Psychol Addict Behav. Author manuscript; available in PMC 2012 March 1.

Published in final edited form as:
Psychol Addict Behav. 2011 March ; 25(1): 69–79. doi:10.1037/a0021958.

Changes in Self-control Problems and Attention Problems During Middle School Predict Alcohol, Tobacco, and Marijuana Use During High School

Kevin M. King,
Department of Psychology, University of Washington

Charles B. Fleming,
Social Development Research Group, School of Social Work, University of Washington

Kathryn C. Monahan, and
Social Development Research Group, School of Social Work, University of Washington

Richard F. Catalano
Social Development Research Group, School of Social Work, University of Washington

Abstract

Although deficits in impulse control have been linked to adolescent use of alcohol and illicit drugs, less attention has been given to variability in change in impulse control across adolescence and whether this variability may be a signal of risk for early substance use. The goals of the current study were to examine growth in two aspects of impulse control, self-control problems and attention problems, across middle adolescence, and to test the prospective effects of level and change in these variables on levels and change over time in substance use. Data are from a community sample of 955 adolescents interviewed (along with their parents and teachers) annually from 6th to 11th grade. Results indicated that greater self-control problems and attentional problems in the 6th grade and increases in these problems over time were associated with higher levels of substance use at 11th grade. Our results suggest that modeling change over time enhances the understanding of how impulse control influences the development of substance use.

Keywords

impulsivity; substance use; adolescence; growth curve models

It is well documented that adolescents engage in a great number of risky activities, including drug (Substance Abuse and Mental Health Services Administration, 2007) and alcohol use (Johnston, O'Malley, Bachman, & Schulenberg, 2008). The peak period of risk for substance use disorders is young adulthood (ages 18 – 22; Kessler, Berglund, Demler, Jin, & Walters, 2005), while the roots of these disorders, such as initiation and escalation, are found during adolescence. Yet risk-taking behavior during adolescence does not appear to be rooted in

Correspondence concerning this article should be addressed to Kevin M. King, Department of Psychology, University of Washington, Box 351525, Seattle WA 98195-1525, kingkm@uw.edu.

variations in appraising the costs of risky behavior or variations in perceived vulnerability to negative consequences of risky behavior (Fischhoff et al., 2000), leading some to suggest that increased risk behavior during adolescence is due to emotional and social factors, rather than cognitive ones (Cauffman & Steinberg, 2000; Scott, Reppucci, & Woolard, 1995; Steinberg & Cauffman, 1996). One factor that may play a strong role in adolescent risk taking is developmental immaturity in the ability to control impulses. Indeed, the period from adolescence to early adulthood is marked by developmental increases in the ability to control impulses (Monahan, Steinberg, Cauffman, & Mulvey, 2009; Steinberg et al., 2008; Steinberg & Cauffman, 1996), and it is likely that these developmental increases impact both initiation and frequency of risk-taking behavior. Given that early substance use places youth at risk for a number of long-term negative outcomes (King & Chassin, 2007), it is especially important to understand how developing impulse control influences the emergence of early substance use.

Multiple studies have documented that poor impulse control (or related constructs such as impulsivity, behavioral undercontrol, or disinhibition) is a risk factor for the use of alcohol and illicit drugs (Gullo & Dawe, 2008; Hawkins, Catalano, & Miller, 1992; King & Chassin, 2004; Kirisci, Tarter, Reynolds, & Vanyukov, 2006; Kirisci, Tarter, Vanyukov, Reynolds, & Habeych, 2004; Mezzich et al., 2007; Sher & Trull, 1994; Tarter et al., 2003). Not only are impulsive youth more likely to use alcohol or drugs, but they disproportionately experience negative consequences when they use substances (King & Chassin, 2007; Stice, Barrera, & Chassin, 1998; Wills et al., 2001). Prior studies have shown that poor impulse control is broadly associated with risk for alcohol, tobacco, and illegal drug use during middle school (e.g., Wills et al., 2001; Wills, Walker, Mendoza, & Ainette, 2006); greater levels of substance use in the sixth grade (Wills & Stoolmiller, 2002); and more rapid increases in substance use from middle school to high school (Wills & Stoolmiller, 2002). One dimension of impulse control, attention problems (often operationalized as attention-deficit disorder), has been consistently linked to risk for smoking, and has been more broadly implicated in substance use problems (Molina & Pelham, 2003). However, other studies using community samples have suggested that this may be due to a subset of children with comorbid ADHD and conduct problems (Jester et al., 2008), and these effects may not be specific to problem with inattention. Finally, impulse control also impacts the long-term course of substance use: individuals with poor impulse control in adolescence are more likely to develop drug disorders in early adulthood (King & Chassin, 2004).

Operationalizing Developing Impulse Control

Krueger and colleagues (2002) have suggested that underlying the associations among substance dependence, antisocial behaviors, conduct disorder, and other disorders along the externalizing spectrum is a genetically mediated, trait-like vulnerability to disinhibition, which may be reflected (at least in part) by poor impulse control. Within this framework, individuals with less ability to control their impulses are more likely to engage in a host of risky behaviors. In addition, rank-order individual differences in impulse control are expected to remain relatively stable over time (although the interaction between genes and environment may change the strength of this association over time; see Blonigen, Carlson, Hicks, Krueger, & Iacono, 2008). In other words, children at high risk for externalizing disorders and eventual substance use would be expected to always be low on impulse control, relative their peers.

However, the ability to control one’s impulses increases developmentally. A growing body of evidence on psychosocial development suggests that there are significant developmental improvements in impulse control throughout adolescence and into early adulthood (Blonigen et al., 2008; Monahan et al., 2009; Roberts, Caspi, & Moffitt, 2001; Steinberg et al., 2008).[1] Prior studies showing linkages from between-individual differences in impulse control to substance use have typically examined impulse control at a single time point, and may have missed how changes in impulse control may be related to risk for substance use. In other words, it may be important to disaggregate the level of impulse control from the rate of change over time in order to understand how deficits in the development of impulse control relative to same-age peers may be related to the development of substance use. Yet no prior research has examined whether individual differences in the rate of developmental change in impulse control during early adolescence are associated with initiation and frequency of substance use in later adolescence. In the present study, we aimed to fill this void in the literature by testing sequential latent growth curve models. This approach allowed us to test whether considering individual differences in rates of change of impulse control during early adolescence improves the prediction of later trajectories of substance use, above and beyond that predicted by initial rank order differences in impulse control.

One of the challenges to the study of impulse control during adolescence is that, despite being one of the most broadly studied constructs in psychology, definitions and measurements of impulse control vary widely across studies (Whiteside & Lynam, 2001). Recent advancements in the personality literature have emphasized that impulsivity is not a unidimensional construct (Dawe & Loxton, 2004; Whiteside & Lynam, 2001). In general, this work suggests that impulsive behavior is a product of the interaction between emotional motivations, or the tendency or desire to act on positive or negative urges, and cognitive control, the ability to planfully and actively control those urges and redirect and focus attention to appropriate stimuli (Smith et al., 2007). Although this research has largely arisen in the adult personality literature, developmental theory and research by Steinberg and colleagues have also supported this framework (Monahan et al., 2009; Steinberg, 2004; Steinberg & Cauffman, 1996), and have suggested that the cognitive and motivational dimensions of impulse control develop at different times and at different rates. For example, Monahan and colleagues linked variation in psychosocial maturity, a construct that includes impulse control as a unique subdomain, to trajectories of antisocial behavior in a high-risk sample of adjudicated adolescents. Their findings indicated that impulse control, on average, increased over time; that adolescents varied in their rate of growth; and that variation in growth was associated with different trajectories of antisocial behavior (Monahan et al., 2009). Finally, using data from the same sample, Chassin and colleagues linked late adolescent alcohol and marijuana use with suppressed trajectories of psychosocial maturity, suggesting that the development patterns of impulse control and substance use are, to some degree, intertwined (Chassin, Modecki, Cauffman, Dmitrieva, Steinberg, Piquero, et al., 2010). Given this prior research, the current study focuses on the cognitive dimension of impulse control, operationalized in two ways: We modeled the tendency to act on urges without considering the consequences as "self-control problems," and difficulties with focusing attention and concentrating as "attention problems."

Prior research has suggested that attention problems and constructs related to our "self-control problems" may differentially predict substance use. For example, retrospectively reported ADHD hyperactivity symptoms (but not inattention) predicted the progression of smoking by age 22 in a nationally representative study of adolescents (Fuemmeler, Kollins, & McClernon, 2007). On the other hand, clinically significant levels of ADHD inattention, but not impulsivity/hyperactivity, were linked to smoking in adolescents around age 15 (Tercyak, Lerman & Audrain, 2002). More generally, Molina and Pelham (2003) found that among children diagnosed with ADHD during childhood, symptoms of inattention were

[1]One potential reason for increases in impulse control during adolescence is the rapid neurophysiological changes that occur during this period, such as maturation of the dorsolateral prefrontal cortex (Giedd, 2004; Luna, Garver, Urban, Lazar, & Sweeney, 2004) and an increase in the connectivity between the cognitive control network and the sensation-seeking system (Steinberg, 2008).

NIH-PA Author Manuscript

NIH-PA Author Manuscript

more consistently and strongly related to adolescent substance use at age 15 compared to impulsivity-hyperactivity, when conduct disorder and oppositional defiant disorder were controlled. Conversely, Elkins, McGue & Iacono (2007) found prospective effects of ADHD hyperactivity/impulsivity symptoms on substance use initiation by age 14 and disorders by age 18, but only found unique effects of inattention on alcohol initiation. Generally, these findings suggest that inattention and hyperactivity/impulsivity may play distinct roles in the development of substance use during adolescence, with inattention being particularly important to early substance use, and impulsivity playing a greater role in the progression to substance-related disorders.

The Association Between Change in Impulse Control and Change in Substance Use

Although the idea that impulse control may show developmental changes is still emerging, it is well established that the prevalence of substance use increases across adolescence, as does the frequency and quantity of use (Johnston et al., 2008). In other words, much like the development of impulse control, the emergence of substance use during adolescence is a developmental process that exhibits inter-individual variability in both the level of substance use at a given age and also the rate at which adolescents change over time. Thus it is important to jointly consider predictors of the level of substance use, and predictors of its developmental course. Prior studies have shown that poor impulse control was associated with both higher initial levels and greater increases over time in substance use across middle school (e.g., Wills & Stoolmiller, 2002). It may also be that individual differences in the developmental course of impulse control may presage later individual differences in the developmental course of substance use, yet no prior studies have examined this hypothesis. The current study aims to test the degree to which considering individual differences in *change* in impulse control improves the prediction of the level of substance use and its course across adolescence. It could be that rank order differences in impulse control largely predict later trajectories of substance use. Alternately, it could be that adolescents whose impulse control worsens through middle school (and who's rank order in impulse control thus changes) engage in substance use that is higher, more rapidly increasing, or both, than their peers across high school.

Thus the goal of the current study was to test latent growth curve models of impulse control, and to connect variation in levels and change in impulse control to levels and change in substance use. We expected that higher initial levels of and increases in self-control problems during middle school would be associated with higher levels of substance use from middle school to high school and greater increases of substance use during the same developmental period.

Methods

Sample

Participants were involved in the Raising Healthy Children (RHC) project, a longitudinal study of students drawn from 10 public schools in a suburban Pacific Northwest school district. RHC is a study of the etiology of problem behaviors as well as a test of a multicomponent preventive intervention. The intervention was delivered at five of the project elementary schools and consisted of instructional staff development for teachers, parenting workshops for parents, summer camps and study clubs for students, and home-based case management services for high-risk students who exhibited academic or behavioral problems (see Catalano et al., 2003; and Haggerty, Catalano, Harachi, & Abbott, 1998 for full description of study methodology). To be included in the RHC sample, students had to remain in their school throughout the entire first year of their participation in the study and have a parent who spoke English, Spanish, Korean, or Vietnamese. In Year 1, 938 parents of 1,239 eligible students provided written consent to participate in the study. In Year 2, the sample was augmented with an additional 102 students from a second eligible pool of 131 students who newly entered 1 of the 10 schools during second grade, thus yielding a total sample of 1,040 students.[2] Prior research had demonstrated some intervention effects on growth in the frequency of use (but not use versus nonuse) of alcohol and marijuana use (but not cigarette use) from Grade 6 to Grade 10 (Brown, Catalano, Fleming, Haggerty, & Abbott, 2005).

Retention in the study was excellent and ranged from n = 960 (92% of the original sample) at Grade 6 to n = 923 (89% of the original sample) at Grade 11. Participants for the current study included 955 participants who had any data from Grade 6 through Grade 11 and complete data on the exogenous covariates (91.2% of the total sample). Eight hundred and fifty-seven participants had complete data from all waves (82% of the total sample). We compared participants who were included in the sample to those excluded (n = 85). Excluded participants were more likely to be female (60% of those excluded) than male [40.0%, $\chi^2(1, 1040) = 6.68$, $p < .05$], but did not differ from included participants in terms of initial age, ethnicity, or intervention status. Of the excluded participants, there were 16 participants who had no Grade 6 conduct problems data but did have some data at later time points. T-tests suggested that these participants did not differ from the included participants on any impulse control or substance use variables across any time point.

Of the analysis sample, 46% were originally enrolled in an intervention school; 54% were male; and 31% were low income, defined by receiving reduced-price or free lunch at school or the child's family receiving public assistance in the form of Temporary Aid to Needy Families or food stamps. The race/ethnic composition of the analysis sample was 81.6% White, 6.9% Asian or Pacific Islander, 4.8% Hispanic, 4.0% Black, and 2.7% Native American.

Data Collection

Surveys were administered to parents, teachers, and students in the spring of each year of the project. For completing surveys, parents received small monetary incentives and children received token gifts. The surveys included items measuring problem behaviors and social development constructs in the family, individual, community, school, and peer domains. Student and parent survey data were collected for all students enrolled in the project, even if they had left their original elementary school or the school district. Student surveys were administered in person, with the interviewer reading the questions aloud and participants marking their answers on an answer sheet. Teacher surveys were mailed to teachers, and parents completed surveys during a telephone interview.

Measures

Alcohol, tobacco, and marijuana use—Frequency of alcohol and marijuana use were assessed at 8th through 10th grades with items asking the adolescent to estimate on how many occasions they had consumed alcohol or used marijuana in the past year. The seven response options for both items were 0 = "Never," 1 = "1–2 times", 2 = "3–5 times," 3 = "6–

[2]Although this study drew participants from a group-randomized evaluation of an intervention, with students clustered within elementary schools, the analyses for the current study were done at the individual level, since the primary independent and dependent variables were individual-level characteristics. Moreover, analyses of the final models correcting for initial clustering indicated that school assignments (elementary, middle, or high school) did not substantively change the relationships among the study variables of interest, supporting the assumption that school assignment in 1st or 2nd grade had little influence on associations between impulse control and substance use across 6th through 11th grade.

9 times,” 4 = “10–19 times,” 5 = “20–39 times,” and 6 = “More than 40 times.” Cigarette smoking was assessed with a single dichotomous item asking the adolescent to report whether they had smoked cigarettes in the past year. Because data on the frequency of cigarette smoking were unavailable, levels and change over time in this construct, as operationalized in a latent growth curve model, could reflect experimentation with smoking, a continuation of irregular smoking (“chipping”; Presson, Chassin, & Sherman, 2002), or a progression to or continuation of regular smoking. Table 1 provides descriptive statistics on substance use across grades. Table 1 shows that mean past-year alcohol use increased from “1–2 times” in 8th grade to “3–5 times” by 11th grade, while mean marijuana use increased from between “Never” and “1–2 times” to between “1–2 times” and “3–5 times.” However, mean use among nonabstainers was higher: for alcohol, mean use rose from “3–5 times” in 8th grade to “6–9 times” by 11th grade, and for marijuana, mean use rose from “3–5 times” in 8th grade to “6–9 times” by 11th grade. The prevalence of substance use for the age groups in the current sample was similar to rates found in national epidemiological samples (Johnston et al., 2008).

Self-control problems—Self-control problems were measured at all waves by five items reflecting acting without thinking or acting without regard to the consequences. It included one self-report item (“I talk in class when I’m not supposed to”), two teacher-report items (“Explosive or unpredictable behavior” and “Impulsive or acts without thinking”), and two parent-report items (“Thinks before acting” and “Thinks of consequences before decision”). All items were coded so that high scores indicated greater problems with self-control. Because these items were chosen on the basis of their face validity, and internal consistency was modest across waves (Cronbach’s $\alpha = .66$ to .69), we performed confirmatory factor analyses for all five items at each wave to test whether these items reflected a unitary latent construct. Fit indices were excellent for these models [e.g., Grade 6: χ^2 (4, n = 956; 4.02= .40; CFI = 1.00; TLI = 1.00; RMSEA = .002], and standardized factor loadings for all items were positive and significantly greater than zero, ranging from $\lambda = 0.40$ to 0.78 across items and waves. On the basis of these factor analyses, we computed a single mean score for each adolescent at each wave.

Because these items had different response options across reporters, ranging from three to five categories across reporter, the response scale for each item was transformed into a “Percent of Maximum Possible” (POMP) score ranging from 0 to 1.0. Such scaling transforms ordered categorical response scales from arbitrary numeric categories into a readily interpretable metric that also allows combining across items with differing response options (Cohen, Cohen, Aiken, & West, 1999). For example, a five-category item with response options ranging from 1 to 5 would be transformed into a scale where the response options include 0, 0.25, 0.5, 0.75, and 1.0. In this case, an individual who scores a 3 on a given item would be assigned a 0.5 for that item, reflecting that the 3 is 50% of the maximum possible score of 5.

Attention problems—Attention problems were assessed with a scale based on four items from the Teacher Observation of Classroom Adaptation-Revised (TOCA-R, Werthamer-Larsson, Kellam, & Ovesen-McGregor, 1990) and two self-report items (“I have trouble paying attention” and “It is hard for me to listen and follow directions”). Teachers rated how often the student’s “mind wanders,” “is easily distracted,” “pays attention,” and “stays on task.” The last two items were reverse coded. All items were coded so that higher scores reflected more attention problems. Similar to the self-control items, the self-report and teacher-report items were on different response scales, so responses were transformed using POMP transformations as described above. We used the mean of these six items as the indicator of attention problems at each grade. Internal consistency was excellent across grades (α = .83 – .84). Across waves, attention problems were strongly correlated with impulse control problems ($r = .58 – .61$, $p < .001$).

Covariates—Because these data came from an intervention designed to reduce substance use, it was important to control for the effects of the intervention on both levels and changes in impulse control and substance use. Males and females are known to have different rates of substance use (Johnston et al., 2008). Moreover, problems with impulse control often overlap with conduct problems (Tarter et al., 2003), and we wanted to ensure that any effects of impulse control problems did not reflect the broader effects of established behavior problems. Thus for the final analyses, we included sex, conduct problems at Grade 6, and intervention status as covariates. Conduct problems at Grade 6 was the mean of teacher (α = .89) and parent (α = .83) report of 10 items about behavior problems The 10 items (e.g., "tells a lot of lies" and "starts fights") were taken from the Teacher Observation of Classroom Adaptation-Revised (Werthamer-Larsson et al., 1990) and the Child Behavior Checklist – Teacher Report (Achenbach, 1991).

Results

Plan of Analyses

The current study had two major stages. First, we tested separate unconditional growth models of self-control problems; attention problems; and alcohol, marijuana, and the likelihood of cigarette use to test for mean change and variability in change in each construct. Next, we estimated sequential latent growth curve models of change in self-control or attention problems predicting levels and change over time in substance use from 8th to 11th grade.[3]

We used a latent growth curve modeling approach to test variation in levels and change over time in self-control problems and attention problems and substance use. We modeled linear growth in self-control problems and attention problems, with Grade 6 fixed as the intercept. We fixed the intercept of alcohol and marijuana use to Grade 11 (3 years following the last assessment of impulse control) to predict variation in change over time from 8th to 11th grade and variation in the final level of substance use at 11th grade from levels and change in self-control. Growth curve models simultaneously estimate individual intercepts and slopes for all adolescents in the sample, and also estimate sample-average intercepts and slopes, as well as between-individual variation around the sample-average intercepts and slopes. Thus, we are examining how variation in levels of self-control problems and attentional problems in the 6th grade and variation in developmental changes in these problems from 6th to 8th grade are associated with both variation in the rate of change over time in later substance use (alcohol, marijuana, and cigarette use) from 8th through 11th grade, and variation in ultimate levels of substance use in Grade 11.[4]

Descriptive data analyses were performed using SPSS 15.0, and the hypotheses were tested using MPlus 5.0 (Muthén & Muthén, 2007) with the Maximum Likelihood Estimator with Robust Standard Errors for the unconditional models of self-control problems and attentional problems (MLR, Yuan & Bentler, 2000), and Weighted Least Squares with robust means and variances for the full sequential growth curve models (because the substance use variables were ordered categories). Both of these estimators have been shown to be robust across different patterns of missing data and to deviations from normally

[3]Because the variance in the slope of self-control was so small, we tested whether an intercept-only growth model (excluding the latent slope factor) fit the data as well as the current model. Chi-square difference testing ($\Delta\chi^2 = 22.96$, df = 3, $p < .001$) indicated that fixing the slope factor mean and variance to zero substantially decreased model fit; thus we retained the slope factor for the current study.

distributed variables. For the growth models, model fit was assessed using Chi-Square as an indicator of exact fit. Where exact fit was not achieved (as chi-square is sensitive to violations of normality and sample size, Hu & Bentler, 1999), we used relative fit indices, specifically the Tucker-Lewis Index (TLI), comparative fit index (CFI) and root-mean square error of approximation (RMSEA). Using these indices, we judged model fit with reference to standards provided by Hu and Bentler (1999) and the cautions of Marsh, Hau & Wen (2004).

Change Over Time in Self-Control Problems, Attention Problems, and Substance Use, and Associations with the Covariates

We developed separate unconditional latent growth curve models for self-control problems and attention problems from Grade 6 to Grade 8, and for alcohol, marijuana and tobacco use from Grade 8 to Grade 11, and regressed the growth factors on the covariates (intervention status, sex, poverty status, and conduct problems) to test their effects on the intercepts and slopes of the growth models.

Self-control and Attention Problems

Unconditional models—Fit indices indicated that the models for both self-control [χ^2 (1, n = 971) = 2.30, p = .13; CFI =.99; TLI = .99; RMSEA = .04] and attention problems [χ^2 (1, n = 971) = .03, p = .85; CFI = 1.00; TLI = 1.00; RMSEA = .00.] fit the data well. Table 2 summarizes these models. For both constructs, the mean intercept was significant and varied across individuals, indicating average non-zero levels of self-control and attention problems at Grade 6. The mean slope was significant for attention problems but not for self-control problems, indicating that, on average, small increases (less than 1% per year) in attention problems were reported, but there was no mean change over time for self-control problems. However, both slopes had significant variance, indicating that there were individual differences in the rate of change over time in both self-control problems and attention problems. Finally, both slopes and intercepts were negatively correlated, such that adolescents with more self-control or attention problems at Grade 6 reported less change in those problems from Grade 6 to 8. Supporting the validity of this growth model, the growth factors explained a substantial amount of variance in self-control problems and attention problems at Grades 6, 7, and 8 (r^2 = .66 – .73, all *ps* <.001).

Conditional models—Model fit indices suggested that the models for both self-control problems [χ^2 (4, n = 971) = 7.818, p = .10; CFI = .99; TLI = .99; RMSEA = .03] and attention problems [χ^2 (4, n = 971) = 9.95, p = .04; CFI = .99; TLI = .99; RMSEA = .03] fit the data well. Controlling for the effects of the other covariates, males tended to have both more self-control problems (Standardized Beta *(B)* = .17, p < .001) and attention problems (*B* = .26, p <.001) at Grade 6. However, males and females did not differ in their rate of change for either self-control (*B* = −.08, p = .09) or attention problems (*B* = −.05, p = .45). Conduct problems at Grade 6 were associated with higher levels of self-control problems (*B*

[4]Although substance use frequency was first measured at Grade 7, so few participants reported any alcohol (<15%), marijuana (<8%), or cigarette (< 14%) use, including this initial timepoint produced substantial problems with model estimation, including non-convergence of many of the estimated models. However, we did re-analyze all models using Grade 7 substance use as a predictor of the slope and intercept of later substance use, to provide a test of whether the effects of levels and change of impulse-control problems on later levels and change in substance use really reflected early initiators who also were high on impulse control problems. Including very early substance use did not substantively change the direction or magnitude of any of the findings presented here; thus we present the results of the simplified models above. It is also possible that very early substance use influences the developmental trajectories of impulse control. To test this possibility, we tested the effects of Grade 6 substance use (three binary variables capturing any past year-use of alcohol, marijuana, or tobacco) on the intercepts and slopes of self-control and attention problems. Moreover, we tested whether substance use at Grade 6 or 7, modeled as time-varying covariates of impulse control, explained residual variation in impulse control at Grade 7 or 8. No effects of substance use on either the latent growth factors or residual variances of impulse control were observed, suggesting that the effects observed in the current study are unidirectional.

= .79, $p < .001$) and attention problems ($B = .65$, $p < .001$) at Grade 6, and predicted less change in self-control problems ($B = -.47$, $p < .001$) and attention problems from Grade 6 to 8 ($B = -.17$, $p = .02$). Intervention status was not associated with levels or change in self-control or attention problems.

Substance Use

Unconditional models—Table 2 summarizes the findings from the unconditional models. The final unconditional models for alcohol [χ^2 (10, n = 955) = 20.08, $p < .05$; CFI = .99; TLI = .99; RMSEA = .03], marijuana [χ^2 (8, n = 951) = 17.53, $p < .05$; CFI = .99; TLI = .99; RMSEA = .03], and tobacco use [χ^2 (2, n = 951) = 1.12, $p = .56$; CFI = 1.00; TLI = 1.00; RMSEA = .00] all fit the data well. The intercept (defined as the level of substance use at Grade 11) mean is fixed to zero for growth curve models with ordinal outcomes to allow model identification. However, all substance use means had significant variance, indicating that at Grade 11 there were significant inter-individual differences in the frequency of alcohol and marijuana use and in the likelihood of cigarette use. Moreover, the means and variances of the slopes were all significant, indicating that adolescents were increasing their substance use from middle to high school but varied in their rate of change. Finally, in each model the intercept and slope were correlated, indicating that individuals' trajectories were jointly determined by how much their alcohol use increased from Grade 8 to 11 and by how much alcohol use they reported at Grade 11. R^2 estimates suggested that the latent growth factors accounted for most of the observed variation in substance use at each timepoint, with estimates ranging from .69 to .94.

Conditional models—We next tested the effects of the covariates on the latent growth factors of substance use. Briefly, conduct problems at Grade 6 were associated with the level of alcohol ($B = .27$, $p < .001$) and marijuana ($B = .26$, $p < .001$) use, and with the likelihood of cigarette ($B = .287$, $p < .01$) use. In addition, females smoked more than males at Grade 11 ($B = -.09$, $p < .05$). Few covariates were related to the rate of change over time in substance use. Specifically, only gender ($B = .25$, $p < .01$) and conduct problems ($B = -.23$, $p < .01$) predicted the rate of change in the likelihood of cigarette use.

Sequential Models of Impulse Control Problems and Substance Use

Self-control problems—We next examined sequential growth curve models of self-control problems and substance use. Results are summarized in Table 3, and fit indices suggested that the models for self-control problems and alcohol [χ^2 (15, n = 955) = 27.93, $p = .03$; CFI = .99; TLI = .99; RMSEA = .03], marijuana [χ^2 (15, n = 955) = 23.16, $p = .08$; CFI = .99; TLI = .99; RMSEA = .02], and cigarette use [χ^2 (15, n = 955) = 29.22, $p = .015$; CFI = .99; TLI = .99; RMSEA = .03] all fit the data well.

Having more self-control problems at Grade 6 predicted higher levels of alcohol and marijuana use, and a higher likelihood of cigarette use at Grade 11, but did not predict rate of change from 8th to 11th grade. Over and above the effects of Grade 6 levels of self-control problems, increases in self-control problems from Grade 6 to 8 predicted higher levels of substance use by Grade 11. On the other hand, change over time in substance use was unrelated to the initial levels of self-control problems, but increases in self-control problems actually predicted less growth in alcohol use and in the likelihood of cigarette use.

We probed this effect in two ways. First, we saved individual's factor scores for the latent self-control slope, and compared substance use among those adolescents whose self-control problems increased the most (the 15% of participants +1 SD above the mean rate of change) to the remainder of the sample. T-tests indicated that both alcohol use and the probability of smoking were significantly higher across all time points among the adolescents whose self-control problems were escalating during middle school (all $t(954) > -3.99$, $p < .001$). Adolescents with the largest increases in self-control problems were more likely to report smoking and were also the heaviest drinkers across all time points. To confirm this, we re-centered the intercept of tobacco and alcohol use to Grade 8 and re-analyzed the current models, regressing the slope of substance use on the intercept of substance use (set at Grade 8), as well as on growth factors for self-control problems and the covariates. Controlling for the level of use at Grade 8 (which was negatively related to the slope of use), there were no effects of the intercept or rate of change in self-control problems on the rate of change in tobacco or alcohol use. Thus adolescents whose self-control problems worsened across middle school were among the heaviest alcohol and tobacco users from Grades 8 through 11, even as substance use converged with low users at 8th grade catching up somewhat with their higher substance-using peers.

Attention problems—Finally, we examined sequential growth curve models of attention problems and substance use. Results are summarized in Table 4, and fit indices suggested that the model for attention problems and alcohol [χ^2 (15, n = 955) = 26.065, p = .07; CFI = .99; TLI = .99; RMSEA = .02], marijuana [χ^2 (15, n = 955) = 23.171, p = .06; CFI = .99; TLI = .99; RMSEA = .03], and cigarette use [χ^2 (15, n = 955) = 20.650, p = .14; CFI = .99; TLI = .99; RMSEA = .02] all fit the data well.

Over and above the effects of the covariates, attention problems at Grade 6 predicted higher levels of alcohol and marijuana use and a higher likelihood of cigarette use. There was also an unexpected, small effect of intervention status on the probability of Grade 11 smoking that was not observed in the original conditional model of growth in smoking on the covariates. Because prior research focusing specifically on the effects of the intervention on cigarette use had found no effects (Brown et al., 2005), it is likely that this is a spurious finding related to the differential longitudinal analyses used across studies. Increases in attention problems from Grade 6 to 8 explained additional variance in level of substance use at Grade 11. On the other hand, the slope of substance use was largely unrelated to levels or changes in attention problems during middle school. Only the slope of attention problems was related to the slope of the likelihood of cigarette use, such that increases in attention problems were related to slower growth in the likelihood of cigarette use. Similar to the results for self-control problems, adolescents whose attention problems increased the most during middle school were the most likely to report smoking across all time points. Moreover, re-centering the intercept of substance use to Grade 8 and controlling for the probability of smoking at Grade 8 in the prediction of the slope of smoking eliminated the effects of slope-on-slope, again suggesting that this is a ceiling effect. In other words, the change-to-change association represents a ceiling effect, where the gap between risky and less risky individuals narrows as smoking becomes somewhat more developmentally normative.

Discussion

Prior research has consistently documented associations between difficulties with impulse control and risk for substance use. With the emerging recognition of impulse control as an individual difference factor that continues to develop across adolescence (Monahan et al., 2009; Steinberg et al., 2008), the current study attempted to determine to what degree differences in the rate of emergence of self-control problems and attention problems influenced the development of substance use. The results of the present study indicate that both the level *and* the rate of change in self-control problems and attention problems during middle school predicted the level, but not the course, of substance use toward the end of high school. Both attention problems and self-control problems exhibited significant individual differences in change over time, suggesting that for some adolescents these problems are actually increasing over time, while for others they are decreasing or potentially staying the same. Our findings suggest that those adolescents whose impulse control is worsening across middle school are at elevated risk for substance use during high school.

Prior studies had suggested that the ability to regulate impulses should demonstrate developmental improvements across adolescence (Blonigen et al., 2008; Roberts et al., 2001; Steinberg et al., 2008; Steinberg & Cauffman, 1996). The current study provided partial support for this notion. Our data suggested that, on average, our indicators of impulse control either exhibited no average changes, or showed slight worsening from Grade 6 to Grade 8, corresponding to ages 13 to 15. This is contrary to what would be expected based on previous studies (e.g., Steinberg et al., 2008) which would have predicted developmental improvements in impulse control as the adolescents got older. Indeed, Steinberg (2004) has argued that increased risk during adolescence stems from rapidly developing motivational drive systems in the brain that mature around puberty, coupled with slowly developing impulse control systems that do not mature until young adulthood. These findings may stem from the relatively short span of development covered in the current study (3 years); other studies with longer time frames may be more likely to show developmental increases in impulse control. Alternately, it may be that adolescents show improvements earlier and/or later in adolescence; data presented by Steinberg and colleagues (2008) suggested that impulse control increases rapidly from late adolescence to young adulthood, but more slowly in earlier developmental periods. As this study examines self-control among early adolescents, we may not have observed patterns of change that may be noted in later adolescence. Alternately, the measures utilized in the current study may capture impulse control that is more cognitively influenced, which may change differently than behavioral indicators of impulse control. Finally, our measure of impulse control may not be specific enough to capture the maturation of cognitive control that is thought to be occurring during this time period, or it may be influenced by measurement error due to having 7th- and 8th-grade teacher ratings when those teachers may spend less time with students than in earlier grades.

Regardless, our findings did indicate that adolescents *differed* in the degree of time-related changes in the ability to consciously regulate their behavior. Specifically, some adolescents showed improvements in impulse control, while other adolescents were stable or possibly declined across the same time period. These findings indicate that although adolescents may be expected to show developmental improvements in the ability to control impulses, not all adolescents will change at the same rate, at the same time, or perhaps even in the same direction. It could be that these individual differences in change reflect adolescents who are on the same general developmental trajectory but at different points. For example, Steinberg et al. (2008) showed that pubertal stage, rather than age, was a more important predictor of the developmental course of sensation seeking. Similarly, it may be that all adolescents follow the same developmental trend of improvements in impulse control, but differ in terms of what age these changes begin, progress, and end. Finally, given that some adolescents appeared to show decreases in impulse control, it is important that future research attempt to explore what factors are related to these unexpected declines. It may be that environmental influences, such as engagement with deviant peer groups or poor family environments, actually hinder the development of impulse control and produce declines, at least in the short term.

Finally, the current study also highlights the importance of considering impulse control as a developing construct for obtaining a more robust understanding of the development of substance use in adolescence. Prior research had considered impulse control, no matter the operationalization, as a single trait-like predictor of substance use. Considering individual differences in the rate of development of impulse control explained substantial additional variation in alcohol, marijuana, and tobacco use 3 years following the final assessment of impulse control. Indeed, the effects of change in attention problems on later marijuana and alcohol use were nearly double the effects of initial levels, suggesting that individual differences in the development of attention problems are an even more potent predictor of later substance involvement. Moreover, this finding implies that rank-order differences in impulse control are not stable across this developmental period, and that changes in rank order may have especially important implications for the development of problem behaviors. Escalations in impulse-control problems seem to be an additional marker of risk, indicating which adolescents are most likely to engage in substance use and potentially develop problems. However, given that impulse control was not assessed beyond eighth grade, our study does not say whether continued escalations in impulse control problems would be concurrently related to escalations in substance use. Indeed, it could also be that consistently high alcohol or tobacco use might worsen self-control over time (e.g. Chassin et al., 2010). For example, some prior research has suggested that adolescent heavy drinkers who do not use marijuana, when compared to heavy drinking marijuana users, show greater deficits in some areas of executive function over time (Tapert, Granholm, Leedy & Brown, 2002; Mahmood, Jacobus, Bava, Scarlett & Tapert, *in press*). Given that impulse control is thought to develop linearly throughout adolescence, future research should seek to test the concurrent effects of developing impulse control on the development of substance use, and especially to determine at what point impulse control begins to improve for those who are most at risk.

Trait problems with impulse control were thought to be central to a deviance proneness pathway to substance use (e.g., Sher & Trull, 1994). Specifically, impulsivity is thought to increase risk for behavioral problems and school failure (among other problems) during adolescence, which in turn leads to deviant peer affiliation and eventual substance involvement. It may be that escalating impulse control problems may represent prodromal increases in behavior problems, such that adolescents whose behavior problems are worsening, who are having school difficulties, and who are spending time with deviant peers may also be more likely to be rated as more impulsive or less likely to think before acting. Alternately, these escalations may reflect interactions of the impulsive adolescent with environmental risk factors such as poor parenting that worsen developing impulse control (King & Chassin, 2004). To the extent that understanding individual patterns of development across adolescence may have important implications for understanding the etiological onset and escalation of substance use during adolescence, research that examines these mechanisms has clear implications for the prevention of adolescent substance use.

Finally, youth with the largest increases impulse control problems exhibited the least growth in alcohol and tobacco (but not marijuana) use over time, but also reported significantly higher levels of use across all time points. This seemed to reflect a ceiling effect, where adolescents who had impulse control problems that worsened across middle school were launched onto the highest trajectories of alcohol and tobacco use that were high but exhibited less growth, while lower-risk adolescent's smoking and alcohol use increased across high school. Given that both tobacco and alcohol use become more normative by the end of high school, many adolescents with few to no impulse control problems should also be expected to initiate and escalate substance use across this time period, albeit at much lower levels. Thus low-risk individuals would exhibit *more* change but *lower* levels of use. These findings illustrate the importance of both considering substance use as a developmental process that unfolds across adolescence and of also jointly interpreting the effects of predictors on slopes and intercepts in growth curve analyses.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

There are several strengths of this study. It uses a large community sample studied longitudinally, used sequential growth curve modeling to study prospective change, and examined alcohol and marijuana use. However, it also has limitations which should lend caution to interpretation of its findings. First, although we used measures reflecting two aspects of impulse control, there are many measures or aspects of impulse control in the literature, and prior research has shown that what is often labeled broadly as "impulsivity" typically reflects a multifaceted construct (Smith et al., 2007). Future research should explore the impact of levels and change over time in other facets of impulse control on adolescent substance use. Also, we explored impulse control over a relatively short (3-year) time frame and it is important to test if these patterns of findings continue into middle and late adolescence. Moreover, we did not have data on puberty, which has been linked to escalations in risk taking due to the rapid neural development of motivational systems paired with the relatively slow development of impulse control systems (Steinberg, 2004). Future research should examine both the motivational (e.g., sensation seeking and reward drive) and impulse control aspects of development and link them to pubertal timing.

In sum, prior studies indicated that one of the important risk factors for the emergence of substance use during adolescence, and the development of later substance use problems and disorders, is diminished ability to control one's impulses (Stice et al., 1998; Wills et al., 2001; Wills & Stoolmiller, 2002). The current findings expand this literature in an important direction, indicating that those at risk will not only show higher levels of impulse control problems during early adolescence, but additional risk is conferred when impulse control problems either worsen over time or show less improvement than expected.

By connecting rates of change in self-control problems and attention problems to the development of substance use, our findings demonstrate that relative levels of impulse control problems, as well as the rate of development in these problems, are important risk factors for later problem behaviors. Substantively, our findings suggest that interventions that aim to improve the development of self-control during middle school may prevent some adolescents from engaging in early substance use, but earlier intervention may provide broader protective effects. It may not be enough to identify which adolescents have impulse control problems at a single point in time; rather, change in impulse control should be assessed as an indicator of a need for preventive intervention.

Acknowledgments

This research was supported by research grant DA-08093-16 from the National Institute on Drug Abuse. The content of this paper is solely the responsibility of the authors and does not necessarily represent the official views of the funding agency. A version of these analyses was presented at the Annual Meeting of the Research Society on Alcoholism, July 2009, in San Diego, CA.

References

Achenbach, TM. Manual for the Teacher's Report Form and 1991 Profile. Burlington: University of Vermont Department of Psychiatry; 1991.

Blonigen DM, Carlson MD, Hicks BM, Krueger RF, Iacono WG. Stability and change in personality traits from late adolescence to early adulthood: A longitudinal twin study. Journal of Personality. 2008; 76:229–266. [PubMed: 18331280]

Brown EC, Catalano RF, Fleming CB, Haggerty KP, Abbott RD. Adolescent substance use outcomes in the Raising Healthy Children Project: A two-part latent growth curve analysis. Journal of Consulting and Clinical Psychology. 2005; 73:699–710. [PubMed: 16173857]

Catalano RF, Mazza JJ, Harachi TW, Abbott RD, Haggerty KP, Fleming CB. Raising healthy children through enhancing social development in elementary school: Results after 1.5 years. Journal of School Psychology. 2003; 41:143–164.

Cauffman, E.; Steinberg, L. Researching adolescents' judgment and culpability. In: Grisso, T.; Schwartz, RG.; Grisso, TE.; Schwartz, RGE., editors. Youth on trial: A developmental perspective on juvenile justice. Chicago: University of Chicago Press; 2000. p. 325-343.

Chassin L, Modecki K, Cauffman E, Dmitrieva J, Steinberg L, Piquero AR, Knight GP, Losoya SH. Does adolescent alcohol and marijuana use predict suppressed growth in psychosocial maturity among male juvenile offenders? Psychology of Addictive Behaviors. 2010; 24:40–60.

Cohen P, Cohen J, Aiken LS, West SG. The problem of units and the circumstances for POMP. Multivariate Behavioral Research. 1999; 34:315–346.

Dawe S, Loxton NJ. The role of impulsivity in the development of substance use and eating disorders. Neuroscience & Biobehavioral Reviews. 2004; 28:343–351. [PubMed: 15225976]

Fischhoff B, Parker AM, Bruine de Bruin W, Downs J, Palmgren C, Dawes R, et al. Teen expectations for significant life events. Public Opinion Quarterly. 2000; 64:189–205. [PubMed: 10984333]

Giedd JN. Structural magnetic resonance imaging of the adolescent brain. Annals of the New York Academy of Sciences. 2004; 1021:77–85. [PubMed: 15251877]

Gullo MJ, Dawe S. Impulsivity and adolescent substance use: Rashly dismissed as 'all-bad?'. Neuroscience & Biobehavioral Reviews. 2008; 32:1507–1518. [PubMed: 18588911]

Haggerty KP, Catalano RF, Harachi TW, Abbott RD. Description de l'implementation d'un programme de prévention des problèmes de comportement à l'adolescence. (Preventing adolescent problem behaviors: A comprehensive intervention description). Criminologie. 1998; 31:25–47.

Hawkins JD, Catalano RF, Miller JY. Risk and protective factors for alcohol and other drug problems in adolescence and early adulthood: Implications for substance-abuse prevention. Psychological Bulletin. 1992; 112:64–105. [PubMed: 1529040]

Hu, Lt; Bentler, PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling. 1999; 6:1–55.

Jester JM, Nigg JT, Buu A, Puttler LI, Glass JM, Heitzeg MM, et al. Trajectories of childhood aggression and inattention/hyperactivity: differential effects on substance abuse in adolescence. Journal of the American Academy of Child & Adolescent Psychiatry. 2008; 47:1158–1165. [PubMed: 18724257]

Johnston, LD.; O'Malley, PM.; Bachman, JG.; Schulenberg, JE. Monitoring the Future national results on adolescent drug use: Overview of key findings 2007. (NIH Publication No. 08-6418). 2008. Retrieved February 14, 2009, from http://www.monitoringthefuture.org/pubs.html

Kessler RC, Berglund P, Demler O, Jin R, Walters EE. Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. Archives of General Psychiatry. 2005; 62:593–602. [PubMed: 15939837]

King KM, Chassin L. Mediating and moderated effects of adolescent behavioral undercontrol and parenting in the prediction of drug use disorders in emerging adulthood. Psychology of Addictive Behaviors. 2004; 18:239–249. [PubMed: 15482079]

King KM, Chassin L. A prospective study of the effects of age of initiation of alcohol and drug use on young adult substance dependence. Journal of Studies on Alcohol and Drugs. 2007; 68:256–265. [PubMed: 17286344]

Kirisci L, Tarter RE, Reynolds M, Vanyukov M. Individual differences in childhood neurobehavior disinhibition predict decision to desist substance use during adolescence and substance use disorder in young adulthood: A prospective study. Addictive Behaviors. 2006; 31:686–696. [PubMed: 15964148]

Kirisci L, Tarter RE, Vanyukov M, Reynolds M, Habeych M. Relation between cognitive distortions and neurobehavior disinhibition on the development of substance use during adolescence and substance use disorder by young adulthood: A prospective study. Drug and Alcohol Dependence. 2004; 76:125–133. [PubMed: 15488336]

Krueger RF, Hicks BM, Patrick CJ, Carlson SR, Iacono WG, McGue M. Etiologic connections among substance dependence, antisocial behavior, and personality: modeling the externalizing spectrum. Journal of Abnormal Psychology. 2002; 111:411–424. [PubMed: 12150417]

Luna B, Garver KE, Urban TA, Lazar NA, Sweeney JA. Maturation of cognitive processes from late childhood to adulthood. Child Development. 2004; 75:1357–1372. [PubMed: 15369519]

Mahmood O, Jacobus J, Bava S, Scarlett AL, Tapert SF. Learning and memory performances in adolescent users of alcohol and marijuana: Interactive effects. Journal of Studies on Alcohol and Drugs. (in press).

Marsh HW, Hau K-T, Wen Z. In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. Structural Equation Modeling. 2004; 11:320–341.

Mezzich AC, Tarter RE, Feske U, Kirisci L, McNamee RL, Day B-S. Assessment of risk for substance use disorder consequent to consumption of illegal drugs: Psychometric validation of the neurobehavior disinhibition trait. Psychology of Addictive Behaviors. 2007; 21:508–515. [PubMed: 18072833]

Molina BS, Pelham WE Jr. Childhood predictors of adolescent substance use in a longitudinal study of children with ADHD. Journal of Abnormal Psychology. 2003; 112:497–507. [PubMed: 12943028]

Monahan KC, Steinberg L, Cauffman E, Mulvey EP. Trajectories of antisocial behavior and psychosocial maturity from adolescence to young adulthood. Developmental Psychology. 2009; 45:1654–1668. [PubMed: 19899922]

Muthén, LK.; Muthén, B. MPLUS: Statistical analysis with latent variables: User's guide. 4th ed. Los Angeles: Muthen & Muthen; 2007.

Presson CC, Chassin L, Sherman SJ. Psychosocial antecedents of tobacco chipping. Health Psychology. 2002; 21:384–392. [PubMed: 12090681]

Roberts BW, Caspi A, Moffitt TE. The kids are alright: Growth and stability in personality development from adolescence to adulthood. Journal of Personality and Social Psychology. 2001; 81:670–683. [PubMed: 11642353]

Scott ES, Reppucci ND, Woolard JL. Evaluating adolescent decision making in legal contexts. Law and Human Behavior. 1995; 19:221–244.

Sher KJ, Trull TJ. Personality and disinhibitory psychopathology: Alcoholism and antisocial personality disorder. Journal of Abnormal Psychology. 1994; 103:92–102. [PubMed: 8040486]

Smith GT, Fischer S, Cyders MA, Annus AM, Spillane NS, McCarthy DM. On the validity and utility of discriminating among impulsivity-like traits. Assessment. 2007; 14:155–170. [PubMed: 17504888]

Steinberg L. Risk taking in adolescence: what changes, and why? Annals of the New York Academy of Sciences. 2004; 1021:51–58. [PubMed: 15251873]

Steinberg L. A social neuroscience perspective on adolescent risk-taking. Developmental Review. 2008; 28:78–106. [PubMed: 18509515]

Steinberg L, Albert D, Cauffman E, Banich M, Graham S, Woolard J. Age differences in sensation seeking and impulsivity as indexed by behavior and self-report: Evidence for a dual systems model. Developmental Psychology. 2008; 44:1764–1778. [PubMed: 18999337]

Steinberg L, Cauffman E. Maturity of judgment in adolescence: Psychosocial factors in adolescent decision making. Law and Human Behavior. 1996; 20:249–272.

Stice E, Barrera MJ, Chassin L. Prospective differential prediction of adolescent alcohol use and problem use: Examining the mechanisms of effect. Journal of Abnormal Psychology. 1998; 107:616–628. [PubMed: 9830249]

Substance Abuse and Mental Health Services Administration. Results from the 2006 National Survey on Drug Use and Health: National Findings. Rockville, MD: Office of Applied Studies; 2007. NSDUH Series H-32, DHHS Publication No. SMA 07-4293.

Tapert SF, Granholm E, Leedy NG, Brown SA. Substance use and withdrawal: Neuropsychological functioning over 8 years in youth. Journal of the International Neuropsychological Society. 2002; 8:873–883. [PubMed: 12405538]

Tarter RE, Kirisci L, Mezzich A, Cornelius JR, Pajer K, Vanyukov M, et al. Neurobehavioral disinhibition in childhood predicts early age at onset of substance use disorder. The American Journal of Psychiatry. 2003; 160:1078–1085. [PubMed: 12777265]

Werthamer-Larsson, L.; Kellam, SG.; Ovesen-McGregor, KE. Teacher interview: Teacher Observation of Classroom Adaptation--Revised (TOCA-R). In: Kellam, SG., editor. Johns Hopkins Prevention Center training manual. Baltimore, MD: Johns Hopkins University; 1990.

Whiteside SP, Lynam DR. The five factor model and impulsivity: Using a structural model of personality to understand impulsivity. Personality and Individual Differences. 2001; 30:669–689.

Wills TA, Cleary S, Filer M, Shinar O, Mariani J, Spera K. Temperament related to early-onset substance use: test of a developmental model. Prevention Science. 2001; 2:145–163. [PubMed: 11678291]

Wills TA, Stoolmiller M. The role of self-control in early escalation of substance use: A time-varying analysis. Journal of Consulting and Clinical Psychology. 2002; 70:986–997. [PubMed: 12182282]

Wills TA, Walker C, Mendoza D, Ainette MG. Behavioral and emotional self-control: relations to substance use in samples of middle and high school students. Psychology of Addictive Behaviors. 2006; 20:265–278. [PubMed: 16938064]

Yuan KH, Bentler PM. Three likelihood-based methods for mean and covariance structure analysis with nonnormal missing data. Sociological Methodology. 2000; 30:165–200.

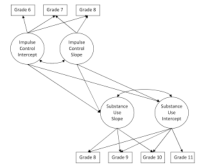

Figure 1. Sequential growth curve model of impulse control and substance use, Grades 6 to 11

This model illustrates the sequential growth curve model of impulse control and substance use. For impulse control, the intercept was fixed to Grade 6, and for substance use the intercept was specified to be Grade 11. Direct effects of both the intercept and slope of impulse control on the slope and intercept of substance use were estimated for all models, and sex, intervention status, and Grade 6 conduct problems were included as covariate predictors of the growth factors of both impulse control and substance use.

Table 1

Descriptive Statistics of Past-year Substance Use

Grade	Alcohol Use Frequency		Marijuana Use Frequency		Cigarette Use (% Yes)	
	M	SD	M	SD	N	%
Grade 8 (n = 940)	0.873	1.478	0.542	1.457	240	24.70%
Grade 9 (n = 926)	1.116	1.630	0.867	1.788	235	24.20%
Grade 10 (n = 929)	1.392	1.789	1.085	1.955	283	29.10%
Grade 11 (n = 923)	1.873	1.997	1.452	2.199	336	34.60%

Table 2

Unconditional Growth Models of Impulse Control and Substance Use

	Factor Mean	SE	Factor Variance	SE	R of Slope & Intercept
Self-control problems					
Intercept	**0.315**	0.006	**0.027**	0.002	r = −.40
Slope	−0.004	0.003	**0.002**	0.001	
Attention problems					
Intercept	**0.348**	0.008	**0.037**	0.003	r = −.33
Slope	**0.008**	0.004	**0.004**	0.001	
Alcohol use					
Intercept	0.000	0.000	**0.784**	0.093	r = .43
Slope	**0.219**	0.013	**0.063**	0.009	
Marijuana use					
Intercept	0.000	0.000	**0.977**	0.179	r = .45
Slope	**0.213**	0.022	**0.068**	0.013	
Likelihood of tobacco use					
Intercept	0.000	0.000	**0.462**	0.060	r = .00
Slope	**0.140**	0.015	**0.025**	0.008	

*Coefficients in bold were significant, $p < .05$

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 3

Effects of Self-Control Problems on Levels and Change in Substance Use

	Grade 11 level					Grades 8–11 slope				
	b	**SE**	**B**	**Z**	**p**	**b**	**SE**	**B**	**Z**	**p**
Alcohol										
Gender	**−0.27**	**0.08**	**−0.14**	**−3.42**	**0.001**	0.01	0.03	0.03	0.41	0.685
Intervention status	−0.10	0.07	−0.05	−1.41	0.158	0.00	0.03	0.01	0.15	0.880
Conduct problems, Grade 6	−0.12	0.32	−0.04	−0.38	0.704	−0.09	0.13	−0.10	−0.68	0.500
Slope self-control problems	**3.06**	**1.34**	**0.17**	**2.28**	**0.023**	**−1.48**	**0.55**	**−0.29**	**−2.71**	**0.007**
Grade 6 self-control problems level	**2.81**	**0.55**	**0.49**	**5.10**	**0.000**	−0.06	0.22	−0.04	−0.27	0.788
Marijuana										
Gender	−0.16	0.11	−0.07	−1.42	0.157	0.02	0.05	0.03	0.41	0.684
Intervention status	−0.08	0.09	−0.03	−0.80	0.422	0.02	0.04	0.03	0.48	0.630
Conduct problems, Grade 6	−0.04	0.44	−0.01	−0.10	0.924	−0.01	0.17	−0.01	−0.05	0.958
Slope self-control problems	**6.02**	**2.00**	**0.27**	**3.01**	**0.003**	0.02	0.72	0.00	0.03	0.979
Grade 6 self-control problems level	**3.61**	**0.90**	**0.51**	**4.00**	**0.000**	−0.02	0.33	−0.01	−0.06	0.954
Cigarette										
Gender	**−0.23**	**0.07**	**−0.18**	**−3.45**	**0.001**	**0.10**	**0.03**	**0.29**	**3.24**	**0.001**
Intervention status	**−0.10**	**0.05**	**−0.08**	**−1.99**	**0.047**	−0.04	0.03	−0.10	−1.37	0.171
Conduct problems, Grade 6	−0.20	0.25	−0.10	−0.82	0.411	−0.09	0.12	−0.15	−0.76	0.447
Slope self-control problems	**2.86**	**1.07**	**0.24**	**2.67**	**0.008**	**−1.04**	**0.50**	**−0.31**	**−2.07**	**0.038**
Grade 6 self-control problems level	**2.35**	**0.53**	**0.63**	**4.49**	**0.000**	−0.36	0.24	−0.34	−1.52	0.129

* Coefficients in bold were significant, $p < .05$

Table 4

Effects of Attention Problems on Levels and Change in Substance Use

	Grade 11 level					Grades 8–11 slope				
	b	**SE**	**B**	**Z**	**p**	**B**	**SE**	**B**	**Z**	**p**
Alcohol										
Gender	−0.16	0.11	−0.09	−1.43	0.152	0.01	0.04	0.02	0.34	0.733
Intervention status	−0.06	0.09	−0.03	−0.65	0.514	−0.01	0.03	−0.01	−0.20	0.838
Conduct problems, Grade 6	**0.88**	**0.30**	**0.27**	**2.96**	**0.003**	−0.04	0.10	−0.04	−0.36	0.723
Slope attention problems	**9.58**	**4.69**	**0.43**	**2.04**	**0.041**	−1.70	1.25	−0.27	−1.37	0.171
Grade 6 attention problems level	**0.92**	**0.39**	**0.18**	**2.38**	**0.017**	−0.02	0.16	−0.02	−0.15	0.881
Marijuana										
Gender	−0.06	0.16	−0.02	−0.36	0.720	0.02	0.05	0.04	0.47	0.639
Intervention status	−0.02	0.13	−0.01	−0.17	0.864	0.02	0.04	0.03	0.52	0.605
Conduct problems, Grade 6	**0.98**	**0.42**	**0.25**	**2.35**	**0.019**	0.00	0.13	0.00	0.00	0.999
Slope attention problems	**13.95**	**6.79**	**0.50**	**2.06**	**0.040**	0.33	1.42	0.05	0.23	0.816
Grade 6 attention problems level	**1.54**	**0.56**	**0.24**	**2.74**	**0.006**	−0.03	0.22	−0.02	−0.11	0.910
Cigarettes										
Gender	**−0.22**	**0.08**	**−0.183**	**−2.75**	**0.006**	**0.09**	**0.04**	**0.246**	**2.25**	**0.024**
Intervention status	−0.09	0.06	−0.075	−1.64	0.100	−0.05	0.03	−0.13	−1.47	0.141
Conduct problems, Grade 6	0.22	0.16	0.109	1.38	0.169	**−0.21**	**0.09**	**−0.36**	**−2.33**	**0.020**
Slope attention problems	**3.28**	**1.70**	**0.244**	**1.93**	**0.050**	**−2.57**	**1.21**	**−0.663**	**−2.12**	**0.034**
Grade 6 attention problems level	**1.32**	**0.39**	**0.404**	**3.41**	**0.001**	−0.13	0.17	−0.139	−0.78	0.435

*Coefficients in bold were significant, $p < .05$