JOURNAL OF
Research on Adolescence

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The Development of Impulse Control and Sensation-Seeking in Adolescence: Independent or Interdependent Processes?

Elizabeth P. Shulman
Brock University

Kathryn Paige Harden
University of Texas at Austin

Jason M. Chein and Laurence Steinberg
Temple University

This study examines whether changes in impulse control and sensation-seeking across adolescence and early adulthood reflect independent or interdependent developmental processes. Data are drawn from a national longitudinal study (*N* = 8,270; 49% female; 33% Black, 22% Hispanic, 45% non-Black, non-Hispanic). An autoregressive latent trajectory model is used to test whether development in one trait influences development in the other. Although levels of these traits are inversely correlated, we do not find evidence that change over time in either trait is influenced by the prior level of the other. This failure to reject the null hypothesis is consistent with the view that sensation-seeking and impulse control are the products of distinct neuropsychological systems that develop independently of one another.

Adolescence has long been regarded as a time of elevated exuberance, rashness, and risky decision-making. The dual-systems model (Casey, Getz, & Galvan, 2008; Steinberg, 2008) offers a theoretical account of this behavioral pattern that centers on the distinct patterns of development in two brain systems: the incentive-processing system, which motivates individuals to pursue rewards, and the cognitive control system, which equips individuals to restrain their impulses. The sensitivity of the incentive-processing system is thought to increase dramatically in the early stages of adolescence and then decline in late adolescence or early adulthood [e.g., Urošević, Collins, Muetzel, Lim, and Luciana (2012); see Somerville, Jones, and Casey (2010) for a review]. In contrast, the cognitive control system is thought to increase in strength gradually and monotonically across this age span (Luna, Padmanabhan, & O'Hearn, 2010). To date, researchers have not examined the extent to which the developmental trajectories of these systems are interrelated.

In the present report, we address this question using data from a large longitudinal study. Consistent with prior work on this data set (e.g., Harden & Tucker-Drob, 2011), we use self-reported tendencies toward sensation-seeking and impulse control as indices of the statuses of the incentive-processing and cognitive control systems, respectively. The key contribution of the present analysis is that we examine whether growth in either of these systems has a prospective influence on growth in the other. We do so by conducting an autoregressive latent trajectory (ALT) analysis (Bollen & Curran, 2004).

The dual-systems model views the incentive-processing and cognitive control systems as distinguishable neural networks that interact continually with one another. Coordination between these systems is necessary every time an impulse arises to satisfy a short-term desire, but when restraining that impulse serves a long-term goal (e.g., resisting an urge to eat a donut to stay true to a long-term health goal). One's behavior in such situations—those in which the incentive-processing and cognitive control systems produce conflicting motivations—is hypothesized to reflect the relative strength of these two systems.

Due to observed (inverse) correlations between measures of sensation-seeking and impulse control, sensation-seeking often has been construed as a facet of impulsivity (the opposite of impulse control). However, a factor analysis of data collected from 400 young adults revealed that sensation-seeking is better characterized as a construct distinct from, but correlated with impulsivity (Whiteside & Lynam, 2001). Moreover, Harden and Tucker-Drob (2011) found that levels of sensation-seeking and impulse control, though inversely correlated, followed distinct courses of development across adolescence and early adulthood. These findings

Requests for reprints should be sent to Elizabeth P. Shulman, Department of Psychology, Brock University, 500 Glenridge Ave., St. Catharines, ON, L2S 3A1, Canada. E-mail: eshulman@brocku.ca

DOI: 10.1111/jora.12181

along with different age-related patterns observed in cross-sectional research (Steinberg et al., 2008) further underscore the separability of sensation-seeking and impulsivity. They also accord with neurobiological evidence that the incentive-processing and cognitive control brain systems are structurally distinct and follow different courses of development across adolescence and early adulthood (see Somerville et al., 2010 for a review).

Evidence for the reduced responsiveness of the incentive-processing system in adulthood relative to adolescence has emerged in several studies (e.g., Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Cohen et al., 2010; Galvan et al., 2006; Luciana, Wahlstrom, Porter, & Collins, 2012). Despite a burgeoning literature examining the dual-systems model and its neurological mechanisms, however, it remains unclear why the responsiveness of this system wanes in early adulthood. One possibility is that the declining responsiveness of the incentive-processing system in late adolescence is causally related to the increasing strength of the cognitive control system, an inference that is easily drawn from existing descriptions of the dual-systems model. For example, Somerville et al. (2010) describe the developmental trajectory of the incentive-processing system as undergoing rapid developmental change in early adolescence and then reaching full maturity prior to the cognitive control system. In their visual depiction of this model (see Figure 1), the magnitude of the gap between the lines representing development of the incentive-processing and cognitive control regions is proposed to correspond to the degree of propensity for risk-taking. The gap grows across the earlier stages of adolescence because maturation of the incentive-processing system outpaces maturation of the cognitive control system, but it shrinks in the latter stages because cognitive control continues to develop after growth in the incentive-processing system tapers off.

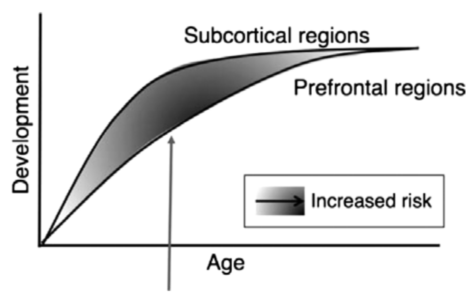

FIGURE 1 Theoretical Model of Development of the Incentive-processing and Cognitive Control Regions. This figure, reproduced with permission from Somerville et al. (2010, Figure 1), is described as a "model for enhanced affective and incentive-based behavior in adolescence" in which the "subcortical regions" correspond to the incentive-processing system and the "prefrontal regions" to the cognitive control system. The gap between the lines representing the rate of development in the subcortical and prefrontal regions is posited to reflect the magnitude of risk-taking propensity.

Although Figure 1 depicts the development of the incentive-processing system as plateauing, evidence reviewed by Somerville et al. (2010) indicates that the responsiveness of the incentive-processing system actually *declines* after mid-adolescence. It seems reasonable, then, to hypothesize that the continued strengthening of cognitive control across the latter stages of adolescence might be responsible for this decline in the responsiveness of the incentive-processing system (e.g., Galvan et al., 2006; Urošević et al., 2012). Indeed, neural connections between prefrontal regions involved in cognitive control and limbic and paralimbic regions that mediate incentive processing strengthen across late adolescence; this, in turn, enables the prefrontal cortex to detect and modulate impulses arising from subcortical regions (Somerville et al., 2010). Such connections could, in theory, permit the cognitive control system to dampen the incentive-processing system's responsiveness, not only on a moment-to-moment basis, but also in an enduring manner. Thus, this presentation of the dual-systems model can easily be interpreted as implying that continued growth in the cognitive control system drives down the responsiveness of the incentive-processing system in late adolescence and early adulthood.

On the other hand, the development of the cognitive control and incentive-processing systems could be independent. As noted earlier, there are distinct temporal patterns in the maturation of these systems, with the incentive-processing system following an inverted-U pattern and the cognitive control system maturing linearly with age. In addition, preliminary evidence suggests that development of the incentive-processing system is more dependent on puberty than is development of the cognitive control system (e.g., Smith, Chein, & Steinberg, 2013; Steinberg, 2008; Steinberg et al., 2008; Urošević, Collins, Muetzel, Lim, & Luciana, 2014).

Longitudinal studies are necessary to examine whether development of the incentive-processing and cognitive control systems reflects independent or interdependent processes. In the absence of long-term longitudinal data directly examining growth in these neurobiological systems, a reasonable approach is to examine the dynamic interplay over time in sensation-seeking and impulse control, which are thought to reflect their functional status.

In prior work, Harden and colleagues examined change over time in self-reported sensation-seeking and impulse control in a large, longitudinal study of adolescents and young adults. Consistent with predictions derived from the dual-systems model, they found that sensation-seeking rises and falls, whereas impulse control increases steadily with age across this span (Harden & Tucker-Drob, 2011). Furthermore, a slower decline in sensation-seeking was associated with increasing use of alcohol, and slower growth in impulse control was associated with increasing the use of alcohol, marijuana, and cigarettes (Quinn & Harden, 2013). Also, increases in sensation-seeking were correlated with increases in delinquency (Harden, Quinn, & Tucker-Drob, 2012).

Although the proposition that the decline in the incentive-processing system's influence in early adulthood is due to continued strengthening of the cognitive control system is intuitively appealing, given the evidence that the incentive-processing and cognitive control systems are distinct from one another, it seems at least equally likely that these systems develop independently. The present analysis builds on Harden and Tucker-Drob's (2011) analysis by going beyond modeling the average growth trajectories for impulse control and sensation-seeking and testing whether growth in these traits is *prospectively* related over time. Specifically, the ALT model employed in this study extends the earlier work by testing whether being higher or lower than expected (given one's prior trajectory) in one trait is related to being higher or lower than expected on the other trait at the subsequent time point. If we were to observe such lagged effects (either unidirectional or reciprocal), it would provide evidence that the developmental processes underlying these traits are interrelated. The large sample in which we test these alternative hypotheses has ample power to detect even very small effects. So, although a failure to find significant lagged effects would not constitute positive evidence that the development of impulse control and sensation-seeking is independent, the sample gives us an excellent opportunity to detect evidence of interdependence if it exists.

METHODS

Sample

Data for the present analyses come from surveys of the biological children of women studied in the NLSY79, a large-scale, longitudinal study that began in 1979, when the women were between 14 and 22. Starting in 1986, researchers began collecting data on the women's children (The NLSY79 Children and Young Adults study or "CNLSY"; see http://www.bls.gov/nls/nlsy79ch.htm for details), and in 1994 they added a self-administered survey to be completed by those aged 10 or older. The response rate was 95% at the initial survey and retention was high (about 90%) through 2006 [see Harden and Tucker-Drob (2011) and Quinn and Harden (2013) for further details].

The analytic sample for the present report consisted of individuals (N = 8,270) who completed measures of impulse control or sensation-seeking at least once between 1994 and 2010 while aged 10–25 (49% female, 33% Black, 22% Hispanic, 44% White). Most participants provided data for four (30.4%) or five (30.0%) (M = 4.00, SD = 1.21) measurement occasions and very few provided data at only one (2.6%) or two (10.3%). Having data at more time points was largely a function of being born earlier and therefore having had the opportunity to provide data at more waves. (This source of "missingness" is accounted for in the analysis by controlling for the age of each participant's mother at the time the participant was born, a variable that is almost perfectly correlated with the participants' own years of birth: r = .93). Consistent with prior studies (Harden & Tucker-Drob, 2011; Shulman, Chein, Harden, & Steinberg, in press), we examine growth in impulse control and sensation-seeking between ages 12 and 25. This allows us to focus on the dynamics that occur within adolescence and the transition to adulthood. Data are organized by age in 2-year groupings (12–13, 14–15, 16–17, 18–19, 20–21, 22–23, and 24–25) because respondents were surveyed biennially.

Measures

Sociodemographic variables. We controlled for respondents' sex and race [*Black, Hispanic, or neither* (the reference category)], as well as *maternal birth age*. It is important to control for maternal birth age because participants born to relatively older mothers are systematically underrepresented at the older end of the age range. Other covariates were *maternal income* at age 30, which included wages and government support (log-transformed); *maternal educational attainment* at age 30; and *maternal intelligence*, assessed in 1980 using the Armed Services Vocational Aptitude Battery. Continuous variables were centered on their means for analysis.

Impulse control and sensation-seeking. Consistent with prior analyses (Harden et al., 2012;

Harden & Tucker-Drob, 2011; Shulman et al., in press), impulsivity was assessed with three items (α = .51): (1) “I often get in a jam because I do things without thinking,” (2) “I think that planning takes the fun out of things,” and (3) “I have to use a lot of self-control to keep out of trouble.” Sensation-seeking was also assessed with three items (α = .69): (1) “I enjoy taking risks”; (2) “I enjoy new and exciting experiences, even if they are a little frightening or unusual”; and (3) “Life with no danger in it would be too dull for me.” Items were rated on a 4-point scale ranging from *strongly agree* to *strongly disagree*. A prior analysis indicated that these scales exhibit measurement invariance across age groups (Shulman et al., in press). We keyed the variables such that higher scores indicated greater impulse control or sensation-seeking. Responses were averaged and, to facilitate direct comparison, converted to z-scores using (for each scale) the grand mean and grand standard deviation (across ages).

Analysis

Correlations of the observed measures of impulse control and sensation-seeking are reported in Table 1. Stability was observed in each construct and increased with age, but was not so high as to preclude analysis of change within these traits over time.

To investigate whether development of impulse control and sensation-seeking is interrelated over time, we estimated a bivariate ALT model with age centered at 18–19 years (see Figure 2 for the specification). (The centering point does not affect the parameters of greatest interest in this model.) The model was estimated using full information maximum likelihood in Mplus version 5.21, and standard errors were adjusted to account for clustering within families.

Based on prior analyses (Shulman et al., in press) demonstrating that growth in both constructs follows a cubic pattern [model fit for impulse control for males was $\chi^2(50)$ = 59.94, comparative fit index (CFI) = .99, root mean square error of approximation (RMSEA) = .007 and for females was $\chi^2(50)$ = 56.75, CFI = 1.00, RMSEA = .006; model fit for sensation-seeking for males was $\chi^2(50)$ = 64.64, CFI = .99, RMSEA = .008 and for females was $\chi^2(50)$ = 111.57, CFI = .97, RMSEA = .017], each construct was specified as having a latent intercept, slope, quadratic, and cubic term. This earlier analysis tested models specifying different forms of growth in sensation-seeking and impulse control (examined separately). The different forms of growth tested included no growth, linear growth, quadratic growth, cubic growth, and latent basis (in which the shape of the growth curve is not specified *a priori*). For both impulse control and sensation-seeking, the cubic models provided the closest fit. The model used in the present report allowed for individual deviance from the average estimate (random effects) in all

TABLE 1
Correlations (Zero-Order) Among Measures of Impulse Control (IC) and Sensation-Seeking (SS) Across Age

		IC							*SS*						
	Age	*12–13*	*14–15*	*16–17*	*18–19*	*20–21*	*22–23*	*24–25*	*12–13*	*14–15*	*16–17*	*18–19*	*20–21*	*22–23*	*24–25*
IC	12–13	1													
	14–15	.30	1												
	16–17	.24	.34	1											
	18–19	.20	.30	.40	1										
	20–21	.22	.26	.35	.44	1									
	22–23	.19	.27	.35	.41	.41	1								
	24–25	.22	.23	.27	.34	.46	.50	1							
SS	12–13	−.33	−.16	−.10	−.10	−.14	−.11	−.10	1						
	14–15	−.09	−.32	−.15	−.13	−.11	−.12	−.09	.37	1					
	16–17	−.07	−.10	−.25	−.13	−.13	−.14	−.09	.29	.43	1				
	18–19	−.06	−.10	−.13	−.25	−.15	−.18	−.07	.27	.39	.45	1			
	20–21	−.06	−.08	−.13	−.10	−.23	−.12	−.08	.25	.37	.42	.46	1		
	22–23	*−.03*	*−.04*	−.08	−.13	−.12	−.23	*−.08*	.22	.29	.37	.52	.49	1	
	24–25	−.10	−.07	−.10	−.11	−.15	−.18	−.24	.17	.30	.37	.43	.51	.58	1

Note. All correlation coefficients are significant at an alpha level of .05 except those that are italicized. Outlined coefficients represent the unadjusted correlations between IC and SS assessed concurrently. Shaded cells provide information about the stability of each construct across age.

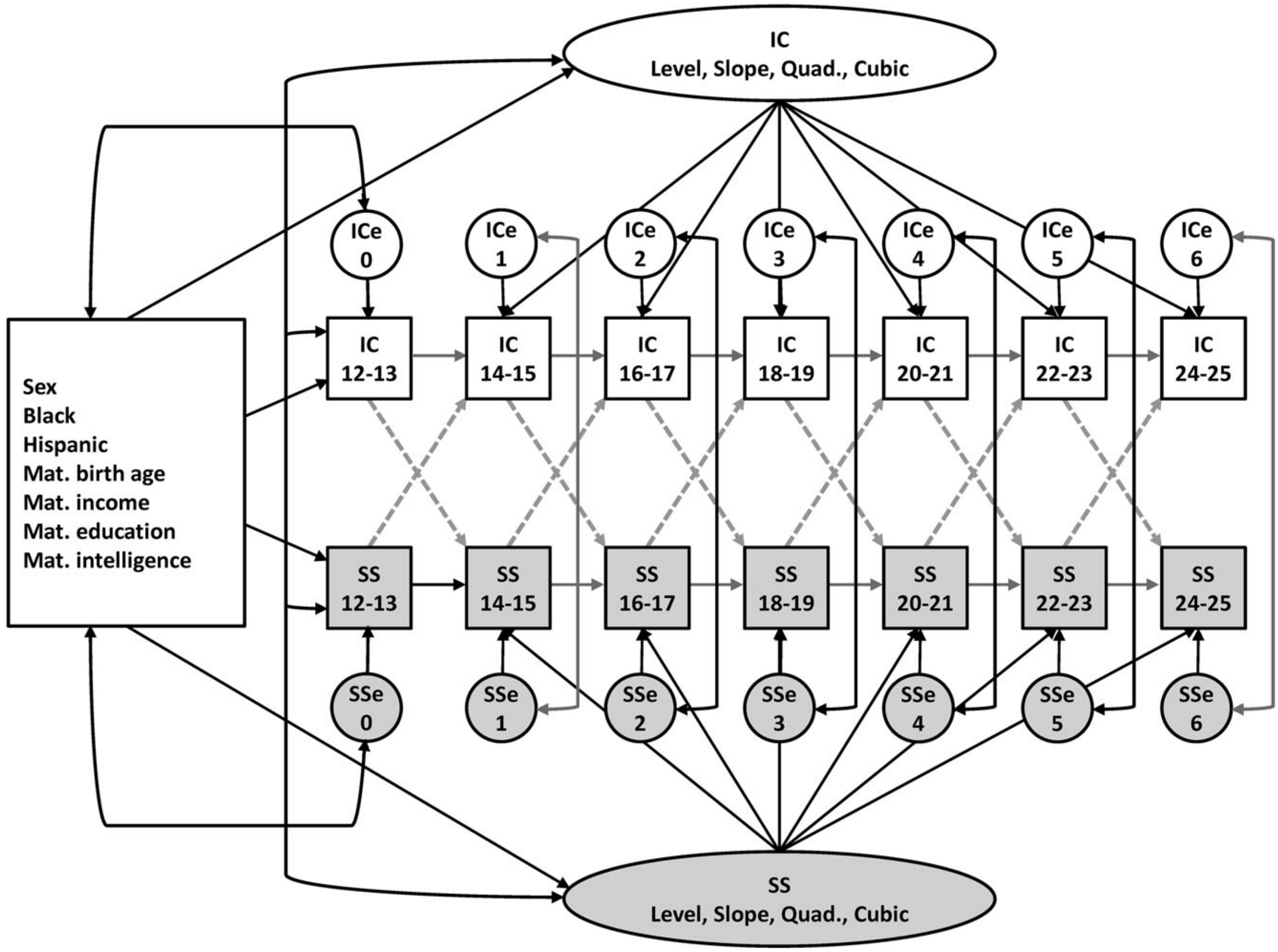

FIGURE 2 Simplified Illustration of the Autoregressive Latent Trajectory Model. IC = impulse control, SS = sensation-seeking. Single-headed arrows represent regressions, and double-headed arrows represent covariances. For visual clarity, the four latent growth parameters for each construct are summarized within a single oval. Mat. = maternal. Rectangles represent observed variables and ovals represent latent parameters (including error terms, labeled "e"). Dashed lines represent the cross-lags. Gray paths were found to be nonsignificant.

the growth parameters except for the cubic ones. (Allowing the cubic terms to be random produced out-of-range estimates, suggestive of overfitting of the model.)

Following Bollen and Curran (2004), we treated the earliest measurements of impulse control and sensation-seeking (at ages 12–13) as exogenous to the growth processes (see Figure 2). These measurements and the latent growth parameters for impulse control and sensation-seeking were allowed to be correlated with one another and were regressed on the control variables. The residual variance terms in the all of the repeated measures of impulse control and sensation-seeking were allowed to vary across age and concurrent measures were allowed to covary. We refer to these covariance terms as *pairings*. We also specified *autoregressions*, which allow residual variance in a construct at a given time point to be accounted for by residual variance in the same construct at the prior time point.

To test our main research question, we specified *cross-lags*. Specifically, the cross-lags assessed whether deviance from one's expected trajectory on one variable (e.g., impulse control) at a given time point predicted deviance from one's expected trajectory on the other variable (e.g., sensation-seeking) at the following time point, controlling for the within-age pairings and other predictors in the model (see Figure 2). It should be noted that these cross-lags represent a conservative test of interdependence in the development of sensation-seeking and impulse control (i.e., the model guards against erroneously finding evidence of interdependence in the development of impulse control and sensation-seeking).

RESULTS

Because the trajectories of sensation-seeking and impulse control in this sample have been reported in detail elsewhere (Harden & Tucker-Drob, 2011), we focus in the Results and Discussion sections primarily on the parameters of the model that directly address our research question—the cross-lags. A full reporting of the model estimates is available in the supporting information.

In the initial ALT model, we allowed all the pairings, autoregressions, and cross-lags to be freely estimated. This model provided a close fit to the data [$\chi^2(59) = 44.19$, $p = .92$, CFI = 1.00; Tucker-Lewis Index (TLI) = 1.00; RMSEA = .00]. As expected, estimated levels (intercepts) of impulse control and sensation-seeking were significantly inversely related ($r_{\text{partial}} = -.52$), meaning that those who tended to be high in impulse control tended to be low in sensation-seeking and vice versa. Re-estimating the model using different ages as the centering point revealed that this inverse partial correlation did not vary much during adolescence, but declined in early adulthood [$r_{\text{partial}} = -.57$ (age 14–15), $-.52$ (age 16–17), $-.47$ (age 20–21), $-.17$ (age 22–23), and $-.24$ (age 24–25)]. At age 24–25, the partial correlation between the intercepts was no longer statistically significant.

In the original model, the pairings were significantly less than zero at every age except 14–15 ($p = .06$) and 24–25 ($p > .10$). However, the magnitudes of the pairings (for ages 14–25) did not vary significantly with age [according to the Satorra-Bentler scaled chi-square difference test, $\Delta\chi^2_{SB}$ (5) = 1.39, $p > .05$] and were, on average, significantly less than zero. That is, individuals reporting higher-than-expected (based on their growth trajectory) levels of impulse control at a given age (before age 24) were also likely to report lower-than-expected levels of sensation-seeking and vice versa.

To determine whether there were lagged reciprocal influences between impulse control and sensation-seeking, we examined the cross-lags. None of these parameters reached statistical significance when freely estimated. When the cross-lags regressing sensation-seeking on prior impulse control were constrained to zero, the resulting change in model fit was not significant [$\Delta\chi^2_{SB}$ (6) = 4.28, $p > .05$. Constraining the reciprocal lags (impulse control regressed on prior sensation-seeking) to be zero also failed to worsen model fit [$\Delta\chi^2_{SB}$ (6) = 7.47, $p > .05$]. Thus, neither the lagged effects of impulse control on sensation-seeking nor the lagged effects of sensation-seeking on impulse control were found to be significant.

To ensure that the null findings for the cross-lags held for male and female participants, we estimated the same series of models for each gender. In both cases, eliminating cross-lagged paths failed to produce a significantly worse model fit [for males, $\Delta\chi^2_{SB}$ (12) = 15.10, $p > .05$; for females, $\Delta\chi^2_{SB}$ (12) = 8.51, $p > .05$]. Thus, despite our large sample sizes (which confer substantial statistical power), our models yielded no evidence of lagged effects of impulse control on sensation-seeking, or of sensation-seeking on impulse control (after controlling for correlations in their growth processes and pairings) at any age for either sex.

DISCUSSION

Numerous studies suggest that sensation-seeking and impulse control represent the outputs of distinct systems within the brain that follow disparate courses of development across adolescence. This study's novel contribution is that it investigated whether development in each trait is influenced by development in the other. The results suggest that the answer to this question is no—or, more precisely, we failed to find evidence that the answer is yes. Despite the use of a large sample with sufficient statistical power to detect small effects, we uncovered no evidence of any lagged effects of impulse control on later sensation-seeking or of sensation-seeking on later impulse control. This finding provides better support for the proposition that the developmental processes underlying age-related changes in impulse control and sensation-seeking are independent (Steinberg, 2008) than for the proposition that they are interdependent.

One of the strengths of the analytic approach we used was that we were able to account for correlations due to common method variance (e.g., concurrent measurement of sensation-seeking and impulse control using a single self-report scale) and among the growth processes for the two constructs. Because our model takes these factors into account, it yields a conservative test of the relations over time between sensation-seeking and impulse control, meaning that the model guarded against erroneous results suggesting interdependence in the development of these two processes. Had we used a less conservative approach—for example, a bivariate cross-lag model that ignored the latent growth processes—the model fit would have been poorer, consistent with model misspecification ($\chi^2(60) = 962.84$, $p < .001$; CFI = .90; TLI = .67; RMSEA = .04). Worse, it would have produced Type 1 errors, because correlations over time between the growth parameters early in adolescence would have been reallocated to the cross-lags. For example, in both this first-order cross-lag model and a fully saturated version that estimated all possible cross-lagged and autoregressive paths (including those between nonadjacent time points), the models suggested that impulse control was lower at ages 14–15 and 16–17 when sensation-seeking had been higher at the prior time point (βs = −0.09 and −0.07, *p*s < .001). That we find these paths in the cross-lag model but *not* in the ALT model suggests that the significant results are artifacts of ignoring the latent growth processes in sensation-seeking and impulse control. Also, it is worth noting that the fact that the cross-lag models *do* produce some significant cross-lagged paths suggests that failure to find such paths in the ALT model is not due to the relatively poor reliability of the scales. In short, had we relied on a less appropriate test of our research question, we might have reached the erroneous conclusion that some of the lagged effects were significant when the more comprehensive model indicates that they are not.

The lack of lagged reciprocal effects between sensation-seeking and impulse control does not imply that there is no association between these traits. On the contrary, our model indicates, as expected, that high levels of sensation-seeking (at any given moment) are correlated with weaker impulse control. This observation is perfectly compatible with the dual-systems model, which focuses on developmental change in these traits and their underlying neurobiological systems—not on their momentary correlations.

Of course, we cannot infer conclusively, based on our results, that the incentive-processing and cognitive control systems develop independently; after all, “the absence of evidence is not evidence of absence.” Aside from the general inability to “prove” the null hypotheses, there are three primary caveats to consider: the indirect measurement of neurobiological systems, reliance on self-report, and the low resolution timescale. Although large-scale studies, such as the CNLSY, allow for the detection of small effects, their measures typically are inexpensive and brief and do not allow direct assessment of neurobiological processes. As a result, we have only indirect measures of the functioning of individuals’ incentive-processing and cognitive control systems. Caution is therefore warranted in interpreting our findings as evidence of the developmental courses of *brain systems*.

Second, sensation-seeking and impulse control were assessed with 3-item scales of merely adequate reliability (in the case of impulse control), which is commonly observed in scales with few items. Despite the lower internal consistency of the impulse control scale, there are many reasons to believe that it does assess the intended construct. Impulse control increases over time and exhibits increasing stability with age, consistent with prior research. In addition, impulse control scores are significantly correlated with concurrent measures of conscientiousness ($r = .28$) and emotional stability ($r = .32$) (Harden & Tucker-Drob, 2011), indicating convergent validity, and with adolescents’ self-reports of delinquency ($r = -.26$), alcohol use ($r = -.15$), marijuana use ($r = -.13$), and cigarette use ($r = -.15$) (Quinn & Harden, 2013), indicating predictive validity. Although both impulse control and sensation-seeking were assessed via self-report, common source and method bias are rendered less problematic by the use of an ALT model, which relegates these biases to the pairings (the covariances of the residual terms at a given age), allowing for reliable tests of the other parameters. Nevertheless, the low reliability of the self-report scales may have interfered with our ability to detect interdependence in the development of impulse control and sensation-seeking.

Finally, although our results fail to support the hypothesis that sensation-seeking and impulse control (and the neurobiological systems that subserve these phenomena) develop interdependently, it could be that the development of these systems is in fact interdependent, but that the 2-year spacing between interviews was too long to detect reciprocal (or unidirectional) influences. A study employing more closely spaced interviews may yet reveal some interdependence in the development of cognitive control capacities and reward-seeking tendencies.

Despite these caveats, the present study represents an important step toward understanding the interplay between the incentive-processing and cognitive control systems as they develop across adolescence. At the same time, because of the limitations enumerated above, it is important that future studies seek evidence of interdependence in the development of sensation-seeking and impulse control using more sensitive methods. For now, we can only conclude that, although the neural systems underlying these traits may be continually engaged with one another, we find no evidence that the developmental trajectories of these traits are interdependent. It may be the case that development of impulse control and sensation-seeking, subserved by distinct brain systems, proceeds independently.

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