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Associations of Alcohol, Nicotine, Cannabis and Drug Use/ Dependence with Educational Attainment: Evidence from Cotwin-Control Analyses

Julia D. Grant, Ph.D.[1,*], **Jeffrey F. Scherrer, Ph.D.**[2,1], **Michael T. Lynskey, Ph.D.**[1], **Arpana Agrawal, Ph.D.**[1], **Alexis E. Duncan, Ph.D.**[1,3], **Jon Randolph Haber, Ph.D.**[4], **Andrew C. Heath, D.Phil.**[1], and **Kathleen K. Bucholz, Ph.D.**[1]

[1]Midwest Alcoholism Research Center at Washington University and the Department of Psychiatry, Washington University School of Medicine, 660 S. Euclid, Campus Box 8134, St. Louis, MO 63110, USA

[2]St. Louis Veterans Administration Medical Center, Research Service (151-JC), 915 North Grand Blvd., St. Louis, MO 63106, USA

[3]George Warren Brown School of Social Work, Washington University, Campus Box 1196, St. Louis, MO 63112

[4]Palo Alto Veterans Affairs Health Care System, 795 Willow Road, MC 151-J, Menlo Park, CA 94025-2539

Abstract

Background—Although substance use is associated with reduced educational attainment, this association may be due to common risk factors such as socioeconomic disadvantage. We tested whether alcohol, nicotine, and illicit drug use and dependence were associated with lifetime educational attainment after controlling for familial background characteristics.

Methods—Data were from a 1987 questionnaire and a 1992 telephone diagnostic interview of 6242 male twins (n=3121 pairs; mean age= 41.9 years in 1992) who served in the U.S. military during the Vietnam-era, and therefore were eligible for educational benefits after military service. Reduced educational attainment (less than 16 years) was examined in twin pairs discordant for substance use history. Substance use and dependence risk factors assessed were early alcohol and cannabis use, daily nicotine use, lifetime cannabis use, and alcohol, nicotine, cannabis, and any illicit drug dependence.

Results—Three significant differences were observed between at risk twins and their cotwins: Compared to their low-risk cotwins, likelihood of completing less than 16 years of education was significantly increased for: (a) twins who used alcohol before age 18 (adjusted OR=1.44; 95%CI: 1.02–2.05), (b) twins with a lifetime alcohol dependence diagnosis (adjusted OR=1.76; 95%CI: 1.27–2.44), and (c) twins who had used nicotine daily for 30 or more days (adjusted OR=2.54, 95%CI: 1.55–4.17). However, no differences in education were observed among twin pairs discordant for cannabis initiation, early cannabis use, or cannabis, nicotine, or any illicit drug dependence.

Conclusions—Even in a veteran population with access to military educational benefits, early alcohol use, alcohol dependence, and daily nicotine use remained significantly associated with years of education after controlling for shared familial contributions to educational attainment.

[*]Corresponding author: Julia D. Grant, Washington University School of Medicine, Dept. of Psychiatry, 660 S. Euclid, Campus Box 8134, St. Louis, MO 63110, USA (grantj@psychiatry.wustl.edu, phone: 011-314-286-2255, fax: 011-314-286-2243).

The association between other substances and educational attainment was explained by familial factors common to these substance use phenotypes and adult educational attainment.

Keywords

cotwin-control design; early substance use; drug dependence; alcohol dependence; educational attainment

INTRODUCTION

Evidence for an association between substance use/abuse/dependence and early school dropout and reduced lifetime educational attainment is mixed (see Townsend et al., 2007 for a review). Although some studies suggest that alcohol use during adolescence is associated with reduced educational attainment (Cook & Moore, 1993; Staff et al., 2008; Wood et al., 2000; Yamada et al., 1996), others have found that the association is not significant when additional control variables are included (Bray et al., 2000; Gotham et al., 2003; King et al., 2006; Koch & Ribar, 2001; Wood et al., 1997).

In contrast, a number of studies have found that smoking is predictive of high school dropout (Aloise-Young et al., 2002; Bray et al., 2000; Ellickson et al., 1998), and of failure to pursue education beyond high school (Chassin et al., 1992; Cook & Moore, 1993; Gfroerer et al., 1997) even after controlling for covariates. Similarly, most studies examining adolescent cannabis use (especially early initiation) suggest that cannabis use remains significantly associated with reduced educational attainment even after controlling for covariates (Bray et al., 2000; Brook et al., 1999; Chatterji, 2006; Fergusson et al., 2003; Horwood et al., 2010; King et al, 2006; Lynskey et al., 2003a; Lynskey & Hall, 2000; Macleod et al, 2004; Register et al., 2001; van Ours & Williams, 2009). Interestingly, McCaffrey et al. (2010) found that the association between cannabis use and school dropout became non-significant once cigarette use was included.

In examining the association between substance use and reduced educational attainment, it is necessary to account for potential confounders, i.e., factors that might contribute to alcohol/drug use liability and also influence academic performance. Previous research has indicated that both educational attainment (Baker et al., 1996; Heath et al., 1985; Lykken et al., 1990) and substance dependence (see reviews by Agrawal & Lynskey, 2006, 2008; Dick et al., 2009; Heath, 1995; Rose et al., 2009) are heritable. Especially pertinent to the present study, Bergen et al. (2008), found evidence suggesting genetic overlap between drug abuse and educational attainment in a twin study, and Dick et al. (2007) found evidence implicating CHRM2 polymorphisms in association studies examining substance use disorders and IQ/cognition.

The discordant twin design provides an elegant strategy for the control of potential genetic and environmental confounds. Similar to a matched pair analysis, in which cases are matched to controls for gender and age, the discordant twin design matches at-risk twins (e.g., those with early cannabis initiation) to control twins (e.g., cotwins without early cannabis use) thereby controlling for genetic and shared environmental influences (which increase twin similarity). In pairs of monozygotic/identical twins discordant for early cannabis use, any reduced educational attainment in the early-onset cannabis using twin can only be attributed to “causal” mechanisms or those environmental factors that are not shared by members of twin pairs, but not to shared genetic or environmental influences. The utility of this design has previously been demonstrated in multiple studies that have found increased likelihood of other illicit drug use in the twin who uses cannabis or alcohol at an

early age when compared with their non-using or later initiating cotwin (Grant et al., 2006; Lynskey et al., 2003b).

In the present paper, we address several limitations in previous research by using a cotwin control design to test the hypothesis that cannabis initiation, early alcohol and cannabis use, daily nicotine use for a month or longer, and lifetime diagnoses of alcohol, nicotine, cannabis, and any illicit drug dependence remain associated with reduced adult educational attainment after controlling for familial influences. First, by examining twin pairs discordant for substance use/dependence, we are able to control for genetic and environmental confounds that might contribute to the association between substance use and educational attainment. Second, because our participants were in their late 30s when their educational attainment was assessed, we are better able to address lifetime educational attainment than are most previous studies, which have focused on high school dropout or educational attainment in 18–25 year-olds whose eventual educational level might not have been reached (although see Bergen et al., 2008; Staff et al., 2008). Third, we examine educational attainment in a veteran cohort that had access to education via benefits of the G.I. bill, thereby alleviating some of the economic barriers to higher education (see Xie, 1992 for a detailed discussion) that might otherwise be confounded with alcohol and drug outcomes.

MATERIALS AND METHODS

Participants

The present sample was drawn from the Vietnam Era Twin Registry (VETR), a national register of 7,375 male-male twin pairs in which both members served in the military during the Vietnam-era (i.e., between 1965 and 1975). Registry creation and the method of determining zygosity have been described in detail elsewhere (Eisen et al., 1987, 1989; Henderson et al., 1990). In 1987, 10,981 veterans completed a mailed questionnaire for the Survey of Health (SOH) assessing education, service in Vietnam, and general health status. In 1992, 8,169 individuals in the Registry completed a telephone administration of the diagnostic interview schedule (DIS-III-R; Robins et al., 1989) for the Harvard Drug Study (HDS) that included lifetime assessments for psychiatric disorders, including use of, abuse of, and dependence on alcohol, nicotine and illegal drugs (Tsuang et al., 1996, 1998).

The present analyses included 6,242 individuals from complete twin pairs (n=3121) in which both members of the pair had complete data for all substance use measures from the 1992 interview and for educational attainment from the 1987 questionnaire. In 1992, the mean age of respondents was 41.9 years (SD=2.7) and most were married (77%). Based on military record data, 94% of the respondents were Caucasian, with 6% being African-American and <1% being of another ethnicity.

Measures

Substance use and dependence—All participants were asked the age at which they had first consumed any form of alcohol “at least once a month for 6 months or more”. Participants who endorsed either this stem question or who indicated they had consumed 5 or more drinks in one day were considered drinkers (91.0% endorsed both items; 6.1% endorsed only the frequency question and 2.9% endorsed only the quantity question). Because alcohol use was endorsed by almost all participants, our base alcohol variable was early alcohol use, which was defined as the onset of alcohol use before age 18. Participants were asked whether they had “ever smoked [tobacco form] daily for a month or more”, but were not asked about age of initiation. Respondents who indicated they had smoked cigarettes, cigars, or pipes daily or used snuff or chewing tobacco daily for a month or more were considered to be nicotine users, which was the base measure of nicotine exposure in

our analyses. Both cannabis use (defined as having ever tried cannabis) and early cannabis use (initiation before age 18) were examined. The early substance use cutoff of age 18 was selected because it was generally prior to entry into the military and was stringent enough to apply to only a minority of participants. All substance use measures were based on the 1992 telephone diagnostic interview.

Alcohol, nicotine (any form), cannabis, and any illicit drug dependence phenotypes were defined according to lifetime DSM-III-R criteria. Any illicit drug dependence combined separate assessments of cannabis, cocaine, stimulants, sedatives, opiates, and hallucinogens/PCP (asked of individuals who used a substance more than 5 times). All substance dependence diagnoses were based on the 1992 telephone diagnostic interview.

Educational Attainment—Educational attainment was assessed in the 1987 mailed questionnaire by a single item “What is the highest grade or year of school you have completed and gotten credit for?”. A cutoff of less than 16 years of education was used for the present analyses because that is the typical timeframe for completion of an undergraduate degree.

Covariates—Because we have previously found DSM-III-R diagnoses of major depression (lifetime), conduct disorder (before age 16), and posttraumatic stress disorder (PTSD, lifetime), as well as service in Southeast Asia, to be significant covariates when examining the relationship between early substance use and adult drug dependence (Grant et al., 2006, 2010), these variables were included in all adjusted models. All DSM-III-R diagnoses were assessed in the 1992 telephone diagnostic interview; service in Southeast Asia was assessed in the 1987 mailed questionnaire.

Analytic Strategy

Data preparation and preliminary analyses were conducted using SAS (SAS Institute, Inc., 1999–2001). Logistic and conditional logistic regression analyses were conducted using STATA (StataCorp, 2005), which uses a robust variance estimator to adjust for the non-independence of data from twins (used in the logistic regression analyses).

Pairs of monozygotic (MZ) and dizygotic (DZ) twins were identified as being concordant/discordant on each of the following drug use behaviors: early alcohol use (before age 18), daily nicotine use, lifetime cannabis use, early cannabis use (before age 18), and alcohol, nicotine, cannabis, and any illicit drug dependence.

In cotwin-control analyses, twin pairs are matched for familial background and vary only in that one is at risk because of “exposure” (exposure is substance use/early use/dependence in these analyses) whereas the other twin is not. The test is whether the “exposed” twin is at increased risk of having a particular outcome (lower educational attainment in this case) compared to the “non-exposed” twin. These cotwin-control analyses permit the assessment of whether the associations observed between substance use behaviors and educational attainment in the general population are: a) attributable to an underlying familial liability (environmental or genetic), b) are causal (or due to other unmeasured environmental risk factors), or c) are influenced by both (a) and (b).

As has been discussed in detail by others (e.g., Agrawal et al., 2004; Kendler et al., 1993; Vitaro et al., 2009), depending on the nature of the association between risk and outcome variables, the pattern of association between substance use (the risk factor) and educational attainment (the outcome) will vary systematically for the general population vs. MZ discordant pairs vs. DZ discordant pairs, and the pattern of association for these groups can indicate which processes are important. If genetic factors fully account for the association

between substance use and educational attainment, then there will be a significant association between the measures in the general population, a moderate association among DZ pairs discordant for substance use, and no association among MZ pairs discordant for substance use (i.e., population > DZ discordant > MZ discordant = 1.0, with 1.0 being an odds ratio and thus indicating no association). If the association is solely due to shared environmental characteristics, then population > DZ discordant = MZ discordant = 1.0. And if the risk factor causes the outcome (or both are attributable to unmeasured variables), then population = DZ discordant = MZ discordant > 1.0. If both causal (or unmeasured) and non-causal factors contribute to the association, we would expect to see a pattern where population > DZ > MZ > 1.0.

Although it is possible to test for differences in the association between MZ and DZ twin pairs by analyzing the groups separately, this results in a loss of statistical power. Another method involves testing for zygosity differences by including an interaction between zygosity and the exposure variable (in addition to the main effect of exposure) in the model. If the interaction term is not significant and DZ = MZ > 1.0, then there is no evidence of differential association by zygosity and it is possible to analyze MZ and DZ discordant pairs simultaneously. Alternatively, if DZ = MZ = 1, then the association is non-causal and attributable to shared familial influences.

Attrition—Previous research has indicated that the Vietnam Era Twin Registry is generally representative of twins who served in the military during the Vietnam-era (Goldberg et al., 1987; Henderson et al., 1990). Goldberg et al. (1987) reported differences in date of enlistment/discharge, duration of service, branch of service, and service in Southeast Asia between individuals included in the Defense Manpower Data Center database (the source of the Registry) and the State of Connecticut twin register (for which a manual search of hard copy military records was conducted). When examining attrition from the full Registry to the SOH, Henderson et al. (1990) found that SOH non-responders were more likely to be non-White, had lower education at enlistment, were younger at enlistment, and were less likely to have served in Southeast Asia.

We examined attrition between the 1987 SOH and the full 1992 HDS sample through logistic regressions predicting loss to follow-up. In addition, we conducted a form of propensity score analysis (Rosenbaum & Rubin, 1983) to check whether differential attrition for concordant versus discordant pairs was biasing our conditional odds ratio estimates. A logistic regression equation was used to predict individual non-participation versus participation in the 1992 HDS as a function of variables assessed in the 1987 SOH. Predicted probability of participation (range: 0.08–0.78, median 0.59) was then categorized into quintiles, and this categorical variable, defined for the first twin from each pair, was then included as a moderator in conditional logistic analyses (i.e.., testing for an interaction of participation probability with the drug risk statuses of twin and cotwin when predicting discordance for educational attainment).

RESULTS

Attrition

Individuals with less than 16 years of education in 1987 were significantly less likely to participate in 1992 (OR=0.84, 95% CI 0.75–0.94), as were minorities (Black OR=0.63, 0.52–0.75 “Other” ethnic group OR=0.46, 0.24–0.86). Those who served in Southeast Asia were more likely to participate in 1992 (OR=1.12, 1.02–1.22). When we tested for interactions between substance use risk factor and participation probability quintile, we found one marginally significant interaction (p=.037, for ever use of cannabis) and two strongly significant interactions (p=.007 for daily smoking, and p=.005 for nicotine

dependence), with a negative Beta coefficient for the interaction term in all three cases, implying higher conditional odds ratios in quintiles associated with low response probability. Thus, selective attrition may have caused us to underestimate the true conditional odds ratios for these variables. Further tests using conditional logistic models indicated that inclusion of the interaction term altered the significance of the substance risk factor only for nicotine dependence in the adjusted model (the OR was significant with the inclusion of the quintile interaction term ($p<.001$), but just failed to reach significance in the main analyses presented below ($p=.07$)); all other models yielded the same significance regardless of whether the quintile interaction term was included.

Descriptive information

The distribution of substance use measures, educational attainment, and covariates is shown in Table 1. By 1987, 96.8% had completed 12 or more years of education and 24.1% had at least 16 years of education. Based on the 1992 survey, almost all participants were drinkers at some point in their lives, with about one-third having met lifetime criteria for alcohol dependence. Almost 70% of respondents had used nicotine daily at some time, and almost 50% met lifetime criteria for nicotine dependence. About half of the respondents had ever used cannabis, with less than 7% having a lifetime DSM-III-R cannabis dependence diagnosis. In addition, about 10% of respondents had DSM-III-R diagnoses of depression (lifetime), PTSD (lifetime), and conduct disorder before age 16. Almost 40% had served in Southeast Asia.

Individual-based associations between risk factors and outcome—Table 2 shows the number of individuals in each substance risk group and the prevalence of having completed less than 16 years of education among individuals at varying degrees of risk based on their substance use history. In general, the prevalence of having less than 16 years of education was highest in pairs concordant for the substance risk factor, and decreased through the at-risk members of discordant pairs, to the low-risk members of discordant pairs, to pairs concordant for low-risk. This pattern is consistent with a model in which the likelihood of lower educational attainment increases with increasing substance exposure risk, with one's own substance use patterns having greater influence than one's cotwin's substance use.

Logistic regression analyses were used to test the significance of the association between substance use and educational attainment within individuals while controlling for the non-independence of twin pairs, as shown in Table 3. The first column of Table 3 confirms that, in the general population, each substance use measure was associated with reduced educational attainment, even after controlling for covariates. The remaining columns of Table 3 display results from tests examining whether the three "at risk" groups (individuals in pairs concordant for substance risk behavior, the substance using twin from discordant pairs, and the non substance using twin from discordant pairs) had significantly lower educational attainment relative to individuals in pairs concordant for low substance risk (the comparison group). In unadjusted models, individuals in all three "at risk" groups had significantly lower educational attainment for almost all substance use measures than did individuals in pairs concordant for low substance risk (the sole exception was a lack of association between alcohol dependence and educational attainment in low risk twins from discordant twin pairs). We observed little change in point estimates after adjustment for depression, conduct disorder, service in Southeast Asia and PTSD, with many effects remaining significant. The exceptions were cannabis dependence for individuals in pairs concordant for high-risk, and cannabis initiation and dependence in the high risk twins from discordant pairs; alcohol dependence remained unassociated with educational attainment in the low-risk individuals from discordant pairs.

Pair-wise associations between risk factors and outcome

Analyses within twin pairs discordant for substance use and dependence are shown in Table 4. The interaction between zygosity and daily nicotine use was significant, and thus was included in the final model along with the main effect of daily nicotine use. Since no other interactions were significant (p-value range: 0.21–0.77), the interaction term was not included in the other conditional logistic models. Compared to their cotwins who did not use alcohol before age 18, individuals who used alcohol before age 18 had significantly lower educational attainment before and after covariate adjustment. Similar results were observed for alcohol dependence and daily nicotine use, with a trend for nicotine dependence (p=0.07 in the adjusted model). However for all cannabis measures and any illicit drug dependence, at risk individuals did not have significantly lower educational attainment than their low-risk cotwin.

DISCUSSION

In this sample of Vietnam-era veteran twins, after controlling for individual-level measured covariates, all of the alcohol, nicotine, and cannabis use and dependence measures were significantly associated with reduced likelihood of completing 16 years of education. However, after additionally controlling for familial contributions to adult educational attainment in cotwin-control analyses, only early alcohol use, alcohol dependence, and daily nicotine use remained significantly associated with reduced educational attainment. Importantly, for all three measures, the odds ratios in the cotwin control analyses (Table 4) fell within the confidence intervals for the odds ratios estimated using the full sample (Table 3, first column), indicating that controlling for family influences did not attenuate the association. Thus, our data were consistent with the possibility that non-genetic causal influences may contribute to the association between daily nicotine use, early alcohol use, alcohol dependence and educational attainment (i.e., population=DZ=MZ>1.0).

In contrast, for all cannabis measures, nicotine dependence, and any illicit drug dependence, the association between substance use and educational attainment was accounted for by non-causal shared environmental factors (i.e., DZ=MZ=1.0 in cotwin-control analyses). This finding is fairly consistent with drug use disorder findings from the Mid-Atlantic Twin Registry reported by Bergen et al. (2008), who found that the DZ regression coefficient was slightly larger than the MZ regression coefficient, although neither was statistically significant. Although they suggested that this was evidence for shared genetic influences between drug abuse and educational attainment, because neither regression was statistically significant these findings could also be interpreted as evidence of a non-causal shared environmental influence. Bergen et al. (2008) did not report findings for alcohol use/dependence or nicotine dependence.

That our effects remained for alcohol but not cannabis is in contrast to results reported by King et al. (2006), who found that alcohol use measures were unrelated to college degree completion after inclusion of predisposing factors, but that drug use slope remained significant. These differences could stem from a number of factors, including sampling and measurement. Whereas King et al.'s (2006) most robust effects were observed for college degree completion, we did not have an index of degree completed and instead used a cutoff based on years of education completed (our cutoff of less than 16 years was designed to be parallel to a bachelor's degree, but we have no indication whether the degree was obtained). For substance use, we analyzed binary measures of use and dependence whereas King et al. used growth models to create continuous slope and intercept measures for consumption. In addition, their drug use measure was a composite of eight illicit drugs; our drug use analyses focused on cannabis, although we did include a measure of any illicit drug dependence (which was not significant in our cotwin-control analyses). Also, our sample was Vietnam-

era veteran male twins with a mean age of roughly 37 years when educational attainment was assessed, whereas King et al. analyzed data from a case-control sample focused on offspring of alcoholics with a mean age of 25 years at the final assessment. Thus age, gender, and military history could also contribute to the different results in our study compared to King et al. (2006).

A unique contribution of our study was the examination of educational attainment in an early-middle-aged sample that, because of the benefits provided by the military, had reduced economic barriers to completing adult education. Xie (1992) conducted an extensive examination of the educational attainment of veteran versus non-veteran U.S. men, and found that veterans exceeded non-veterans in educational attainment sometime between their late 20s and early 30s; prior to that age veterans had lower educational attainment. This later attainment is important to bear in mind in any examination of veteran samples, as assessments with younger veterans might underestimate lifetime educational attainment. In our data, by 1987 52.2% of Vietnam-era veterans had completed some additional formal schooling beyond their education at enlistment, with 24.1% of the sample having 16+ years of education in 1987 compared to 6.7% at military enlistment. Importantly, in our sample the mean years of education ($\underline{M}$=14.0) was identical to that observed by Lyons et al. (2006) in their Vietnam Era Twin Study of Aging (which was based on a subsample of the same veterans included in our analyses), despite the fact that their participants had a mean age of 54.4 years at interview (compared to roughly 37 years for our sample when education was assessed). This suggests that any individuals interested in educational benefits from the military had taken advantage of this opportunity before 40 years of age.

Our finding of a potentially causal association between some substance use/dependence measures (early alcohol use, alcohol dependence, and daily nicotine use) and educational attainment, but no support for such a relationship between education and other substance measures (nicotine dependence, multiple cannabis measures, and illicit drug dependence), was unanticipated and warrants further attention. It is possible that the initiation of alcohol use and daily nicotine use occurred during a key developmental time for these individuals, whereas the cannabis initiation fell outside this period. There is some support for this, given that our mean age of onset for alcohol use was 18.5 years and for cannabis initiation was 20.1 years. Thus many of these individuals were drinking while still in high school, but most initiated cannabis use after leaving high school. Another potentially important distinction between our measures is that while we examined repeated alcohol use and daily nicotine use, we examined ever use for cannabis. It is possible that repeated use is more critical than initiation in looking at long-term effects on educational attainment. Finally, it is also possible that unmeasured variables are confounding the relationship between education and the licit substances (alcohol and nicotine), but not the relationship between education and cannabis/other illicit drugs.

Our study is not without limitations. One important limitation is that we have not confirmed that the substance measures predated the educational attainment. We can be almost certain that early use (and probably daily nicotine use) occurred before participants finished their schooling, however there is less certainty regarding the temporal sequence for the dependence measures. Although we can date the onset of first dependence symptom, we do not have any measures that assess when the individuals completed their formal education, making such an examination impossible with the present data.

We cannot exclude the possibility that unmeasured environmental confounders impacted both our substance disorder measures and educational attainment. Although we attempted to control for possible confounders, additional work is needed to confirm that this association holds in other populations and after control for additional variables. For example, cognitive

ability has been implicated in both substance use disorders and educational attainment, although without prospective data it is impossible to tell whether low cognitive ability is a cause or consequence of substance involvement. Along this line, research by Latvala et al. (2009) has shown that verbal ability and psychomotor processing speed are reduced in individuals with substance use disorders, with evidence that educational attainment may mediate the association between verbal ability and substance use disorders.

Our use of a veteran sample potentially limits the generalizability of our results. First, the near universal requirement of completion of high school (or a GED) for service in the military means that while our analyses are able to address the effects of substance use history on educational attainment among high school graduates, they can say nothing about the effects of high school dropout on early substance use and vice versa. Second, because the Registry is based on twin pairs in which both individuals were in the military during the Vietnam-era, the sample may not generalize to twin pairs that were excluded from the Registry (because one or both members were not in the military, e.g., because one or both were in school still, married, parents, deemed medically ineligible, or because one/both found other ways of avoiding the draft). Third, Henderson et al. (1990) found that non-responders in the Survey of Health were less educated at military enlistment than responders, so the educational attainment in this sample may not be representative of all veterans. Finally, the present sample of male Vietnam-era veterans was predominantly Caucasian, thus results may not generalize to other ethnicities, to women, to non-veterans, or to cohorts who grew up in an era with different levels of acceptance of and/or access to cannabis.

Regarding the cotwin-control analyses, it is possible that selective attrition biased our results, although our examination suggests that any selective attrition for smoking-related behaviors contributed to an underestimation of conditional odds ratios and thus reduced our likelihood of finding differences. Additionally, given the small numbers of pairs discordant for early cannabis use, cannabis dependence, and any illicit drug dependence, our conditional logistic regression effects have broad confidence intervals that do not allow us to exclude important effects.

A final potential limitation of the present analyses is our reliance on retrospective reports. Although prospective data would be ideal since it eliminates recall bias and increases the ability to test causal models, such data would take many years to collect, and retrospective reports are a useful alternative.

The present analyses have several strengths and provide an important extension of previous work examining associations between substance use and educational attainment. First, by using twin pairs discordant for substance use/dependence, we were able to control for genetic and environmental confounds that might contribute to the association between substance use and educational attainment. Second, because our participants were in their late 30s when their educational attainment was assessed, we were better able to address lifetime educational attainment than are most previous studies, which have generally focused on high school dropout or educational attainment in 18–25 year-olds whose eventual educational level might not have been reached. Third, we examined educational attainment in a veteran cohort that had access to education via benefits of the G.I. bill, thereby alleviating some of the economic barriers to higher education.

In conclusion, after controlling for genetic and environmental confounds that might contribute to observed associations, there remained evidence consistent with non-genetic (and potentially causal) associations between some substance use/dependence measures (early alcohol use, alcohol dependence, daily nicotine use) and educational attainment, but

no support for a causal relationship between other substance measures (nicotine dependence, cannabis use/dependence, any illicit drug dependence) and educational attainment. These findings lend credence to ongoing public health efforts to reduce adolescent smoking and drinking, which in turn may have beneficial effects on school dropout and lifelong educational attainment. However, the possibility that the association for alcohol and daily nicotine use is due to an unmeasured third variable (e.g., cognitive ability) needs further examination and replication in additional samples.

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Table 1

Demographic and substance use characteristics.

	All men (n=6242)
Age in 1992	41.9 yrs
Years of education at military enlistment	12.3
Years of education in 1987	14.0
Race	
White	94.0%
Black	5.7%
Other (incl. Hispanic)	0.3%
Marital Status in 1992	
Married	77.3%
Sep/Div/Widowed	15.3%
Never Married	7.4%
Years of education in 1987	
12 or less	33.7%
13–15	42.2%
16 or more	24.1%
Substance use and psychiatric history in 1992	
Ever had a drink of alcohol	96.2%
Drinker	90.8%
Early drinker (< age 18)	25.8%
Alcohol dependence	34.9%
Daily nicotine use (30+ days, lifetime)	69.1%
Nicotine dependence	47.4%
Lifetime cannabis use	47.0%
Early cannabis use (< age 18)	8.0%
Cannabis dependence	6.6%
Any illicit drug dependence	9.5%
Depression (lifetime)	9.1%
Conduct disorder	8.6%
Served in Southeast Asia	38.7%
PTSD (lifetime)	9.5%

Table 2

Prevalence (%) of having less than 16 years of education among individuals of varying substance risk status.

Substance Risk Factor	Individuals in pairs concordant for substance risk	At risk twin from risk-discordant pairs	Low risk twin from risk-discordant pairs	Individuals in pairs concordant for no substance risk
Early alcohol use	82.0% (n=722)	82.9% (n=889)	79.9% (n=889)	72.1% (n=3742)
Daily nicotine use	81.9% (n=3610)	76.1% (n=702)	70.4% (n=701)	61.2% (n=1228)
Early cannabis use	89.6% (n=222)	86.2% (n=276)	83.7% (n=276)	74.4% (n=5468)
Cannabis initiation	80.7% (n=1988)	75.5% (n=947)	76.9% (n=947)	71.5% (n=2360)
Alcohol dependence	84.2% (n=1156)	79.6% (n=1023)	75.1% (n=1023)	71.7% (n=3040)
Nicotine dependence	84.0% (n=1898)	78.9% (n=1059)	76.3% (n=1059)	67.3% (N=2226)
Cannabis dependence	84.9% (n=132)	80.5% (n=282)	81.2% (n=282)	75.2% (n=5546)
Any illicit drug dep.	86.0% (n=214)	83.9% (n=379)	80.5% (n=379)	74.6% (n=5270)

Table 3

Unadjusted and adjusted logistic regression results: likelihood (ORs and 95% CIs) of having completed less than 16 years of education among twins with varying substance risk factors.

Substance Risk Factor	Full Sample[1]	Concordant High Risk[2]	High Risk Twin from Disc. Pairs[2]	Low Risk Twin from Disc. Pairs[2]	Significant Covariates
Unadjusted					
Early Drinker	**1.69 (1.45 – 1.97)**	**1.77**[a,b] **(1.39 – 2.23)**	**1.87**[a] **(1.54 – 2.28)**	**1.53**[b] **(1.27 – 1.85)**	n/a
Daily Nicotine Use	**2.34 (2.04 – 2.68)**	**2.87**[a] **(2.40 – 3.43)**	**2.01**[b] **(1.60 – 2.53)**	**1.50**[c] **(1.21 – 1.87)**	n/a
Early Cannabis Use	**2.42 (1.78 – 3.27)**	**3.01 (1.74 – 5.20)**	**2.15 (1.51 – 3.06)**	**1.76 (1.27 – 2.45)**	n/a
Cannabis Initiation	**1.39 (1.22 – 1.58)**	**1.67**[a] **(1.40 – 1.99)**	**1.22**[b] **(1.01 – 1.47)**	**1.31**[b] **(1.09 – 1.59)**	n/a
Alcohol Dependence	**1.72 1.50 – 1.97)**	**2.10**[a] **(1.69 – 2.60)**	**1.52**[b] **(1.27 0 1.83)**	1.18[c] (0.99 – 1.40)	n/a
Nicotine Dependence	**1.95 (1.71 – 2.22)**	**2.54**[a] **(2.11 – 3.05)**	**1.80**[b] **(1.49 – 2.17)**	**1.55**[c] **(1.30 – 1.86)**	n/a
Cannabis Dependence	**1.47 (1.12 – 1.94)**	**1.86 (1.03 – 3.36)**	**1.36 (1.00 – 1.84)**	**1.42 (1.05 – 1.94)**	n/a
Any Illicit Drug Dep.	**1.85 (1.44 – 2.37)**	**2.11 (1.31 – 3.38)**	**1.78 (1.34 – 2.36)**	**1.41 (1.08 – 1.83)**	n/a
Adjusted [3]					
Early Drinker	**1.62 (1.39 – 1.89)**	**1.68**[a,b] **(1.32 – 2.13)**	**1.80**[b] **(1.48 – 2.20)**	**1.49**[b] **(1.24 – 1.80)**	SEA
Daily Nicotine Use	**2.26 (1.97 – 2.59)**	**2.76**[a] **(2.30 – 3.31)**	**1.97**[b] **(1.57 – 2.48)**	**1.48**[c] **(1.19 – 1.85)**	---
Early Cannabis Use	**2.36 (1.74 – 3.21)**	**3.01 (1.73 – 5.23)**	**2.10 (1.47 – 3.00)**	**1.74 (1.25 – 2.42)**	SEA
Cannabis Initiation	**1.34**[d] **(1.17 – 1.52)**	**1.59**[a] **(1.33 – 1.91)**	1.18[b] (0.98 – 1.43)	**1.29**[b] **(1.07 – 1.57)**	SEA
Alcohol Dependence	**1.64 (1.43 – 1.89)**	**1.99**[a] **(1.61 – 2.48)**	**1.45**[b] **(1.21 – 1.75)**	1.15[c] (0.97 – 1.37)	SEA
Nicotine Dependence	**1.88 (1.64 – 2.14)**	**2.45**[a] **(2.03 – 2.96)**	**1.73**[b] **(1.43 – 2.09)**	**1.52**[b] **(1.27 – 1.83)**	---

Substance Risk Factor	Full Sample[1]	Concordant High Risk[2]	High Risk Twin from Disc. Pairs[2]	Low Risk Twin from Disc. Pairs[2]	Significant Covariates
Cannabis Dependence	**1.34 (1.01 – 1.77)**	1.62 (0.89 – 2.95)	1.27 (0.93 – 1.73)	**1.38 (1.02 – 1.89)**	CD, SEA
Any Illicit Drug Dep.	**1.72 (1.33 – 2.22)**	**1.91 (1.18 – 3.08)**	**1.69 (1.26 – 2.26)**	**1.38 (1.06 – 1.80)**	CD, SEA

[1]Within-individual odds of having lower educational attainment based on substance risk status;

[2]Within-risk-group odds ratio relative to pairs concordant for low risk;

[3]All adjusted models included four covariates: depression (DEPR), conduct disorder (CD), Southeast Asia service (SEA), and post-traumatic stress disorder (PTSD).

a, b, c risk groups with different superscripts are significantly different;

[d]CD and SEA significant for this full sample OR; other full sample covariates matched the covariates for the analyses within-risk-group

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Table 4

Unadjusted and adjusted conditional logistic regression results: likelihood (ORs and 95% CIs) of the at-risk twin (based on substance use history) having lower educational attainment than his cotwin.[a]

Predictor	Number of Discordant Pairs	Unadjusted Conditional Odds ratio	Adjusted Conditional Odds ratio[1]
Early Drinker	n=889	**1.47 (1.05 – 2.05)**	**1.44 (1.02 – 2.05)**
Daily Nicotine Use [b]	n=702	**2.42 (1.50 – 3.89)**	**2.54 (1.55 – 4.17)**
Early Cannabis Use	n=276	1.32 (0.76 – 2.29)	1.35 (0.76 – 2.41)
Cannabis Initiation	n=947	0.86 (0.64 – 1.16)	0.90 (0.65 – 1.24)
Alcohol Dependence	n=1023	**1.67 (1.24 – 2.25)**	**1.76 (1.27 – 2.44)**
Nicotine Dependence	n=1059	**1.34 (1.00 – 1.80)**	1.31 (0.98 – 1.77)
Cannabis Dependence	n=282	0.93 (0.56 – 1.56)	0.93 (0.48 – 1.78)
Any illicit drug dependence	n=379	1.39 (0.89 – 2.18)	1.23 (0.72 – 2.09)

[1] All adjusted models included four covariates: depression (DEPR), conduct disorder (CD), Southeast Asia service (SEA), and post-traumatic stress disorder (PTSD); no covariates were significant at $p < .05$.

[a] The only significant interaction between zygosity and risk behavior was for daily nicotine use in the adjusted model ($p=0.04$; all others $p > 0.20$), conditional logistic regression analyses were collapsed across zygosity for all measures except daily nicotine use (for which the interaction was retained in both the unadjusted and adjusted models);

[b] interaction OR=0.51 (0.25–1.04) in the unadjusted model and 0.46 (0.22–0.97) in the adjusted model