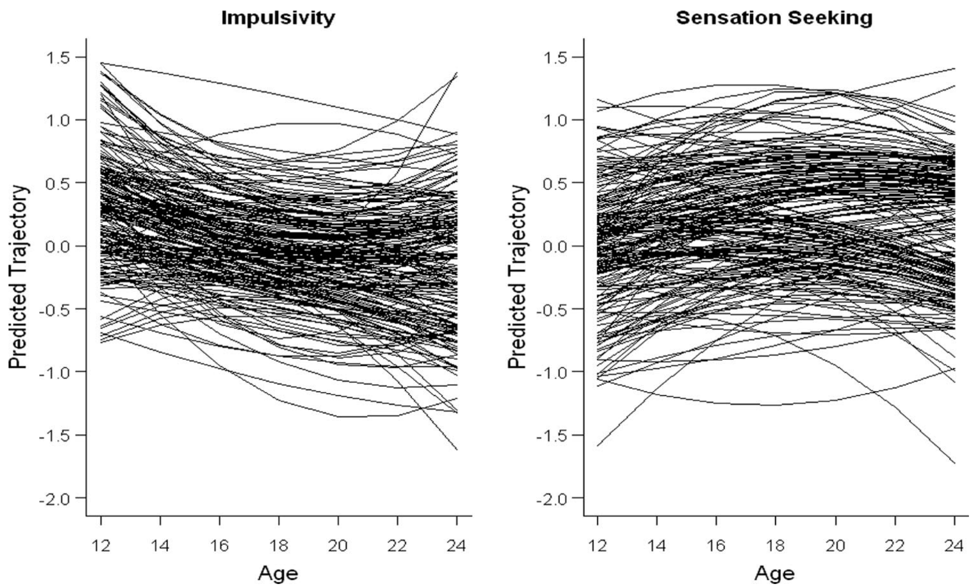

Figure 3. Development of impulsivity and sensation seeking as implied by parameters from univariate latent growth curve models. See Table 2 for parameter estimates and confidence intervals.

Our second major finding is that there were significant individual differences in all three components of change in impulsivity and sensation seeking. The finding of individual differences in change indicates that although most individuals do show increases in sensation seeking and decreases in impulsivity during early adolescence, the magnitudes of these changes differ from person to person, with some teenagers experiencing developmental changes that resemble the normative trends very little, if at all. It will be important for future neuroscience research in this area to pay attention to person-to-person variation that is likely to exist in

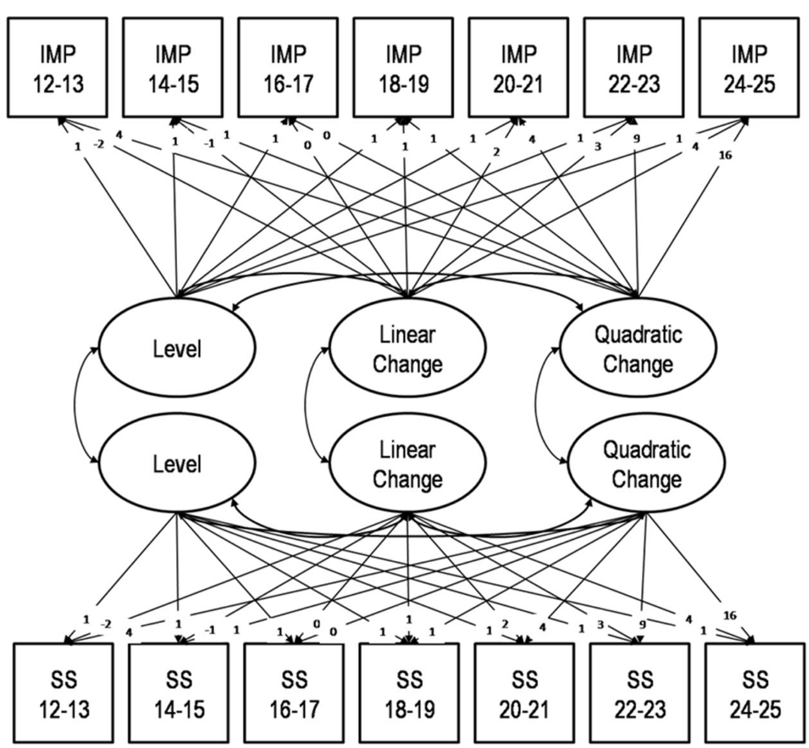

Figure 4. Bivariate latent growth curve model of the association between age-related changes in impulsivity and sensation seeking. IMP = impulsivity; SS = sensation seeking.

Table 3
Correlations Among Latent Growth Curve Factors of Impulsivity (IMP) and Sensation Seeking (SS)

Factor	1	2	3	4	5	6
1. SS Level	—					
2. SS Linear Change	.09 [−.05, .22]	—				
3. SS Quadratic Change	−.41 [−.55, −.27]	−.71 [−.86, −.57]	—			
4. IMP Level	**.35 [.26, .45]**	−.14 [−.28, .01]	−.01 [−.20, .19]	—		
5. IMP Linear Change	.17 [.03, .31]	**.21 [−.01, .44]**	−.32 [−.63, −.02]	.15 [.00, .30]	—	
6. IMP Quadratic Change	−.17 [−.32, −.03]	−.14 [−.40, .11]	**.41 [.04, .78]**	−.30 [−.44, −.16]	−.82 [−.93, −.69]	—

Note. Estimates come from Model 3. Bolded values highlight the level–level correlations and slope–slope correlations. The 95% confidence intervals are in brackets.

brain activity patterns and that may potentially underlie the person-to-person variation we have documented at the behavioral level in this report. Finally, the correlation between individual differences in change in impulsivity and sensation seeking was only .21 and was not significantly different than zero, suggesting that the two personality traits develop relatively independently of one another. These findings support the contention by Steinberg et al. (2008) that impulsivity and sensation seeking are "distinct phenomena that are subserved by different brain systems and follow different developmental trajectories" (p. 1766). However, given that the socioemotional and cognitive control systems thought to underlie these personality constructs are functionally and anatomically connected, it will be important for future research to examine how intraindividual changes in impulsivity and sensation seeking interact with each other to influence risk-taking behaviors in adolescence.

A significant strength of the current analyses is the size and scope of the CNLSY project: The predicted mean trends were found in a very large data set of over 7,000 ethnically and economically diverse adolescents with up to five longitudinal measurements spanning 12 years. One customary and unfortunate trade-off in data sets of this size is the depth and quality of measurement. Impulsivity and sensation seeking were measured using only six items. It is important to note that despite the limitations inherent in relying on an abbreviated self-report measure, the mean trends observed in the current article are highly consistent with previous cross-sectional research by Steinberg et al. (2008) that used multiple behavioral and self-report measures of impulsivity and sensation seeking in a smaller sample. Thus evidence from different studies that have different methodological strengths and weaknesses are converging on a similar result.

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