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Unfazed or Dazed and Confused: Does Early Adolescent Marijuana Use Cause Sustained Impairments in Attention and Academic Functioning?

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Abstract

There is some suggestion that heavy marijuana use during early adolescence (prior to age 17) may cause significant impairments in attention and academic functioning that remain following sustained periods of abstinence. However, no longitudinal studies have examined whether both male and female adolescents who engage in low (less than once a month) to moderate (at least once a monthly) marijuana use experience increased problems with attention and academic performance, and whether these problems remain following sustained abstinence. The current study used within-individual change models to control for all potential pre-existing and time-stable confounds when examining this potential causal association in two gender-specific longitudinal samples assessed annually from ages 11 to 16 (Pittsburgh Youth Study $N=479$; Pittsburgh Girls Study $N=2296$). Analyses also controlled for the potential influence of several pertinent time-varying factors (e.g., other substance use, peer delinquency). Prior to controlling for time-varying confounds, analyses indicated that adolescents tended to experience an increase in parent-reported attention and academic problems, relative to their pre-onset levels, during years when they used marijuana. After controlling for several time-varying confounds, only the association between marijuana use and attention problems in the sample of girls remained statistically significant. There was no evidence indicating that adolescents who used marijuana

experienced lingering attention and academic problems, relative to their pre-onset levels, after abstaining from use for at least a year. These results suggest that adolescents who engage in low to moderate marijuana use experience an increase in observable attention and academic problems, but these problems appear to be minimal and are eliminated following sustained abstinence.

Marijuana is the most widely used illicit drug among adolescents in the United States (Johnston, O'Malley, Bachman, & Schulenberg, 2013). Due in part to marijuana's popularity among young people and successful efforts to legalize its recreational use in some states, there has been a recent surge in interest regarding the short- and long-term effects of regular use in adolescence. Indeed, one of the most debated issues with respect to early-onset marijuana use (typically defined as prior to age 17) is whether it causes irreversible cognitive deficits. Some evidence suggests that individuals who engage in early-onset marijuana use tend to exhibit poorer performance on neuropsychological tests measuring attention, verbal memory, intelligence, executive function, and verbal fluency, even following abstinence (For a review see, Lisdahl & Tapert, 2012). However, the few longitudinal studies that have examined this topic have not been able to rule out pre-existing factors and self-selection as potential confounds when examining links between adolescent marijuana use and adult cognitive functioning (Brook, Stimmel, Zhang, & Brook, 2008; Fergusson & Horwood, 1997; Meier et al., 2012). In addition, prior studies have focused primarily on the association between heavy adolescent marijuana use (typically defined as using multiple times a week) and cognitive deficits (Fried, Watkinson, & Gray, 2005; Meier et al., 2012), making it unclear whether low (less than monthly) to moderate (at least monthly) use may negatively impact aspects of cognitive functioning. Furthermore, few prospective studies have examined whether early-onset marijuana use is associated with observable increases in attention problems (e.g., distractibility, forgetfulness) and functional impairments in life domains that rely on intact cognitive functioning (e.g., school performance), or whether these impairments remain following sustained abstinence. Lastly, existing studies have not sufficiently controlled for the large number of potential confounding factors that vary between adolescents (e.g., genetics, pre-existing neurocognitive functioning) when examining linkages between marijuana use and cognitive impairments. To address these issues, the current study uses two large gender-specific longitudinal studies to examine whether adolescents (ages 11 to 16) who engage in experimental to moderate marijuana use experience an increase in their pre-onset levels of attention and academic problems, and whether any increase persists following sustained abstinence and after controlling for several potential confounds.

Marijuana Use and Neurocognitive Impairments

In adolescents, some cross-sectional studies have found that prior marijuana use is associated with poorer performance on tests measuring multiple aspects of cognitive functioning (e.g., processing speed, attention, memory, executive function), even following sustained abstinence (Fried et al., 2005; Lisdahl & Tapert, 2012). Studies have also found differences in both brain structure (e.g., grey matter volume, white matter integrity) and function between adolescents who use marijuana heavily versus those who are non-users (Lisdahl & Tapert, 2012). In contrast, studies that have focused on heavy marijuana use

initiated in adulthood have found few consistent non-acute associations with cognitive test performance (Gonzalez, Carey, & Grant, 2002; Grant, Gonzalez, Carey, Natarajan, & Wolfson, 2003; Meier et al., 2012), suggesting that adolescents may be particularly vulnerable to experiencing longer-term effects of marijuana use on the brain. However, most of these studies have not sufficiently examined whether premorbid cognitive functioning and other pre-existing confounds account for the hypothesized causal association between marijuana use and impairments in cognitive functioning.

The few longitudinal studies that have controlled for premorbid cognitive functioning and other confounds when examining linkages between marijuana use and cognitive impairments have produced mixed results (For a review see, Lisdahl & Tapert, 2012). For example, one longitudinal study found that former adolescent heavy marijuana users (5+ joints per week) who were abstinent in late adolescence were not significantly different from non-users on several tests of cognitive functioning (e.g., IQ, processing speed, memory), after controlling for premorbid cognitive abilities (Fried et al., 2005). In contrast, a recent prospective study of a large birth cohort found that adults who reported engaging in heavy marijuana use (four times per week) before age 18 and were later diagnosed with cannabis dependence exhibited a significant decline in IQ from childhood to adulthood, whereas non-users and adult-onset users showed no significant change in IQ (Meier et al., 2012). However, most of the adolescent-onset cases had used marijuana in the year prior to completing the adult neuropsychological assessment, making it unclear whether these deficits would remain following a more sustained period of abstinence.

Early-Onset Marijuana Use and Observable Cognitive Problems

Although heavy adolescent marijuana use may lead to decrements in neuropsychological test performance, these deficits may not translate into observable impairments in daily living. Specifically, it remains unclear whether early-onset marijuana use is associated with an increase in observable difficulties with sustained attention, memory, and cognitive persistence when engaged in daily tasks. One recent longitudinal study found that adolescents who used marijuana heavily were rated by collateral informants as having more problems with sustained attention and memory in middle adulthood, even after controlling for childhood intellectual functioning (Meier et al., 2012). However, this study did not control for observable problems with attention and memory prior to marijuana use onset, as well as other potential confounds (e.g., prenatal substance use, early conduct problems). This is particularly problematic because attention and memory problems are core features of Attention Deficit Hyperactivity Disorder (ADHD), which emerges in early childhood and has been associated with early-onset marijuana use (Wilens, Biederman, & Spencer, 1996). Furthermore, several studies have found that the association between attention/memory problems and adolescent marijuana use (as well as other substance use) is largely accounted for by co-occurring conduct problems (Disney, Elkins, McGue, & Iacono, 1999; Flory, Milich, Lynam, Leukefeld, & Clayton, 2003; Loeber, Stouthamer-Loeber, & White, 1999; Molina, Smith, & Pelham, 1999). For these reasons, there is a need for longitudinal studies to examine whether youth who begin using marijuana experience an increase in the pre-onset levels of attention problems, even after controlling for co-occurring conduct problems.

Marijuana Use and Academic Problems

If early adolescent marijuana use causes clinically significant decrements in cognitive functioning, one would expect that it would also negatively impact school performance (Brook et al., 2008). Several studies examining this issue have found that adolescent marijuana use is associated with a wide variety of school-related problems, including lower grades, lower attachment and commitment to school, and truancy (Lynskey & Hall, 2000; Macleod et al., 2004). Adolescent marijuana users are also more likely to drop out of high school and less likely to continue their education after graduating from high school (Brook, Balka, & Whiteman, 1999; Fergusson, Horwood, & Beautrais, 2003). Some have suggested that linkages between marijuana use and academic problems may be bidirectional (Andrews & Duncan, 1997; Krohn, Lizotte, & Perez, 1997), as academic failure has been associated with an increased risk for initiating and escalating marijuana use during adolescence (Duncan, Duncan, Biglan, & Ary, 1998; Henry, Smith, & Caldwell, 2007; Newcomb & Bentler, 1986). However, others have found that the association between marijuana use and later academic problems may be attributed to common correlates of both behaviors, such as co-occurring conduct problems and other substance use, affiliation with delinquent peers, and family socio-economic status (Bachman et al., 2008; McCaffrey, Liccardo Pacula, Han, & Ellickson, 2010). Given these inconsistencies, it is pertinent for studies to examine whether early adolescent marijuana use is associated with drops in pre-morbid academic performance after extensively controlling for potential confounds.

Lingering Impairments Following Abstinence from Marijuana Use

A particularly controversial issue is whether any cognitive and/or academic impairments caused by adolescent marijuana use are sustained following periods of abstinence. Several randomized studies have found that THC (the primary psychoactive substance in marijuana) causes acute impairments in several aspects of cognitive functioning (For a review see, Gonzalez, 2007). However, some evidence suggests that many of these impairments are alleviated following a month or more of abstinence (Fried et al., 2005; Pope, Gruber, Hudson, Huestis, & Yurgelun-Todd, 2001). However, no prospective studies have demonstrated that youth who begin using marijuana in early adolescence show concurrent declines in their premorbid levels of observable attention problems and academic functioning that remain (at least in part) following periods of sustained abstinence lasting a year or longer. Moreover, most available studies have focused on heavy or regular marijuana use in adolescence, which is typically defined as using several times a week or near daily use by the age of 17 or 18 (Fried et al., 2005; Meier et al., 2012). In these studies, the comparison groups are typically former users or occasional and light users combined with non-users. This is an important limitation given that occasional use in early adolescence (prior to age 17) is far more normative than chronic or heavy use (Johnston et al., 2013). For example, daily marijuana use occurs in only 1.1% of 8th graders, 4.0% of 10th graders, and 6.5% of 12th graders (Johnston et al., 2013). Therefore, we know little about the lingering effect of low to moderate levels of use during early adolescence on attention problems and academic functioning.

Gender Differences and Early-Onset Marijuana Use

Many of the longitudinal studies outlined above have been based on predominately male marijuana users, due in part to the relatively low frequency of marijuana use among girls in early adolescence. However, a growing number of studies have begun to suggest that both acute and persistent marijuana use may differentially impact cognitive functioning in males and females (Gonzalez & Swanson, 2012). For example, one study conducted with adolescents and young adults, ages 18-26, found that marijuana use was more strongly associated with impairments in psychomotor speed/sequencing in males than females, but impairments in sustained attention did not differ by gender (Lisdahl & Price, 2012). Some have speculated that gender differences in the timing and rate of neurodevelopment may lead marijuana use in early adolescence to produce differential effects on cognitive functioning for males and females in early adolescence (Lisdahl & Tapert, 2012). However, there are relatively few longitudinal studies with a large enough sample of females regularly assessed across early adolescence to examine the impact marijuana use may have on difficulties with attention and academic functioning.

Current Study

Although evidence suggests a potential causal link between early adolescent marijuana use and deficits in cognitive and academic functioning, existing studies have suffered from several limitations. Specifically, many have not: 1) examined whether changes in marijuana use in early adolescence precede declines in cognitive/academic functioning; 2) sufficiently controlled for pre-existing and co-occurring confounding factors; 3) assessed marijuana use and cognitive/academic functioning repeatedly across early adolescence; 4) tested whether declines in cognitive/academic functioning persist after sustained abstinence in both males and females; and 5) examined whether early marijuana use results in observable difficulties engaging in daily activities that require sustained attention, such as academic performance. There are also no studies that have examined the potential negative effect of low to moderate adolescent marijuana use on changes in observable attention problems and academic achievement.

The current study is designed to overcome these limitations using two large gender-specific longitudinal studies that annually assessed community-dwelling at-risk adolescents using comparable measures from age 11 to 16. We examine whether adolescents tend to experience more attention problems and academic difficulties during years when they report using marijuana experimentally (less than monthly) or moderately (at least once a month), relative to their levels of attention problems and academic difficulties before marijuana use was initiated. In addition, analyses examine whether these problems persisted after abstinence lasting at least a year, consistent with the notion that regular adolescent marijuana use can cause long-term impairments in cognitive and academic functioning (Fergusson & Boden, 2008; Meier et al., 2012). Importantly, analytic models that focus on within-individual change are used to eliminate all pre-existing and time-invariant factors (e.g., early psychosocial adversity, genetics, intellectual abilities, prenatal complications, race) that vary between individuals as potential confounds, thereby strengthening causal inference (Allison, 2009; Osgood, 2010). In addition, changes in co-occurring substance use

(e.g., alcohol, tobacco) and other time-varying confounds that may affect attention and academic performance are included as controls, such as changes in family structure/functioning, neighborhood problems, youth antisocial behavior, and deviant peer group affiliation. It is hypothesized that during years when adolescents engage in at least moderate (i.e., monthly) marijuana use, they will experience an increase in their attention and academic problems, and these effects will remain significant after controlling for co-occurring changes in other substance use and other potential confounds. However, these problems are anticipated to return to pre-onset levels after youth remain abstinent for at least 1 year, suggesting these impairments are by and large transient in nature.

Method

Design and Sample

The data come from two studies: The Pittsburgh Girls Study (PGS) and the Pittsburgh Youth Study (PYS). The PGS consists of 2,451 girls initially recruited from households in the city of Pittsburgh when they were 5 to 8 years of age, with an oversampling of families in low-income neighborhoods. Sample recruitment began by first dividing the 89 neighborhoods in Pittsburgh into 23 disadvantaged and 66 non-disadvantaged communities using information on poverty from the 1990 Census. Neighborhoods where at least 25% of the families were living at or below the poverty level were fully enumerated (i.e., all homes were contacted to determine if an eligible girl lived there), while in the other neighborhoods a random selection of 50% of the households were visited. A total of 103,238 households were enumerated and 2,876 families were identified as eligible for the study (i.e., girl age 5-8 years, no severe developmental delay, English as first language). Of the eligible families, 2,451 (85.2%) agreed to participate. The girls averaged 7.2 (SD=1.23) years of age at wave 1 (data collected in 2000-2001) and were predominately Black (53%) or White (41%). Nearly all primary caregivers were biological mothers (92%), with 58.7% cohabiting with a partner and 16.8% completing less than 12 years of schooling. Over one-third of families (38.9%) were receiving public financial assistance (e.g., food stamps). Further details regarding sample recruitment can be found elsewhere (Hipwell et al., 2002).

The current study will focus on annual assessments conducted between the ages of 11 to 16, because marijuana use was practically non-existent prior to this time in both the PGS and PYS. There were 2,296 girls (93.7% of sample) who were assessed at least once during this timeframe. In addition, parent reports of attention and academic problems were available up to age 16 in both samples. Interviews were conducted separately with parents and children, typically within the participants' homes. Phone interviews were conducted with families that moved outside of a reasonable driving distance. Parental consent and child assent was obtained prior to conducting the interviews. All study procedures were approved by the University of Pittsburgh Institutional Review Board.

The PYS is a longitudinal study of boys who were initially recruited from the Pittsburgh Public Schools in 1987-1988. The current study includes the youngest cohort of the PYS, who were selected from a larger pool of 1,165 children registered to attend the 1st grade. Of these families, 849 were selected to undergo a multi-informant (i.e., parent, teacher, child report) screening that assessed early conduct problems (e.g., fighting, stealing). Boys

identified at the top 30% on the screening risk measure ($N=256$), and a roughly equal number of boys randomly selected from the remainder ($N=247$), were selected for longitudinal follow-up (total $N=503$). The follow-up sample was not significantly different from the screening sample in terms of race, family composition, or California Achievement Test reading scores. The boys' mean age at screening was 6.9, and racial composition was predominately White (40.6%) and Black (55.7%). Nearly all primary caregivers were biological mothers (92%), with 45.3% cohabiting with a partner and 16.9% completing less than 12 years of schooling. Over half of families (61.3%) were receiving public financial assistance (e.g., food stamps). Greater detail on participant selection and sample characteristics is available elsewhere (Keenan et al., 2010; Loeber, Farrington, Stouthamer-Loeber, & White, 2008).

Identical to the PGS, analysis with the PYS will involve annual assessments collected from ages 11 to 16. Interviews were conducted separately with parents and children, typically within the participants' homes. Phone interviews were conducted with families that moved outside of a reasonable driving distance. Parental consent and child assent was obtained prior to conducting the interviews. All study procedures were approved by the University of Pittsburgh Institutional Review Board. Because the PYS is a grade-based cohort, time-series data were realigned by age to place youth on a common developmental metric with the PGS.

Measures

The PGS and PYS contain a similar set of predictor and outcome variables that were used in the current study to facilitate comparability. In addition to marijuana use and attention/academic problems, time-varying confounds (described below) were included in analyses: other substance use, familial disruption/disadvantage, parental stress, conduct problems, and peer delinquency/substance use. All constructs listed below were assessed annually across ages 11 to 16 in both studies.

Marijuana Use—In the PGS, the Nicotine, Alcohol and Drug Use questionnaire (NADU; adapted from Pandina, Labouvie, & White, 1984) was used to assess frequency of marijuana use in the past year. The Substance Use Questionnaire (SUQ) from the National Youth Survey (Loeber, Farrington, Stouthamer-Loeber, & Van Kammen, 1998) was used to assess the past year frequency of marijuana use in the PYS.

Due to the relatively low frequency of marijuana use across the study period (see Table 1), the current analysis examined the concurrent and sustained impact of less than monthly use (1-11 times) and at least monthly use (12 or more times) on adolescents' attention and academic problems relative to their levels of these problems prior to initiating any marijuana use. This was done using four mutually exclusive dummy coded variables. To index the concurrent impact of marijuana use on attention and academic problems, two variables were created to indicate waves when the participant reported using less than monthly during the past year (0=did not use 1-11 times; 1=used 1-11 times) and waves when the participant reported using at least monthly during the past year (0=did not use 12+ times; 1= used 12+ times) for each wave. Two additional dummy coded variables were created to index the lingering effect that initiating less than monthly and at least monthly use had on academic

and inattention problems during subsequent assessments when the participant reported no use in the past year. To index the lingering effect of less than monthly use, a variable was coded “1” for assessment waves that met the following criteria: 1) the participant reported no past-year marijuana use; 2) the participant reported less than monthly marijuana use at a prior wave; and 3) the participant had not reported using marijuana at least monthly at a prior wave. Waves that did not meet these criteria were coded “0”. To index the lingering effect of at least monthly use, a variable was coded “1” for assessment waves that met the following criteria: 1) the participant reported no past-year marijuana use; and 2) the participant reported at least monthly marijuana use at a prior wave. Waves that did not meet these criteria were coded “0”. Using this coding scheme, the only wave(s) coded “0” across all four mutually exclusive (i.e., orthogonal) variables are those that occurred prior to the onset of marijuana use, making this the contrast condition. Online resource 1 provides examples of how this coding scheme was implemented. More detailed explanations regarding the use of dummy coding when examining intra-individual change over time can be found elsewhere (Osgood, 2010).

Academic Problems—In both the PYS and PGS, academic problems were assessed each year using parent report of school performance on reading, writing and arithmetic, adapted from the Child Behavior Checklist (Achenbach, 1991). In the PGS, achievement in each of the domains was rated on a 5-point scale ranging from 1 (*failing*) to 5 (*far above average*). Domains were rated on a slightly different 4-point scale in the PYS, which ranged from 1 (*failing*) to 4 (*above average*). Items were reverse-scored before being summed so that higher scores represented more academic problems. Parent-report ratings of academic achievement have been shown to be moderately correlated with academic achievement test scores across numerous studies (Gilger, 1992).

When participants in the PGS were 10 years of age, they were administered the reading, writing and arithmetic subtests of Wide Range Achievement Test-3, a nationally normed performance-based screener to assess academic abilities (Wilkinson, 1993). To further validate the parent-report measure of academic problems, correlation analysis was conducted between parent-reported academic problems and the mean of the age-based subtest standard scores on the WRAT-3. The two measures were moderately correlated ($r = .56$), which is similar to correlations reported between academic achievement test scores and students' actual grades (Duckworth & Seligman, 2006) and teacher ratings of academic achievement (Gilger, 1992).

Attention Problems—In the PGS, attention problems were assessed using parent report on the Adolescent Symptom Inventory-4 [ASI-4 (Gadow & Sprafkin, 1997)], which is a DSM-IV based checklist. Parents were asked to rate the extent to which their child exhibited each of the nine inattentive symptoms of ADHD on a 4-point scale ranging from 0 (*never*) to 3 (*very often*), such as being forgetful, making careless mistakes, not paying attention, being easily distracted, having difficulty organizing and finishing tasks. The ADHD subscale has shown good sensitivity and specificity in distinguishing youth with clinical impairment from healthy controls (Gadow & Sprafkin, 1997). The PYS measured attention problems using five parent-report items on the Child Behavior Checklist that have been rated as consistent

with inattention symptoms outlined in the DSM-IV (Achenbach, Dumenci, & Rescorla, 2003), including being inattentive, being easily distracted, failing to finish things, and having difficulties concentrating and following directions. Parents were asked to rate the extent to which each item is true of their child on a 3-point scale ranging from 0 (*not true*) to 2 (*very true*). Evidence for the construct validity and high internal consistency of the inattention scale has been demonstrated in previous studies (Pardini, Obradovic, & Loeber, 2006). Data from a meta-analysis indicate that parent and other informant (e.g., teacher) ratings of observable attention problems show small to moderate correlations ($r_s = .23-.34$) with children's performance on neuropsychological tests measuring cognitive abilities such as short-term and working memory, processing speed, and intelligence (Willcutt et al., 2012). In the PYS and PGS, items were summed so higher scores represented more attention problems.

Potential Confounds

A number of different time-varying covariates that may account for the association between marijuana use and attention/academic problems were included in the models as potential confounds.

Tobacco, Alcohol, and Hard Drug Use—In the PGS, the NADU was used to assess the girls' past-year frequency of tobacco, alcohol, and six hard drugs (e.g., cocaine, stimulants, opiates). In the PYS, the SUQ assessed the boys' past year frequency of tobacco, alcohol and nine hard drugs (e.g., cocaine, stimulants, opiates). Due to the relatively low frequency of tobacco and alcohol use, dummy coded variables were created indexing years of less than monthly and at least monthly use, as well as years of abstinence following initiation, using the same coding scheme outlined for marijuana use. Because the base rate of any hard drug use was extremely low at each age in the PYS and PGS (i.e., < 5%), a single binary variable was created indicating whether or not youth had used any of the drugs in the past year.

Familial Disruption/Disadvantage—Four separate variables were used to assess changes in family structure and disadvantage: single parent in the home, family socioeconomic status, moving residence, and neighborhood disadvantage. In both studies, parent report on the Family Information Questionnaire obtained information about the existing household structure (single or dual parent) and changes in residence since the last assessment. In the PGS, socioeconomic status was indexed based on the family's receipt of public assistance in the past year (e.g., WIC, food stamps, welfare). Because information on this variable was not consistently available in the PYS, information on the educational attainment and current occupation of the parent(s) in the home were used to calculate the Hollingshead index of socioeconomic status (Hollingshead, 1975). In both the PGS and the PYS, neighborhood disadvantage was assessed using the 17-item parent-reported Neighborhood Impressions Questionnaire, which asked about problems associated with poverty, physical disorder and crime in the surrounding neighborhood (Loeber et al., 1998). For each item, parents indicated the severity of the problem using a 3-point scale ranging from 1 (*not a problem*) to 3 (*a big problem*), with items being summed to create a neighborhood disadvantage score.

Parental Stress—In the PYS and PGS, the level of parental stress was measured using the 14-item Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983). Items assessed subjective levels of stress parents experienced over the past month and their perceived capacity to cope with stressful events. Parents rate each item on a five-point scale ranging from 0 (*never*) to 4 (*very often*), with some items being reverse-scored before being summed so higher levels represent greater perceived stress. Prior studies have reported evidence supporting the reliability and construct validity of this measure (Loeber et al., 2008).

Conduct Problems—In the PGS, conduct problems were indexed using the 15 items representing DSM-IV symptoms of conduct disorder (e.g., fighting, stealing, truancy) assessed using the youth-reported ASI-4 (Gadow & Sprafkin, 1997). In the PYS, conduct problems were measured using items from the Self-Reported Delinquency Questionnaire (Loeber et al., 1999) and Youth Self-Report (Achenbach, 1997; Achenbach, 1991) that are also consistent with DSM-IV symptoms of conduct disorder. Thirteen of the 15 symptoms of CD could be indexed using items from these measures (excluded: bullies, threatens, intimidates others, stays out late). This scale has been associated with the onset of alcohol and marijuana use in previous analysis using the PYS (Cerdá et al., 2013). In both studies, symptoms were summed and then log transformed to help normalize the distribution of scores prior to analyses.

Peer Delinquency and Substance Use—Both studies used the self-reported Peer Delinquency Scale to assess the degree to which the participants' friends engaged in a variety of deviant acts (Loeber et al., 1998). In the PYS, the measure included nine items assessing delinquent acts (e.g., stealing, fighting) and three items assessing the use of alcohol, marijuana, and hard drugs. Boys rated how many of their friends engaged in the acts over the past year using a five-point scale from 0 (*none*) to 4 (*all of them*). An adapted version of this measure was administered in the PGS. Items on this scale were rated on a 4-point scale rather than a 5-point scale. In both the PYS and PGS, separate peer delinquency and peer substance use variables were created by summing relevant items. All scales were log transformed to help normalize the distribution of scores prior to analyses.

Data Analysis Plan

In longitudinal studies, causal inference is strengthened by statistically controlling for potential confounding factors, including pre-existing factors that vary between individuals (Allison, 2009; Osgood, 2010). When studying the impact that marijuana use has on cognitive functioning, this approach is limited because it is impossible to control for all pre-existing confounds that differ between youth who do and youth who do not use marijuana. To overcome this problem, the current study used fixed effects regression models with Stata 12.0 (StataCorp, 2011). Fixed effects models focus exclusively on understanding the drivers of change within persons over time, thereby ruling out all time-stable factors that vary between individuals as potential confounds (Allison, 2009; Osgood, 2010). In the context of this study, these models focus on examining whether changes in an individual's marijuana use influence changes in his/her own level of attention and academic problems across ages 11 to 16. Because these models examine drivers of change within individuals, time-invariant characteristics that vary between individuals cannot be used to explain this change (e.g.,

race, genetic factors, intelligence, early learning problems, prenatal drug exposure). For example, prenatal alcohol exposure cannot explain why a given individual's attention problems fluctuate from year to year (i.e., within-individual change), although it may explain why some people have more attention problems than others (between-individual differences). In other words, the strength of focusing on factors that influence within-individual change is that any variable that remains constant over time (whether measured or not) cannot explain why these changes occur. Although other factors besides marijuana use that change over time within individuals must still be considered as potential confounds (e.g., changes in deviant peers, other substance use), ruling out all between-individual differences as potential confounds provides a particularly stringent test of a potential causal association (For a discussion see, Allison, 2009; Curran & Bauer, 2011; Osgood, 2010). To date, the benefit of examining within-individual change to test potential causal relations has not been fully exploited in social science research (Curran & Bauer, 2011), including studies designed to examine the impact of marijuana use on cognitive functioning during adolescence.

All fixed models were estimated separately for the PYS and PGS due to differences in sampling design and minor differences in the measures administered across the studies. Within each sample, identical models were used to predict the outcomes of within-individual change in attention and academic problems. In all models, the four mutually exclusive dummy coded variables described in the measure section indexing frequency of marijuana use at each age (i.e., either less than monthly or at least monthly) and whether youth were abstinent at each age that followed the initiation of different levels of marijuana use (i.e., either less than monthly or at least monthly) were included as predictors. Using this coding scheme, the contrast condition in all models is the assessment wave(s) that occurred prior to the participant first reporting marijuana use (i.e., the only assessment wave(s) coded "0" across the four variables). As a result, the predictors indexing different levels of use represent the sample estimated amount of change that occurs in a youth's attention and academic problems during year(s) when he/she uses marijuana (either less than monthly or at least monthly) relative to his/her levels of these problems in the year(s) prior to the initiation of use. This contemporaneous effect would be consistent with a relatively short-lived (less than a year) impact of marijuana use on a youth's premorbid levels of attention and academic problems, albeit temporal ordering cannot be definitely determined. The binary variables indexing assessment wave(s) when youth did not use marijuana following the initiation of use (either less than monthly or at least monthly) represent the sample estimated difference between a youth's level of attention and academic problems during year(s) of abstinence following initiation relative to year(s) prior to the initiation of use. This tests whether there is evidence of an enduring negative impact of marijuana use on attention and academic problems that persists following at least a year of abstinence.

Two sets of models were estimated for the outcomes of attention and academic problems. The first examined the association between changes in marijuana use and changes in attention/academic problems when only controlling for age related changes in the outcomes (e.g., linear and quadratic age trends). Next, the models were re-run after controlling for the time-varying potential confounds discussed previously. Specifically, the dummy coded variables indexing concurrent tobacco, alcohol, and hard drug use, as well as years of

abstinence following the initiation of these substances, were added to the model. The other time-varying confounds outlined in the measures section were also included (i.e., family SES, change in residence, single parent family, neighborhood disadvantage, parental stress, peer delinquency, peer substance use, and conduct problems). All models were estimated with robust standard errors.

Missing Data

Missing data in longitudinal studies is an unavoidable problem that must be addressed. Model parameters within fixed effects regression are estimated using all available information. The parameters are unbiased when data in a time series are missing at random, meaning the missing data mechanism is unrelated to the unobserved outcome after controlling for observed predictors in the model (Allison, 2009). Although it is impossible to determine whether the missing at random assumption has been violated, regression analyses were conducted to determine whether participants with any missing data across the time series differed from those with complete data on the outcomes of attention and academic problems at each age, after controlling for the observed predictors.

In the PGS, most girls completed at least one assessment during the age period of interest in the present study ($n = 2,296$, 93.7%) and there were 1,515 (61.8%) participants with complete data across all assessment waves. On average, participants completed 5.01 of the 6 assessments (83%). Relative to girls with complete data, girls with any missing data had significantly higher attention problems at each age and higher academic problems at age 16, after controlling for all study predictors. However, the magnitude of this association was extremely small ($R^2 = .004$), suggesting the missing data mechanism was not substantively related to the unobserved value of the outcome.

In the PYS, missing data occurred as the result of two mechanisms. First, because youth were recruited as part of a grade-based cohort study, some youth were not age 16 when parent-report data was discontinued ($n = 126$; 25%). This can be considered random missingness due to the study design. The second type of missingness is related to participants not completing scheduled assessments and/or study drop-out. Most participants from the PYS had at least one observation between 11 and 16 ($n = 479$, 95.2%), and 329 (65.4%) participants had complete data across all ages. On average, participants completed 5.09 of the 6 assessments (84.8%). Boys with missing data were not significantly different from those with complete data in terms of attention and academic problems at any age, after controlling for the observed study predictors. In sum, there was no evidence that missingness was strongly associated with levels of the dependent variables in the PGS and PYS after controlling for model covariates, suggesting that any potential violation of the missing at random assumption was likely minimal and would not substantively bias parameter estimates.

Results

Descriptive Statistics

Information on the levels of attention and academic problems and the use of marijuana in the past year across ages for the PGS and PYS are presented in Table 1. Mean levels of academic and attention problems remained relatively flat between ages 11-16 in the PGS and PYS. In both studies, marijuana use was rare at age 11 but accelerated fairly rapidly until reaching a peak at age 16. However, the prevalence of marijuana use was much higher in the boys relative to the girls. In the PGS, there were 852 (37.1%) girls who reported using marijuana at some point between the ages of 11 to 16, with 639 (27.8%) reporting less than monthly use and 473 (20.6%) reporting at least monthly use at one or more assessments. In the PYS, there were 230 (48.0%) boys who reported using marijuana at some point between the ages of 11 to 16, with 162 (33.8%) boys reporting less than monthly use and 140 (29.2%) reporting at least monthly use at one or more assessments. The few individuals who reported using marijuana at or before the age 11 assessment were excluded from the analysis because their pre-onset attention and academic problems could not be specified within the time series (PGS $n = 15$; PYS $n = 16$).

Proportion of Within-Individual Change in Attention and Academic Problems

Because fixed effects models focus on predicting within-individual variation in the outcomes of interest, we initially examined the proportion of variance in both attention and academic problems that was attributable to changes within individuals over time versus stable between-individual differences. In the PGS, 38% of the variance in academic problems and 35% of the variance in attention problems was due to within-individual change over time, with the remaining variance being attributable to differences between individuals. In the PYS, 51% of the variance in academic problems and 29% of the variance in attention problems was due to within-individual change over time, with the remaining variance attributable to between individual differences. This indicates that across both studies there was significant within-individual variation in parent ratings on both dependent variables across time. Although it tended to be smaller than the between-individual variation, just over half of the variance in academic achievement in males was attributable to within-individual variability.

Marijuana Use and Attention Problems: Before Controlling for Potential Confounds

We initially examined the association between marijuana use and changes in attention problems in a baseline model that only controlled for linear and quadratic age trends. In the PGS, girls experienced increases in their attention problems in years when they used marijuana less than monthly ($B = .61, SE = .16, p < .001$) and at least monthly ($B = .92, SE = .24, p < .001$) relative to years prior to the onset of use. However, the results indicated that during years when girls stopped using marijuana following initiating either less than monthly ($B = -.12, SE = .31, p = .681$) or at least monthly ($B = .21, SE = .39, p = .575$) use, their attention problems were not significantly different from their pre-onset levels.

In the PYS, a baseline model controlling only for age trends also indicated that boys tended to experience increases in their attention problems in years that they used marijuana less

than monthly ($B = .32, SE = .14, p = .020$) and at least monthly ($B = .53, SE = .16, p < .001$), relative to years prior to use onset. Consistent with the PGS results, the findings indicated that during years when boys stopped using marijuana following initiating either less than monthly ($B = .48, SE = .28, p = .097$) or at least monthly ($B = .46, SE = .32, p = .147$) use, their attention problems were not significantly different from their pre-onset levels.

Marijuana Use and Attention Problems: After Controlling for Potential Confounds

We next examined the association between marijuana use and attention problems after controlling for all time-varying covariates in both studies (see Table 2). In the PGS, less than monthly and at least monthly marijuana use remained significantly associated with within-individual increases in attention problems, even after controlling for all time-varying covariates. However, the analysis indicated that during years when girls stopped using marijuana (following initiating either monthly or less than monthly use), their attention problems were not significantly different from their pre-onset levels. There were no significant concurrent associations between alcohol, tobacco, or hard drug use and changes in attention problems, nor was there evidence indicating that girls exhibited significantly higher attention problems in the year(s) after they stopped using these substances.

In the PYS, multivariate models indicated that boys did not experience significantly higher attention problems during years when they used marijuana less than monthly or at least monthly relative to their pre-onset levels, after controlling for all time-varying confounds (see Table 2). The results also indicated that during years when boys stopped using marijuana (following initiating either monthly or less than monthly use), their attention problems were not significantly different from their pre-onset levels. No significant concurrent associations between alcohol, tobacco, or hard drug use and changes in attention problems were found, nor was there evidence that boys experienced significantly higher attention problems in the years after they stopped using these substances.

Marijuana Use and Academic Problems: Before Controlling for Potential Confounds

We next examined the association between changes in marijuana use and academic problems across ages 11 to 16 within a baseline model only controlling for age trends. In the PGS, results indicated that girls experienced significant increases in their academic problems in years when they used marijuana less than monthly ($B = .19, SE = .09, p = .031$) and monthly ($B = .42, SE = .11, p < .001$) relative to years prior to the onset of use. However, during years when girls stopped using marijuana following the initiation of either less than monthly ($B = .02, SE = .16, p = .91$) or at least monthly ($B = .17, SE = .24, p = .47$) use, their academic problems were not significantly different from their pre-onset levels.

When controlling only for age trends in the PYS, the analysis indicated that boys experienced increases in their academic problems in years that they used marijuana at least monthly ($B = .85, SE = .22, p < .001$) relative to years prior to the onset of use. However, this effect was non-significant for less than monthly use ($B = .11, SE = .19, p = .55$). Findings also indicated that during years when boys stopped using marijuana following the initiation of either less than monthly ($B = .25, SE = .32, p = .43$) or at least monthly ($B = -$

01, $SE = .54$, $p = .98$) use, their academic problems were not significantly different from their pre-onset levels.

Marijuana Use and Academic Problems: After Controlling for Potential Confounds

We next examined the association between marijuana use and attention problems after controlling for all time-varying covariates in both studies (see Table 3). Findings from the PGS and the PYS were identical. Results from both studies indicated that less than monthly and monthly use of marijuana, alcohol, and tobacco, and any hard drug use were not significantly associated with changes in academic problems after including all other confounds in the model. These analyses also indicated that youth in both studies did not experience higher academic problems, relative to their pre-marijuana use onset levels, in the years following abstaining from use of these substances.

Supplemental Analysis

The findings indicated that the significant bivariate associations between contemporaneous changes in marijuana use and attention problems in the PYS and academic problems in the PYS and PGS were reduced to non-significance after controlling for several confounding factors. A set of supplemental analyses were conducted to examine whether extreme collinearity and/or the inclusion of a large number of predictors that were not significantly associated with the study outcomes contributed to this finding. Correlations calculated using person-mean centered variables indicated that there was low to moderate collinearity between within-individual change in marijuana use and the other model covariates across the time series in the PYS (r s from $-.05$ to $.47$) and PGS (r s from $-.02$ to $.38$). Separate fixed effects models were then estimated to determine which study predictors were significantly related to changes in academic and attention problems after controlling only for age trends (see Online Resource 1). A final set of multivariate models were then run that included only those predictors that were significantly related to the outcomes at the bivariate level. Results from these multivariate models produced identical findings to those reported in the primary analyses (see Online Resource 1). Specifically, there was no evidence that youth experienced significantly greater attention problems in the PYS or academic problems in the PYS and PGS during years when they used marijuana either less than monthly or at least monthly, relative to years of non-use.

Discussion

This is the first study to examine the short-term and sustained influence that low to moderate adolescent marijuana use has on attention and academic problems within two gender specific samples using comparable measures collected annually from ages 11 to 16. To strengthen causal inference, within-individual change models were used to rule out all pre-existing and time-stable factors (e.g., premorbid cognitive functioning, prenatal substance use) as potential confounds. Several pertinent time-varying factors were also accounted for as potential confounds, including co-occurring changes in tobacco, alcohol, and hard drug use. Baseline models that did not control for potential time-varying confounds indicated that adolescents displayed more academic and attention problems, relative to their pre-onset levels, in years when they used marijuana in both the PYS and PGS samples. However, the

only finding that remained significant after controlling for several potential confounds was the association between changes in marijuana use and attention problems among girls in the PGS. Moreover, the average increase in girls' attention problems during years when they used marijuana relative to the years prior to initiation was less than a single Likert scale point (See *B* coefficients in Table 1), suggesting that this increase is not clinically meaningful. In addition, there was no evidence indicating that adolescents who used marijuana tended to have lingering attention and academic problems after abstaining from use for a year or more. Taken together, these results suggest that low to moderate levels of marijuana use during early adolescence may not cause pronounced impairments in observable attention and academic functioning that are sustained following abstinence.

Early Marijuana Use and Observable Attention Problems

Although some studies have found that adolescents who regularly use marijuana exhibit poorer performance on a wide variety of neuropsychological tests, it is unclear whether marijuana use causes observable cognitive impairments that interfere with day-to-day functioning. The current findings indicated that adolescents tend to exhibit an increase in their premorbid levels of attention problems (as rated by their parents) during years in which they report using marijuana. However, this association was reduced to non-significance after accounting for co-occurring changes in several pertinent time-varying factors in the PYS, but remained significant in the PGS. Although this finding indicates that adolescent girls tended to exhibit increases in their attention problems during years in which they used marijuana, it is possible that this increase in attention problems occurred prior to initiating use within a given year. This lack of clear temporal precedence weakens any potential causal inference. In addition, there was no evidence of a dose-response relationship between the frequency of marijuana use and changes in attention problems in girls. Specifically, girls experienced a statistically equivalent increase in their premorbid level of attention problems whether they used marijuana 1 to 11 times in the last year or 12 or more times within a given year (i.e., $B = .45$ vs. $B = .59$, respectively). This runs counter to the notion that as adolescents smoke marijuana more frequently it causes them to experience a greater degree of cognitive impairments. In addition, there was no evidence indicating that when adolescents abstained from marijuana use for a year or longer, they continued to exhibit higher attention and academic problems relative to their pre-onset levels. Together, these findings argue against a causal association between marijuana use and permanent attentional impairments as observed by parents. Instead, these findings are in line with research indicating that any impairments in attention problems caused by regular marijuana use are reversible with sustained abstinence (Fried et al., 2005).

Adolescent Marijuana Use and Academic Performance

Investigators have speculated that early onset marijuana use can lead to reduced academic performance by negatively impacting adolescents' processing speed, attention, working memory, and problem-solving abilities (Lisdahl & Tapert, 2012). Although adolescent marijuana use has been associated with increased levels of academic failure and lower educational attainment into adulthood, the current study found mixed support for the notion that adolescent marijuana use causes significant and sustained declines in academic functioning relative to pre-onset levels. Across both studies, analyses indicated that

adolescents exhibited reductions in their pre-use levels of academic achievement during years when they used marijuana at least monthly. However, this association became non-significant in both studies after controlling for several co-occurring risk factors in the PYS. Moreover, there was no evidence indicating that adolescents who began using marijuana continued to experience significant impairments in academic functioning after sustained abstinence in either study.

Differential Effects of Marijuana Use By Gender

It is unclear why adolescent girls, but not boys, tended to experience more attention problems during years when they used marijuana, relative to their pre-use levels, even after controlling for other substance use and several potential confounds. Although this result is consistent with the idea that marijuana use may significantly impair key cognitive processes, there are other plausible explanations for this finding. For example, adolescent girls who begin using marijuana may also start engaging in other rebellious behaviors such as ignoring requests from authority figures and failing to follow through on assigned household duties, leading their parents to rate them as having more attention problems. However, the current findings remained significant after controlling for concurrent increases in girls' conduct problems and their affiliation with deviant and substance-using peers. Although it remains unclear whether the association between marijuana use and attention problems is causal, the current findings suggest that the association in girls is not simply due to an overall deviant lifestyle.

Because the current findings were based on two gender-specific longitudinal studies, it is important to remember that differences in findings across studies may have arisen from factors other than gender. For example, although comparable measures were used to assess the same constructs, differences in administration format and item content may account for differences in the results. The two studies also differed in term of their sampling strategy and sample size, with the PGS having greater statistical power to detect significant effects. Furthermore, the PGS data were collected approximately ten years later than the PYS data. During this time span the potency of marijuana has increased significantly and may have contributed to differences between the samples.

Limitations and Future Directions

In the current study, the use of within-individual change models, coupled with extensive controls for several time-varying confounds, provides particularly stringent tests of potential causal associations between early adolescent marijuana use and increases in attention and academic problems. However, these models can produce unreliable estimates when there is little variation within individuals in the predictor variables across multiple assessments (e.g., abstinence following monthly marijuana use). Therefore, larger samples with more fluctuations from active to non-active use may be necessary to more reliably assess the sustained impact that regular use has on attention and academic functioning. It is possible that marijuana use produces longer-term impairments on cognition and related behaviors (e.g., academic performance) only after heavy use lasting multiple years into late adolescence. In the current study, the number of adolescents who repeatedly engaged in weekly or daily use was insufficient to reliably model within-individual change in heavy

use. For this reason, the current findings are most relevant for understanding the associations between experimental to moderate marijuana use and problems with attention and academic functioning. However, these findings are important given that few adolescents engage in weekly marijuana use prior to age 17, and we know little about the potential detrimental effect of moderate use on attention and academic performance among young adolescents.

Consistent with prior investigations, the current study examined self-reported frequency of marijuana use within the past year (Meier et al., 2012). Although procedures to maximize validity of self-reported substance use were used (e.g., assurance of confidentiality), studies should also obtain biochemical verification of abstinence. Additionally, several other factors such as the amount of marijuana used, the type of marijuana (e.g., skunk, hashish), and the mode of administration (e.g., blunts, bong, vaporization, butane hash oil) may be important for understanding the impact that marijuana use has on aspects of cognitive functioning. On a related note, the potency of marijuana (i.e., THC content) has steadily increased over the past several decades (ElSohly, 2009), and the legalization of marijuana in some states has resulted in a growing number and variety of foods infused with high levels of THC. For this reason, contemporary longitudinal studies are needed to determine the extent to which highly potent forms of marijuana and related products negatively affect cognitive and academic functioning when used during adolescence.

Another limitation of the current study is that parent-report measures were used instead of performance-based tasks to assess attention problems. Studies have shown that both parent and teacher ratings of attention problems tend to show small and somewhat inconsistent correlations with performance-based indices of attention and executive functioning (Epstein et al., 2003; Toplak, West, & Stanovich, 2013), suggesting they are measuring different aspects of the same underlying construct. Behavioral ratings scales measure the degree of dysfunction experienced in everyday contexts and performance-based tasks measure cognitive processing in controlled laboratory-based settings, which has less ecological validity in terms of characterizing adolescents' behavior in real-life settings. For this reason, recommended best practices for diagnosing ADHD in adolescence involves collecting parent-report ratings of inattention (Pliszka, 2007), and studies examining the effectiveness of psychosocial treatments and stimulant medication in treating ADHD commonly use parent ratings of attention problems (Sibley, Kuriyan, Evans, Waxmonsky, & Smith, 2014). Randomized placebo trials have also shown that parent ratings of attention problems show greater improvements when youth are assigned to take stimulant medication versus placebo (Sibley et al., 2014), suggesting that parent ratings of inattention are sensitive to real world behavioral change. Although these studies support the validity of parent ratings of attention problems, more subtle deficits in cognitive functioning may have been detected using performance-based measures. For this reason, future studies should assess aspects of attention using a combination of ratings scales and cognitive tests, including ratings from teachers who are able to observe adolescents while they are engaged in cognitively demanding tasks.

Parent ratings were also used to assess academic problems in the current study. Ideally, it would have been useful to assess aspects of academic achievement using teacher ratings and/or official school records since parents may not be aware of their adolescents' academic

functioning. However, the parent-report measure used here was moderately correlated with scores on a brief academic achievement screener in the PGS (see Measures section). The magnitude of this correlation was similar to those found between achievement test scores and students' grades in school and teacher-report ratings of achievement (Duckworth & Seligman, 2006; Gilger, 1992), suggesting that the parent-report measure used in this study is an adequate index of academic functioning. Additionally, a strength of using parent-report measures of attention and academic problems is that it eliminated the possibility that the associations observed were caused by shared-informant method variance, as adolescents reported on their own marijuana use.

Conclusions

The current study used within-individual change models to examine whether early adolescent marijuana use may result in substantive impairments in attention and academic functioning, as well as whether these impairments remain following periods of abstinence lasting at least one year. When controlling for all between-individual differences and several time-varying confounds, the results from two longitudinal studies suggest that the impact of low to moderate adolescent marijuana use on observable attention problems and academic performance is likely small and is not sustained following abstinence lasting at least a year. These findings illustrate the importance of controlling for both between- and within-individual differences when examining whether marijuana use leads to clinically meaningful, observable, and sustained impairments in aspects of day-to-day functioning. Further research in this area is pertinent for public policy decision-making as it can help elucidate the potential real-world consequences associated with recent attempts to legalize marijuana for medical and recreational use.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1
Descriptive Statistics for Attention Problems, Academic Problems, and Marijuana Use in the Pittsburgh Girls Study and Pittsburgh Youth Study

	<u>Age 11</u>		<u>Age 12</u>		<u>Age 13</u>		<u>Age 14</u>		<u>Age 15</u>		<u>Age 16</u>	
	M/%	(SD)/N	M/%	(SD)/N	M/%	(SD)/N	M/%	(SD)/N	M/%	(SD)/N	M/%	(SD)/N
<u>Pittsburgh Girls Study</u>												
Attention problems	6.66	(4.43)	7.23	(4.50)	7.28	(4.65)	7.28	(4.59)	7.16	(4.73)	6.94	(4.67)
Academic problems	7.16	(2.23)	7.16	(2.30)	7.13	(2.37)	7.11	(2.40)	7.20	(2.41)	7.21	(2.39)
<u>Marijuana Use</u>												
< monthly use	0.1%	3	0.5%	11	1.4%	29	4.1%	85	7.4%	151	9.8%	198
monthly use	0.4%	8	1.3%	28	2.8%	58	7.1%	149	9.7%	198	11.3%	229
No marijuana use	99.5%	2091	98.2%	2074	95.9%	2015	88.8%	1858	82.9%	1697	78.9%	1592
Total valid N	2102		2113		2102		2092		2046		2019	
<u>Pittsburgh Youth Study</u>												
Attention problems	2.77	(2.40)	2.82	(2.49)	2.54	(2.35)	2.51	(2.44)	2.47	(2.36)	2.27	(2.19)
Academic problems	5.74	(1.82)	6.16	(2.00)	6.15	(2.04)	6.48	(2.25)	6.59	(2.33)	6.50	(2.22)
<u>Marijuana Use</u>												
< monthly use	2.4 %	10	3.9 %	17	9.5 %	41	11.0%	48	11.8%	50	15.3%	50
monthly use	0.0 %	0	2.1 %	9	5.1 %	22	12.2%	53	16.5%	70	21.5%	70
No marijuana use	97.6%	411	94.1%	411	85.5%	370	76.8%	334	71.8%	305	63.2%	206
Total valid N	421		437		433		435		425		326 ^a	

^a Parent-report of attention and academic problems was discontinued prior to age 16 for some participants.

Table 2
Effect of Marijuana and Other Substance Use on Within-Individual Change in Attention Problems from Ages 11 to 16

	<u>Attention Problems</u>					
	<u>Pittsburgh Girls Study</u>			<u>Pittsburgh Youth Study</u>		
	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>
<u>Concurrent Use^a</u>						
Marijuana use						
< monthly	0.45	0.17	0.010	0.22	0.14	0.115
monthly	0.59	0.26	0.026	0.19	0.18	0.298
Tobacco use						
< monthly	0.29	0.21	0.172	0.26	0.21	0.210
monthly	0.38	0.27	0.153	0.23	0.15	0.132
Alcohol						
< monthly	0.03	0.12	0.811	-0.09	0.13	0.485
month	-0.23	0.26	0.380	0.21	0.18	0.246
Any hard drug use	0.52	0.55	0.344	-0.04	0.34	0.901
<u>Impact Following Abstinence^b</u>						
Marijuana use						
< monthly	0.06	0.31	0.855	0.43	0.30	0.147
monthly	0.69	0.42	0.098	0.40	0.34	0.239
Tobacco use						
< monthly	0.10	0.26	0.690	-0.02	0.26	0.927
monthly	-0.70	0.46	0.130	-0.05	0.27	0.865
Alcohol						
< monthly	0.02	0.15	0.884	0.05	0.14	0.719
month	-0.54	0.36	0.135	-0.12	0.36	0.735
Any hard drug use	0.54	0.53	0.313	0.04	0.48	0.937

Note.^a Estimates represent average within-individual difference in attention problems during years of substance use relative to pre-onset levels.^b Estimates represent average within-individual difference in attention problems during years of abstinence following substance use onset relative to pre-onset levels. All effects depicted are after controlling for time-varying covariates representing age, age², family SES, moving residence, single parent, neighborhood disadvantage, parental stress, peer delinquency, peer substance use, and conduct problems.

Table 3
Effect of Marijuana and Other Substance Use on Within-Individual Change in Academic Problems from Ages 11 to 16

	<u>Academic Problems</u>					
	<u>Pittsburgh Girls Study</u>			<u>Pittsburgh Youth Study</u>		
	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>
<u>Concurrent Use^a</u>						
Marijuana use						
< monthly	0.13	0.09	0.171	-0.05	0.19	0.800
monthly	0.24	0.12	0.053	0.30	0.27	0.266
Tobacco use						
< monthly	-0.05	0.11	0.671	-0.22	0.23	0.328
monthly	0.06	0.13	0.627	0.07	0.19	0.732
Alcohol use						
< monthly	0.05	0.07	0.465	0.02	0.15	0.872
month	0.12	0.13	0.352	0.49	0.25	0.052
Any hard drug use	0.11	0.26	0.655	0.13	0.37	0.720
<u>Impact Following Abstinence^b</u>						
Marijuana use						
< monthly	0.02	0.15	0.889	0.08	0.31	0.783
monthly	0.23	0.25	0.364	-0.32	0.56	0.564
Tobacco use						
< monthly	-0.10	0.15	0.482	0.00	0.33	0.994
monthly	-0.08	0.24	0.741	0.13	0.43	0.761
Alcohol use						
< monthly	0.07	0.09	0.433	0.27	0.18	0.141
month	-0.23	0.19	0.246	0.61	0.44	0.172
Any hard drug use	-0.01	0.33	0.965	0.44	0.57	0.437

Note.

^a Estimates represent average within-individual difference in academic problems during years of substance use relative to pre-onset levels.

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η Estimates represent average within-individual difference in academic problems during years of abstinence following substance use onset relative to pre-onset levels. All effects depicted are after controlling for time-varying covariates representing age, age², family SES, moving residence, single parent, neighborhood disadvantage, parental stress, peer delinquency, peer substance use, and conduct problems.