# Unpacking the Longitudinal Associations between the Frequency of Substance Use, Substance Use Related Problems, and Academic Achievement among Adolescents

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**Abstract**

Previous research repeatedly observed associations between academic achievement and substance use during adolescence. However, the simple frequency of substance use was not differentiated from the emergence of substance use related problems, such as abuse and dependence. This study presents autoregressive cross-lagged models describing inter-relations between academic achievement, frequency of substance use, and substance use related problems among a sample of 1,034 seventh graders (46% female; 83% White North Americans; $M$age = 12.64 years, $SD_{age}$ = .65) who participated in a four-year longitudinal study. The stability of measurement structure of frequency of substance use and substance use related problems was supported. Higher frequency of substance use and substance use related problems did not predict lower academic achievement. A higher academic achievement predicted a later increase in frequency of substance use and substance use related problems in boys, whereas a higher academic achievement predicted a lower frequency of substance use in girls. Although substance use related problems were mainly predicted by frequency of substance use, substance use can remain, nonetheless, non-problematic during adolescence.

**Keywords**: substance use, frequency, problems, academic achievement, adolescents, structural equation modelling

# Introduction

Associations between substance use and lower levels of academic achievement in adolescents have often been reported in the research literature (e.g., Bradley & Greene, 2013). Further research is needed, however, to determine the directions of this association and to examine how these two phenomena are related to one another over time (Busch et al., 2014). In addition, research is also needed to better delineate the extent to which these associations hold, and differ, when the simple frequency of substance use is differentiated from the presence of problems emerging from this use, such as abuse or dependence (Silins et al., 2015). Considering that adolescent boys and girls are known to differ from one another in terms of substance use, substance use related problems, and academic achievement, gender effects need to be taken into account when assessing associations between these three distinct variables (Crosnoe, 2002). Filling these research gaps will contribute to the development of more targeted interventions aiming to increase positive developmental outcomes, such as academic achievement. This current study presents autoregressive cross-lagged models seeking to disentangle the nature of the longitudinal associations between academic achievement, frequency of substance use, and substance use related problems in a sample of 1,034 adolescents who participated in a four-year longitudinal study.

## Substance Use in Adolescence

In a 2017 survey of Canadian youth, 56.8% of 15-19 year olds reported drinking alcohol, 7.9% declared being tobacco smokers, and 21.6% mentioned experimenting with drugs, such as cannabis, psychostimulants, opioids, and hallucinogens in the previous 12 months (Government of Canada, 2018). Among US 12th graders, about a third reported drinking alcohol, approximately a tenth smoking tobacco, and around a quarter using cannabis and illicit drugs in the past 30 days (Johnston et al., 2018). Substance use is thus far from being uncommon among North American youths. Although using alcohol, tobacco, or drugs does not automatically leads to substance use related problems, substance use has been repeatedly shown to predict a wide range of difficulties later in life for some young people (Chen & Lin, 2009). Previous observations have shown that multiple pathways might be involved in these negative outcomes, which complicates efforts to reduce later harms related to substance use.

## Substance Use and Academic Achievement

Substance use has been repeatedly shown to be associated with lower levels of academic achievement, persistence, and attainment (Bradley & Greene, 2013), which are themselves recognized to be broadband drivers of favorable developmental outcomes in adulthood. Among these indicators of academic success, academic achievement is of particular interest and is most often operationalized in terms of grade point average in psychosocial research, reflecting its widespread use in real-life academic decisions. As an example of the generalized use of grade point average, applications into a number of post-secondary academic programs (e.g., medicine, law, or engineering) and into prestigious colleges or universities are based on this measure obtained during the secondary school years. Secondary school grade point average, as a measure of academic achievement, is also a known predictor of educational attainment and income earnings in adulthood (French, Homer, Popovici, & Robins, 2015).

**Theories explaining associations between substance use and academic achievement.** The mechanisms underlying the associations between substance use and academic achievement remain unclear, inconsistently supported across studies (Brière et al., 2014), and possibly bidirectional in nature (Bryant, Schulenberg, O'Malley, Bachman, & Johnston, 2003). Over the years, a variety of theoretical models have been proposed to explain these associations. Psychogenic theory suggests that, because schoolwork, examinations, and grades represent a substantial source of stress for students, those who perform poorly may feel demotivated, stressed or anxious, and turn to substance use as a coping strategy to deal with these negative affective states (Leonard et al., 2015). The social development model suggest that low achievement can lead some adolescents to become disconnected from positive school-related influences, which in turn tends to increase the likelihood of affiliation with deviant peers who promote substance use (Hawkins & Weis, 1985). It has also been theorized that substance use can drive low academic achievement through interference with brain development, or other mechanisms (e.g., motivation), therefore leading to lower cognitive functions (attention, memory) and learning capacities (Squeglia, Jacobus, & Tapert, 2009). Finally, problem behavior theory posits that low academic achievement and substance use are linked because they share common risk and protective factors, such as family structure, socio-economic status, etc. (Jessor, 1987). These theoretical models all seek to explain the directionality of associations between substance use and academic achievement. To bring empirical support to these models, research needs to rely on longitudinal designs allowing for an assessment of the directionality of these associations. Unfortunately, most research conducted on this topic has been cross-sectional in nature (Zimmerman & Schmeelk-Cone, 2003).

**Longitudinal studies on academic achievement and substance use.** A few longitudinal studies have attempted to examine the association between substance use and academic achievement (Busch et al., 2014). Unfortunately, most of these studies have looked at only one direction, focusing on the predictive role of substance use on academic achievement. For instance, Balsa, Giuliano & French (2011) found that heavy alcohol use, operationalized as having over 100 drinks per month or monthly binge drinking, had modest negative impacts on academic achievement one year later among youth aged 12 to 18 years old. Likewise, Crosnoe, Benner & Schneider (2012) found, in nationally representative of seventh to twelfth graders, that drinking predicted alcohol use and low social integration at school one year later, two outcomes which in turn predicted lower academic achievement at the end of high school. Interestingly, a Canadian longitudinal study found that students who shift from never using alcohol or cannabis to some degree of use for either substance one to two years later also tended to present lower levels of achievement in English or mathematics over this time period (Patte, Qian, & Leatherdale, 2017). Although these studies, taken together, suggest that alcohol and cannabis use tends to predict lower levels of academic achievement a few years later, some studies reported mixed results. As an example of inconclusive findings, Peleg-Oren, Saint-Jean, Cardenas, Tammara & Pierre (2009) found that drinking before the age of 13 predicted low self-reported school achievement in Grades 11 and 12 in the Florida Youth Substance Abuse Survey, but they failed to replicate this association using data from the Youth Risk Behavior Survey. In addition, another study found that frequency of binge drinking in adolescents was associated with lower academic achievement one year later, but this effect became statistically non-significant after correcting for other forms of substance use and psychosocial wellbeing (Sabia, 2010).

Fewer studies considered the possibility that these associations could follow the opposite direction, going from academic achievement to substance use. Bryant, Schulenberg, Bachman, O'Malley, & Johnston (2000) reported that low levels of academic achievement directly and indirectly contributed to increased cigarette use two years later, even after controlling for school misbehavior and school bonding. Likewise, Morin, Rodriguez, Fallu, Maïano & Janosz (2012) reported an increase risk for tobacco smoking onsets among adolescents characterized by low and unstable academic achievement trajectories. In contrast, a last study covering a 25 years period failed to find evidence that poor academic achievement could predict cannabis use (Fergusson, Horwood, & Beautrais, 2003).

A final set of studies have considered the possibility of bidirectional relations between substance use and academic achievement. One such study found, in a sample of adolescents frequenting rural schools, that the direction tended to go from academic achievement to substance use, rather than the other way around (Henry, 2010). More precisely, students who showed a decline in academic achievement from Grade 6 to 9 tended to present an increase in substance use (defined as any use of alcohol, tobacco, and/or cannabis). In addition, those who had better academic achievement at baseline displayed a reduced increase of substance use over the course of the study. However, change in substance use levels did not have any statistically significant impact on later levels of academic achievement. In a Finnish study, deterioration of school achievement predicted tobacco smoking at follow up, and smoking behavior was associated with later school achievement deterioration throughout the three-year study period (Pennanen et al., 2011). Likewise, Ansary & Luthar (2009) reported that a subgroup of adolescents using cannabis in Grade 10 exhibited worse academic achievement levels across Grade 10 to Grade 12, and that low achieving adolescents in Grade 10 also tended to present higher levels of alcohol, tobacco and cannabis use over all three waves. A final study by Crosnoe (2002) revealed that academic achievement at baseline did not influence later changes in substance use (composite measure of alcohol, tobacco and illicit drugs), but that initial levels of substance use did predict later changes in achievement, although this later result was limited to students involved in sports.

## Research Gaps on the Association between Substance Use and Academic Achievement

**Substance Use and Substance Use Related Problems: Two Linked, but Distinct Phenomena.** To better comprehend inconsistent results on the association between substance use and academic outcomes, some have rightly noted that the definition of substance use could explain part of the observed variability in outcomes across studies (Silins et al., 2015). Substance use can first be dichotomized between the presence or absence of these behaviors over a period of time. This first operationalization lacks nuance, because recreational and occasional substance use may not be accompanied by the same consequences as more intensive forms of frequency of substance use, volume, abuse or dependence. Likewise, substance use is operationalized often in terms of frequency, with higher levels considered as problematic. Probably due to the sociopolitical context of drug policies for most of the 20th century, the term “use” has drifted to become synonymous of “abuse” (Nicholson, Duncan, White, & Watkins, 2012), especially in adolescence. However, a high frequency of substance use does not necessarily involve harmful or problematic consequences, whereas individual using substances more occasionally may still match diagnostic criteria for substance abuse or carry negative consequences (Temple, Brown, & Hine, 2011). As an example, binge drinking can occur on rare episodes, but it is still a high risk behavior for acute and long term substance use related problems (Kuntsche, Kuntsche, Thrul, & Gmel, 2017). It is noteworthy that most aforementioned studies focus on the frequency of substance use itself, without considering the presence of substance use related problems, such as abuse.

When the mechanisms proposed to account for the effects of substance use on academic achievement are considered, most explanations refer to the social (e.g., deviant peer associations), behavioral (e.g., delinquency, legal issues), and physiological (e.g., attention) problems surrounding substance use, rather than to substance use itself (Lynskey & Hall, 2000). Likewise, previous studies have reported that a proportion of high-achieving students use substance recreationally, mainly alcohol, tobacco and/or cannabis (Bryant & Eccles, 2007), suggesting the need to distinguish substance use from substance use related problems when examining academic outcomes. In a related way, research has generally shown that among users, those who initiated at an early age (compared to those who started at a later age) generally tend to display the worst academic outcomes and to present more problems related to use of alcohol (Peleg-Oren et al., 2009), cannabis (Melchior et al., 2017) or "hard drugs" (Ellickson et al., 2001). Taken together, a better understanding of the associations between substance use and academic achievement could benefit from a more precise disaggregation of the effects attributed to substance use, in and of itself, relative to those attributed to the problems that tend to accompany more intensive or frequent substance habits.

**Gender effects.** Importantly, some studies suggest gender differences in the association between academic achievement and alcohol/tobacco/illicit drug use among adolescents (Crosnoe, 2002). For instance, Balsa et al. (2011) found a negative yet small effect of alcohol use on academic achievement for boys, while this same result were not statistically significant for girls. This study also reported that female drinkers had a higher probability of experiencing school difficulties than non-drinkers. The authors explain that girls tend to work harder, study more, and show greater levels of self-discipline than boys. This dedication for schoolwork may allow their grades to remain unaffected by drinking, although they might still experience other types of school-related difficulties. Likewise, Wheeler (2010) reports that high achieving girls, but not boys, tend to use substances (i.e. any recreational use of an illegal substance: cannabis, cocaine, injected drugs, inhalants, methamphetamines, and/or any other illegal substance) less frequently than their low achieving peers. Interestingly, this gender-differentiated pathway appears to be related to the presence of competitiveness and accomplishment oriented values, two values which tend to be more prevalent among in boys, and that tend to be associated with higher levels of both academic achievement and substance use, i.e. alcohol, tobacco, cannabis and/or other illicit drugs (Skultéti, Luszczynska, & Gibbons, 2010). However, Pennanen et al. (2011) observed no difference between girls and boys in the bidirectional and longitudinal associations between school achievement and tobacco smoking. Hence, although some preliminary evidence suggest that gender might affect the nature of the associations between academic achievement and substance use, this possibility has to be examined more systematically in research.

## Current Study

To gain a better understanding of the associations between academic achievement and substance use in adolescence, it appears important to longitudinally examine the direction of these associations, to disentangle the effects of substance use form those of substance use related problems, and to consider possible gender-related variations in these relations. The main objective of the present study is to propose a model which describes the mutual interactions between academic achievement, frequency of substance use, and substance use related problems in adolescents over the course of their high school years, while taking into account gender differences. First, it is hypothesized that frequency of substance use and substance use related problems will negatively predict later levels of academic achievement, as previously reported by Balsa et al. (2011), Crosnoe et al. (2012), and Patte et al. (2017) (Hypothesis 1). Second, it is hypothesized that academic achievement will predict lower levels of frequency of substance use and substance use related problems, replicating findings reported by Bryant et al. (2000) and Morin et al. (2012) (Hypothesis 2). Third, it is hypothesized that these associations will be more pronounced for boys, similar to results previously reported by Balsa et al. (2011) (Hypothesis 3).

## Method

### Participants and Procedures

Participants were 1,034 secondary school adolescents (54% male, 83% White North Americans), aged on average 12.64 (SD= .65) in Grade 7 at baseline, taking part in the four-year Montreal Adolescent Depression Development Project [MADDP] (Morin, Janosz, & Larivée, 2009). This project was initially designed as a one-year follow-up study, with three measurement points: September/October 2000, February 2001, and May/June 2001. All seventh-grade students from five Montreal-area secondary schools were asked to participate in September 2000, upon starting their secondary education. A total of 1,370 participants consented to participate (parental consent was obtained) and completed the first set of measures and at least one follow-up. Only participants who completed at least one follow-up were contacted, during their second year of secondary school (2001-2002), to participate in a longer-term follow-up comprising three additional years, with one measurement period per year. This longer follow-up study included 1,034 participants (58 refused to sign the consent form; 142 were absent or impossible to locate; and 136 were excluded due to parental refusal). Frequency of substance use and substance use related problems were recorded once a year from adolescents self-reports and annual academic achievement was recorded at the end of each of the four years of the study, resulting in a total of four annual measurement points considered in the present study covering Grades 7 to 10. Additional details on the MADDP sample and procedures are reported in Morin et al. (2009).

### Measures

**Academic achievement.** To measure academic achievement, annual grade point average across all subject matters was taken from objective school records at the end of each school year, across four years, and was coded on a on a 1–100 scale as per norms in vigor in the Canadian Province of Quebec, with 60 as the achievement threshold.

**Frequency of substance use.** Frequency of substance use was assessed with five items from the Measures of Quebec Adolescent' Social and Personal Adjustment, an instrument that was validated on a representative sample of the Quebec adolescent population (Le Blanc, 1996). Items retrospectively assessing the frequency to which various substances (tobacco, alcohol, cannabis, stimulants, and "hard drugs") were used since the beginning of the school year the previous year on a four-point ordered-categorical scale (1- never, 2-once or twice, 3- several times, 4- very often; $\alpha$ = .74 to .80). Grade- and gender- specific estimates of the prevalence of substance use are reported in Table 1, with estimates of correlations with academic achievement are reported in Table 2. Preliminary verifications confirm that including or excluding the items related to tobacco and alcohol use in the measurement models did not change the overall pattern of results reported in the present study.

---insert Tables 1 and 2 about here---

**Substance use related problems.** The presence of social and personal problems emerging from substance use was evaluated with nine items ($\alpha$ = .93) developed specifically for the MADDP on the basis of: (i) an adaptation of Ewing's CAGE questionnaire for substance use related problems (Ewing, 1984; Zoccolillo, Vitaro, & Tremblay, 1999), and (ii) the items used in the Epidemiological Catchment Area Study to assess the social consequences of drug abuse (Robins & Regier, 1991). These items are rated on a combination of yes-no answer scales (e.g. "were you ever drugged at school," "did you ever feel bad or guilty about your drug use") and of behaviorally-anchored ordered-categorical scales (e.g. "In which circumstances do you most often use drugs: never, alone, with friends at school, with friends out of school").

**Analyses**

**Model estimation.** The models were estimated using the robust weight least square estimator (WLSMV) available in Mplus 7.0 (Muthén & Muthén, 2012), which has been found to outperform Maximum Likelihood (ML/MLR) estimation with ordered-categorical items involving four or less categories such as those used in the present study (for a review, see Finney & DiStefano, 2013). To account for missing data, all models were estimated based on the full information that was available, based on algorithms implemented in Mplus for WLSMV estimation (Asparouhov & Muthén, 2010). This procedure has been found to result in generally unbiased parameter estimates under Missing At Random (MAR) assumptions, i.e. the propensity for missing data on a variable can be correlated to other variables in an analysis, but not to levels of the variable itself (Shin, Davison, & Long, 2009). Although the specific algorithm implemented in Mplus to handle missingness under WLSMV estimation slightly differs from Full Information algorithms typically used with ML/MLR estimation, the end result is similar for autoregressive cross lagged models such as those used in the present study given that all latent variables are involved in predictive relations (for additional details, see Asparouhov & Muthén, 2010).

**Model fit.** The fit of all models was evaluated using various indices as operationalized in Mplus in conjunction with the WLSMV estimator (Hu & Bentler, 1999): the WLSMV Chi-square statistic ($\chi^2$), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA) and its 90% confidence interval. These fit indices are interpreted as in ML/MLR estimation, with values greater than .90 and .95 for both the CFI and TLI considered to be respectively indicative of adequate and excellent fit to the data. Values smaller than .08 or .06 for the RMSEA support respectively acceptable and excellent model fit. However, the estimated WLSMV chi-square values are not exact, but "estimated" as the closest integer necessary to obtain a correct p-value. Thus, in practice, only the p-value should be interpreted. This specificity of the WLSMV chi-square explains why sometimes the chi-square values and resulting CFI values can be non-monotonic with model complexity. For the CFI, any increase when constraints are added should thus simply be interpreted as random, rather than as an improvement in fit.

**Confirmatory factor analyses.** The adequacy of the a priori longitudinal factor model was first verified, as well as its invariance across time points and gender groups. An assumption of longitudinal models is that the constructs measured by the different indicators remain the same across time, i.e. measurement invariance (Millsap, 2012). Similarly, any comparisons conducted across meaningful subgroups of participants (i.e. gender) rely on the assumption that the constructs remain the same in each group. The goodness-of-fit of these preliminary measurement analyses are reported in Table 3, while additional details related to the estimation of these models and final parameters estimates are reported in Appendices A and B. These results revealed that the measurement model provided a satisfactory representation of the data, and was fully invariant across time waves and genders. The latent correlations estimated between all constructs in this preliminary measurement model are reported in Table 4.

---insert Table 3 and 4 about here---

**Predictive models.** The predictive models are illustrated in Figure 1, where ovals represent latent variables. The measurement part of the model (specified based on the conclusions from the tests of measurement invariance), as well as the freely estimated correlations between constructs within each time-point, are not included in the figure. As a baseline model, an autoregressive model was first estimated in which each latent construct measured at Time t predicted itself at Time t+1. This is illustrated in the figure by the dotted arrows. All other longitudinal relations were constrained to be zero, but correlations between constructs were freely estimated within time-wave (Jöreskog, 1979). Next, the main predictive autoregressive model was estimated in which all constructs measured at Time t were allowed to predict the other constructs measured at Time t+1 (the full black arrows) in order to test Hypotheses 1 and 2. At each step, the equivalence of the predictive paths across time periods was also tested, in order to assess whether the predictive system could be considered to have reached equilibrium. Equilibrium means that the associations between constructs remains the same across time periods, so that the results can be expected to generalize to different time periods (Cole & Maxwell, 2003). Finally, all predictive models were re-estimated across gender groups via multiple-group models in order to test Hypothesis 3. The relative strength of the predictive associations across genders was investigated using the multivariate delta method, implemented in Mplus through the “model constraint” function (Raykov & Marcoulides, 2004) The multivariate delta method allows for direct tests of the significance of the difference of the regression paths across gender, i.e. to directly test whether gender plays a moderating role on the estimated relations (Marsh, Hau, Wen, Nagengast, & Morin, 2013).

---insert Figure 1 about here (figure caption on page 24)---

## Results

The fit indices from the predictive models are reported in the top section of Table 5. An autoregressive model was first estimated in which each construct predicted itself over time (Model P1) and constrained the autoregressive paths to equivalence across time periods (Model P2). The results confirmed that this model is equivalent across time periods (as shown by negligible changes in fit indices) and provided an adequate fit to the data. As shown in the top section of Table 6, all autoregressive paths are substantial (with standardized autoregressive coefficients varying between *ß*=.837 and .889) and statistically significant, attesting to the longitudinal stability of the constructs. Model 2 clearly did not fit the data as well as the fully saturated model where all possible relations between constructs were freely estimated (Model P5), suggesting that at least some of the longitudinal associations between the constructs could not be reflected solely through the autoregressive paths. This suggested that a better representation of the data was possible. The cross lagged paths were then included, whereby each construct measured at time t was allowed to predict the other constructs measured at time t+1 while simultaneously controlling for the reciprocal effects of the other constructs at time t on the target construct at time t+1 (Model P3). This model provided a better fit to the data than Model P2 as shown by a substantial improvement in fit indices and a statistically significant MD$\Delta\chi^2$. These additional paths proved to be fully equivalent over time (Model P4), confirming the predictive equilibrium of the system. This model also fitted the data as well as the less parsimonious (in terms of having 36 fewer degrees of freedom) fully saturated model P5, as shown by a non-significant MD$\Delta\chi^2$ and negligible change in fit indices. Model P4 was thus retained as the final model. When multiple-group predictive models were estimated according to gender (see lower section of Table 5), results closely replicated those obtained from the main models estimated in the total sample, supporting the complete autoregressive cross-lagged predictive model, the invariance of the estimated predictive paths over time, and the fact that this model fit the data as well as the fully saturated model.

---insert Table 5 and 6 about here, within the Results section---

Parameter estimates from the retained model P4 are reported in Table 6. Inspection of the parameter estimates from this model confirmed the strong autoregressive relations between academic achievement (*ß*= .869 to .898) and frequency of substance use (*ß*= .774 to .834) already identified in the autoregressive model P2. However, although the previously identified autoregressive relations between levels of substance use related problems remained statistically significant in this model (*ß*= .233 to .250), they were much smaller than those identified in the previous model (*ß*= .849). In fact, the main predictor of substance use related problems was the previous level of frequency of substance use (*ß*= .647 to .760), rather than previous levels of substance use related problems. Although substance use related problems significantly predicted later levels of substance use, the relation remained relatively small (*ß* = .105 to .113). These effects proved to be completely equivalent for boys and girls.

Although academic achievement and frequency of substance use presented moderately strong negative cross-sectional associations (Table 4, with *r*= -.314 to -.462), they presented statistically non-significant longitudinal associations with one another (Table 6), thus failing to support Hypotheses 1 and 2 in relation to frequency of substance use. Gender differentiated analyses also failed to support Hypothesis 3 in relation to frequency of substance use, revealing a positive effect of academic achievement on later increases in frequency of substance use was observed among boys (*ß* = .068 to .081) and a matching negative effect among girls (*ß* = -

.073 to -.081).

Levels of substance use related problems did not significantly predict later levels of academic achievement, providing additional evidence against Hypothesis 1 in relation to substance use related problems. However, results identified an unexpected relation whereby higher levels of academic achievement predicted later increases in student's levels of substance use related problems (*ß*= .059 to .064), thus failing to support Hypothesis 2 in relation to substance use related problems. However, this positive association between academic achievement levels and later increases in substance use related problems appeared limited to boys (*ß* = .114 to .125), whereas the same relation was statistically non-significant for girls, thus providing some partial support for Hypothesis 3 to substance use related problems, although the direction of the observed association was not anticipated.

## Discussion

Previous cross-sectional studies have reported negative correlations between substance use and academic achievement among adolescents (Bradley & Greene, 2013). However, the direction of the associations between substance use and academic achievement remained mixed and inconclusive in the context of previous longitudinal studies, reinforcing the need for further research specifically designed to disentangle the direction of these associations (Busch et al., 2014). Another area of ambiguity concerns the differentiated effects of the frequency of substance use relative to those of the problems emerging from this use, such as abuse and dependence. The separate consideration of these two components of substance use (frequency versus problems) would help to achieve a better understanding of the effects of merely using a psychoactive substance for perhaps more recreational purposes, from those associated with a problematic use of the same substance. In addition, Crosnoe (2002) reinforced the importance of taking into account gender differences when examining the association between academic achievement and substance use. Unlike previous studies, the present study was specifically designed to address these research gaps related to the directionality and gender differences in the longitudinal associations between academic achievement, frequency of substance use, and substance use related problems across the secondary school years. Attesting to the added-value of this improved longitudinal design, this study's results contributed to current scientific knowledge by highlighting four main conclusions, which will now be presented in turn.

### Frequency of Substance Use and Substance Use Related Problems Do Not Predict Academic Achievement over Time

First, this study unexpectedly failed to support the idea that higher frequency of substance use or higher levels of substance use related problems were related to lower levels academic achievement over time, as expressed in Hypothesis 1. However, it is important to keep in mind the high stability associated with academic achievement levels in the general adolescent population, as supported by this data and by previous research (Ansary & Luthar, 2009). Morin et al. (2012) reported that the subpopulation of low and unstable achievers that they found to regroup the majority of upcoming smokers only represented 12% of the student population, whereas the remaining study presented higher and more stable achievement trajectories. This stability, coupled with the results from the present study, suggests that frequency of substance use and substance use related problems are not sufficient on their own to exert a lasting impact on later levels of achievement, and probably require interactions with other variables (e.g. school motivation, problematic or antisocial behavior, parent and peer influences, etc.) to significantly impact academic achievement.

As suggested by Morin et al. (2012), effects could possibly be related to some small subpopulations of students, possibly heavy or more dependent users, so that these effects could have been diluted when considering this larger and more heterogeneous sample. For example, it is possible to speculate that substance use could be seen as beneficial in gaining social status for some adolescents, therefore maintaining a positive well-being that brings them to be more receptive and motivated in school (Crosnoe et al., 2012). Yet, for other adolescents, substance use may actually have negative impacts on academic performance (Crosnoe et al., 2012). Likewise, Morin et al. (2017) identified a “geek” profile of students who appeared to have come to overinvest the academic area to the detriment of other areas and to use substance as a way to cope with increasing levels of negative emotions. Clearly, the possible existence of subpopulations of youth among which the effects of frequency of substance use and substance use related problems could differ, and the role of the mechanisms proposed to play a role in these associations (e.g., popularity, coping, affects) should be more thoroughly examined in future research.

It is also important to keep in mind the presence of moderately large time-specific correlations observed between frequency of substance use ($r$= -.314 to -.462) or substance use related problems ($r$= -.304 to -.386) and academic achievement. These correlations do support the idea that heavier substance users tend to present lower levels of academic achievement, and that fluctuations in frequency of substance use and substance use related problems tend to accompany fluctuations in academic achievement levels. However, despite these time-specific associations, it seems that frequency of substance use and substance use related problems are not sufficient to predict later changes in academic achievement levels, possibly suggesting that the observed time-specific associations could reflect the action of common determinants (e.g., deviant peer associations, victimization, family problems, novelty-seeking), a possibility that should be more thoroughly investigated in the future.

**Academic Achievement Predicts Frequency of Substance Use in Boys: Gender-Differentiated Effects**

When the full sample was considered, academic achievement did not predict frequency of substance use over time, thus failing to support Hypothesis 2 in relation to frequency of substance use. A previous study have shown that academic achievement was unable to predict frequency of substance use on its own (Bryant & Eccles, 2007). Yet, this apparently null effect served to camouflage gender-differentiated pathways. More precisely, and contrary to Hypothesis 3, whereas a higher academic achievement was found to predict a later increase in frequency of substance use among boys, an opposite relation was observed among girls for whom higher academic achievements predicted lower levels of frequency of substance use over time. Gender-differentiated coping mechanisms might possibly be at play in explaining why lower levels of frequency of substance use is being predicted by higher academic achievement. While girls tend to engage in social relationships to cope with stress, boys are more likely to rely on diversion, avoidance and stress reduction activities such as using alcohol and other drugs as a way to alleviate distress (Copeland & Hess, 1995). The hypothesis that gender-differentiated coping mechanisms might explain the differentiated relations between frequency of substance use and academic achievement should be more thoroughly investigated in future research.

Another speculative explanation for these gender-differentiated pathways may be related to a desire for social inclusion. High achieving boys are more likely to be labelled as “nerds” or “geeks”, etiquettes which are often associated with peer rejection (Rentzsch, Schütz, & Schröder-Abé, 2011). As noted before, substance use may act as an attempt to better fit in and be accepted by popular peers (Fallu, Brière, Vitaro, Cantin, & Borge, 2011). Previous reports suggest that popular adolescents appear to present higher levels of alcohol and cannabis use, which are sometimes perceived by peers as a demonstration of autonomy from parents’ and teachers’ norms (Allen, Porter, McFarland, Marsh, & McElhaney, 2005). Furthermore, “being risky”, such as drinking and smoking, is more likely to be considered as a component of popularity in boys than in girls (Closson, 2009). Taken together, substance use could be seen as a way to gaining popularity for boys feeling more socially excluded because of the “geeky” stereotype attached of having high grades. In contrast, high achieving girls may to be less affected by these stereotypes, and to enjoy a more widespread level of social acceptance (Rentzsch et al., 2011). Generally, girls also tend to present higher levels of academic achievement than boys during the secondary school years (Houtte, 2004), and thus expected to perform well in school. In other words, it seems reasonable to hypothesize that, for highly achieving boys, the costs of substance use may be less important that its' social benefits. In contrast, for highly achieving girls, these costs may simply outweigh potential benefits. The idea that the social benefits of substance use might outweigh their costs for boys, but not for girls, should be more systematically verified in future studies.

Yet another alternative tentative explanation resides in the differences in terms of available "free" time between high-achieving boys and girls, which could, to an extent, translate into a different ease of access psychoactive substances. According to Lareau (2002), many middle-class parents enroll their children in organized extracurricular activities as a way to expose them to important life skills required to help them in becoming "successful adults". This childrearing approach, which Lareau (2002) refers to as "concerted cultivation", comes to regulate most (if not all) of youth time outside of school. This high level of extracurricular involvement thus create a new form of social inequity whereby youth exposed to such enriched and intensive organized activities may reap benefits in terms academic achievement and attainment. Importantly, gender differences have been reported by previous studies, showing that parents were more likely to exposed their daughters to "concerted cultivation", while sons tend to be exposed to lower levels of supervision and regulation of their leisure activities (McCoy et al., 2012). High-achieving girls, when monitored and controlled in such a close manner in order to support their "successful" academic trajectories, may have fewer opportunities to use psychoactive substances in a recreational manner than high-achieving boys. The proposition that high achieving girls might be somehow protected from substance use to a greater extent than boys due to gender-differentiated "concerted cultivation" processes remains speculative and should be the object of future investigations.

**Academic Achievement Predicts Increases in Substance Use Related Problems among Boys**

Contrary to Hypothesis 2 in relation to substance use related problems (and providing partial support to Hypothesis 3 by showing more pronounced effects among boys), higher levels of academic achievement appeared to predict later increases in substance use related problems among boys. Although this relation was weak ($ß$ = .059 to .064), its implications are serious and deserve specific attention. Despite the fact that this relation is not aligned with the results from previous studies focusing on smoking (Bryant et al., 2000) or general substance use (Henry, 2010), it is important to keep in mind that none of these previous studies considered gender-differentiated pathways or the possibility that the observed relations effects could differ across measures of frequency of substance use and substance use related problems. In addition, contrary to Bryant (2000), the current study also considered the reciprocal effects of frequency of substance use and substance use related problems on academic achievement, and contrary to Henry's (2010) study of rural schools, the present study relied on a socioeconomically diverse sample of schools located in an urban metropolis.

To fully understand the current result, it is important to consider the nature of the predictive model in which it was obtained. This model is an autoregressive cross lagged model in which each variable is already controlled for its own longitudinal stability so that predictive relations reflect the impact of predictors on changes in the outcomes. This model is also multivariate, in that the effects of predictors are estimated net of the variance they share with other predictors. This specific positive effect of academic achievement on later levels of frequency of substance use or substance use related problems reflect the effects of academic achievement over and above the effects of previous levels of substance use and substance use related problems, and over and above the high level of cross-sectional associations between academic achievement. The two substance variables already show that, at any specific time point, higher achievers present lower levels of frequency of substance use as well as substance use related problems. In other words, this effect suggests that, all things being equal, higher achieving males will tend to develop higher levels of substance use related problems than other students initially presenting similar levels of substance use and substance use related problems. It is possible to hypothesized that at least some high achieving boys may turn to substance more frequently in order to gain popularity, which in turn makes it more likely for them to experience substance use related problems, possibly by exacerbating already existing negative feelings, such as feelings of loneliness or marginalization (Crosnoe et al., 2012). The hypothesis that substances could be used by high achieving boys to gain popularity, therefore leading them to experience more substance use related problems should be studied more extensively in future studies.

**Frequency of Substance Use as a Key Predictor of Substance Use Related Problems**

Frequency of substance use emerged expectedly as a key predictor of substance use related problems. Interestingly, this prediction even appeared stronger than the autoregressive paths whereby substance use related problems impacted later levels of substance use related problems. Thus, the generally endorsed assumption that substance use can result in negative effects by generating problems is supported by the current model. Despite this conclusion, the results also highlight that these two concepts are not redundant with one another, so that frequency of substance use does not necessarily involve problems, although it does increase the risk for such problems. Substance users are known to represent an extremely diverse and heterogeneous population, including recreational users leading well-adjusted lives without being exposed to adverse or problematic consequences (Hser, Longshore, & Anglin, 2007). However, for other individuals, substance use does tend to escalate in intensity or frequency, which may eventually lead to negative consequences. More studies using pattern-centered approaches to differentiate subgroups of young substance users are needed to target interventions towards those who are really a risk of developing problems related to substance use (Bryant & Eccles, 2007).

**Limitations**

This study has a number of limitations that need to be considered. First, although a longitudinal design was used, causality cannot be inferred. However, structural equation modelling over a four-year period clarified the stability of the observed relations over time. Second, although this study led to the suggestion of various mechanisms possibly at play in explaining the current results, including academic motivation, peer popularity, peer group integration, loneliness, coping, and negative affectivity, these suggestions remain speculative given that the role of these additional variables has not been systematically considered in this study. Likewise, additional variables may possibly help to enrich interpretations. For example, conduct problems have been shown to be correlated with substance use (Brière et al., 2014), especially when associated with higher academic achievement (Harty, Thorn, Kalmar, Newcorn, & Halperin, 2004), extrinsic academic motivation (Wormington, Anderson, & Corpus, 2011) or low school engagement (Li et al., 2011). It thus appear important for future studies to more specifically test the role of these various mechanisms.

Third, participants were recruited from private or public schools located in the greater Montreal area, the second largest Canadian city in terms of population. Different results may be observed if semi-urban or rural schools were considered, or if other countries, cultures, or school systems had been considered. Fourth, frequency of substance use and substance use problems were self-reported and were thus subject of social desirability bias. Finally, it was not possible, in the present study, to disentangle the effects of academic achievement on the emergence of substance use and substance use related problems among non-users relative to the effects of academic achievement on increases in the frequency of substance use and substance use related problems among current users. Future research is needed to better unpack the mechanisms involved in these two distinct pathways.

## Conclusion

Although the presence of associations between substance use and lower levels of academic achievement among adolescents is well documented, many aspects of this associations remain unclear. More specifically, the true directionality, or temporal ordering, of associations between academic achievement and substance use, once frequency of substance use is properly differentiated form substance use related problems, remains undocumented. Likewise, despite knowledge of marked gender differences related to all of these variables, the extent to which longitudinal associations among them varies as a function of youth gender remains unknown. This current study sough to provide preliminary responses to these areas of uncertainty by considering proposing gender-differentiated models of the directional associations between academic achievement, frequency of substance use, and substance use related problems across the secondary school years. One of this study's original contribution is the observation that, among boys, high academic achievement tended to predict a higher frequency of substance use and more frequent substance use related problems over time, with the later association possibly reflecting the strong predictive role of frequency of substance use in the emergence of substance use related problems. In contrast, girls' academic achievement was associated with less frequent use of substances over time. Future research is warranted to explain why some high achieving boys tend to develop substance use related problems. Adults working with adolescents, such as teachers, parents, or counsellors, should not overlook adolescents who perform well in school, particularly high-achieving boys, when considering substance use. Finally, substance use appears to be associated with later substance use related problems, but not systematically, thus giving support to the notion that recreational substance use can remain non-problematic. This study suggests that future research will need to consider disentangling the concept of frequency of substance use from substance use related problems, as they appear to be overlapping, but distinct, variables sharing differentiated relations with external constructs.

**Authors' Contributions**

CH drafted the manuscript, and interpreted the data. AJSM conceived the study, participated in its design, coordinated the data collection, helped to draft the manuscript, performed the statistical analysis, and interpreted the data. JSF participated to the study at all stages (conception, design, data collection), and helped draft the manuscript and interpret the results. JML and ADB contributed to the literature review, and helped to draft the manuscript. MJ conceived the study, participated in its design, data collection, and helped to draft the manuscript. All authors read and approved the final manuscript.

**Data Sharing Declaration**

This manuscript's data will not be deposited.

**Conflicts of Interest**

The authors declare that they have no conflict of interest.

**Compliance with Ethical Standards**

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**Ethical approval**

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent**

Informed consent was obtained from all individual participants included in the study, as well as and their legal guardian.

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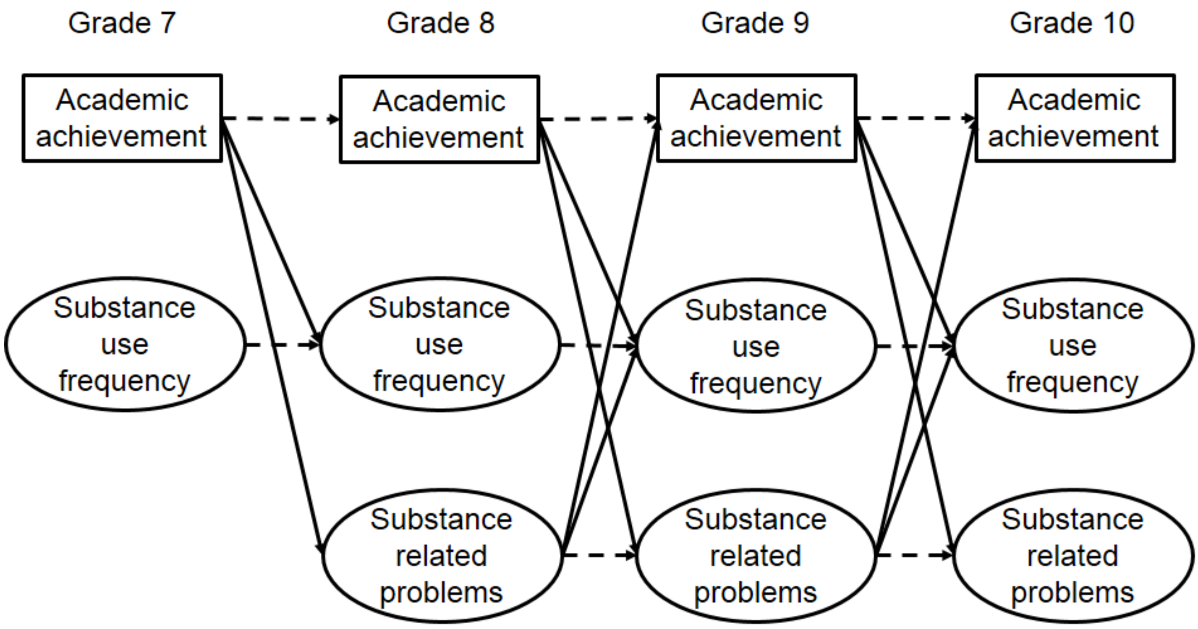
**Figure 1** Predictive models




**Note**. The dotted arrows reflect the autoregressive paths whereby each construct at Time t predicts itself at Time t+1. The full arrows represent the autoregressive paths whereby each construct at Time t predicts the other constructs at Time t+1. Ovals reflect latent variables defined by multiple indicators. Rectangles reflect manifest variables (school grades taken from official school records). All variables are specified as correlated within time point, but not across time points (over and above the predictive paths).

**Table 1**

Substance Use Prevalence Estimates

| | **Grade 7** | **Grade 8** | **Grade 9** | **Grade 10** |
|---|---|---|---|---|
| Cigarette | 18.0% | 20.9% | 15.6% | 16.3% |
| Boys | 14.5% | 15.3% | 11.1% | 12.7% |
| Girls | 22.0% | 27.5% | 20.8% | 20.5% |
| Alcohol | 25.8% | 40.0% | 42.2% | 47.4% |
| Boys | 25.3% | 37.7% | 42.9% | 47.2% |
| Girls | 26.4% | 42.8% | 41.3% | 47.6% |
| Cannabis | 21.7% | 34.4% | 34.1% | 34.8% |
| Boys | 22.8% | 32.3% | 34.3% | 35.0% |
| Girls | 20.3% | 36.9% | 34.0% | 34.6% |
| Stimulants | 6.0% | 7.3% | 7.0% | 9.8% |
| Boys | 7.4% | 7.5% | 8.3% | 7.9% |
| Girls | 4.4% | 6.9% | 5.5% | 11.9% |
| “Hard drugs” | 6.3% | 6.3% | 4.2% | 3.5% |
| Boys | 6.3% | 7.2% | 5.0% | 3.1% |
| Girls | 6.3% | 5.2% | 3.1% | 4.0% |
| Any substance | 36.3% | 48.8% | 49.3% | 52.0% |
| Boys | 35.5% | 44.9% | 49.6% | 51.3% |
| Girls | 37.1% | 51.6% | 49.1% | 52.8% |

**Table 2**

Correlations between Substance Use and Achievement

| | Grade 7 | Grade 8 | Grade 9 | Grade 10 |
|---|---|---|---|---|
| Cigarette | -.301** | -.377** | -.329** | -.240** |
| Boys | -.159** | -.281** | -.283** | -.211** |
| Girls | -.453** | -.494** | -.423** | -.314** |
| Alcohol | -.290** | -.335** | -.256** | -.120** |
| Boys | -.189** | -.266** | -.158** | -.009 |
| Girls | -.403** | -.418** | -.353** | -.215** |
| Cannabis | -.263** | -.335** | -.299** | -.223** |
| Boys | -.192** | -.296** | -.247** | -.138** |
| Girls | -.339** | -.385** | -.348** | -.299** |
| Stimulants | -.159** | -.209** | -.231** | -.166** |
| Boys | -.119** | -.186** | -.143** | -.093 |
| Girls | -.208** | -.250** | -.328** | -.262** |
| “Hard drugs” | -.202** | -.201** | -.203** | -.054 |
| Boys | -.174** | -.184** | -.161** | -.059 |
| Girls | -.236** | -.231** | -.259** | -.059 |
| Any substance | -.306** | -.356** | -.296** | -.200** |
| Boys | -.218** | -.288** | -.181** | -.097 |
| Girls | -.407** | -.443** | -.419** | -.296** |

**Table 3**

Results from the preliminary measurement models tested in this study.

| *Models* | $\chi^2$ | *dl* | *RMSEA (90% CI)* | *CFI* | *TLI* | *MDΔ*$\chi^2$ | *Δdl* | *ΔRMSEA* | *ΔCFI* | *ΔTLI* |
|---|---|---|---|---|---|---|---|---|---|---|
| *Measurement models* | | | | | | | | | | |
| Longitudinal a priori model | 2591.446* | 1116 | .036 (.034-.038) | .993 | .992 | --- | --- | --- | --- | --- |
| *Longitudinal invariance of the measurement model* | | | | | | | | | | |
| M1. Configural Invariance | 2600.497* | 1116 | .036 (.034-.038) | .993 | .992 | --- | --- | --- | --- | --- |
| M2. Weak invariance (loadings) | 2662.802* | 1144 | .036 (.034-.038) | .993 | .992 | 100.636* | 28 | .000 | .000 | .000 |
| M3. Strong invariance (intercepts) | 2699.658* | 1195 | .035 (.033-.037) | .993 | .992 | 110.238* | 51 | -.001 | .000 | .000 |
| M4. Strict invariance (uniquenesses) | 2506.061* | 1228 | .032 (.030-.034) | .994 | .994 | 72.352* | 33 | -.003 | +.001 | +.002 |
| M5. Variance-covariance invariance | 2507.880* | 1240 | .031 (.030-.033) | .994 | .994 | 41.768* | 12 | -.001 | .000 | .000 |
| M6. Latent means invariance | 2791.511* | 1245 | .035 (.033-.036) | .992 | .992 | 187.276* | 5 | +.004 | -.002 | -.002 |
| *Measurement invariance of the model across gender and time waves* | | | | | | | | | | |
| M7. Configural Invariance | 3483.142* | 2248 | .033 (.030-.035) | .994 | .993 | --- | --- | --- | --- | --- |
| M8. Weak invariance (loadings) | 3530.829* | 2316 | .032 (.030-.034) | .994 | .993 | 115.763* | 68 | -.001 | .000 | .000 |
| M9. Strong invariance (intercepts) | 3675.705* | 2427 | .032 (.029-.034) | .994 | .993 | 240.526* | 111 | .000 | .000 | .000 |
| M10. Strict invariance (uniquenesses) | 3600.870* | 2493 | .029 (.027-.031) | .994 | .994 | 111.541* | 66 | -.003 | .000 | +.001 |
| M11. Variance-covariance invariance | 3649.808* | 2567 | .029 (.026-.031) | .995 | .995 | 163.519* | 74 | .000 | +.001 | +.001 |
| M12. Latent means invariance | 3794.791* | 2579 | .030 (.028-.032) | .994 | .994 | 79.266* | 12 | +.001 | -.001 | -.001 |

***Note***. $\chi^2$ = WLSMV chi square; *df*= degrees of freedom; *RMSEA* = Root mean square error of approximation; *90% CI* = 90% Confidence Interval for the RMSEA; *CFI* = Comparative fit index; TLI = Tucker-Lewis index; Δ since previous model; MDΔ$\chi^2$ : chi square difference test based on the Mplus DIFFTEST function for WLSMV estimation;
* $p < .01$.

**Table 4**

Latent correlations from the longitudinal confirmatory factor analytic model

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Grade 7* | | | | | | | | | | |
| 1. Frequency of substance use | | | | | | | | | | |
| 2. Academic achievement | -.407 | | | | | | | | | |
| *Grade 8* | | | | | | | | | | |
| 3. Frequency of substance use | .773 | -.425 | | | | | | | | |
| 4. Academic achievement | -.418 | .789 | -.462 | | | | | | | |
| 5. Substance use related problems | .721 | -.320 | .912 | -.386 | | | | | | |
| *Grade 9* | | | | | | | | | | |
| 6. Frequency of substance use | .737 | -.377 | .834 | -.457 | .797 | | | | | |
| 7. Academic achievement | -.357 | .741 | -.427 | .771 | -.333 | -.443 | | | | |
| 8. Substance use related problems | .685 | -.316 | .824 | -.361 | .815 | .910 | -.379 | | | |
| *Grade 10* | | | | | | | | | | |
| 9. Frequency of substance use | .677 | -.296 | .789 | -.369 | .725 | .875 | -.304 | .802 | | |
| 10. Academic achievement | -.242 | .706 | -.315 | .705 | -.249 | -.349 | .832 | -.302 | -.314 | |
| 11. Substance use related problems | .619 | -.232 | .733 | -.303 | .734 | .827 | -.297 | .818 | .887 | -.304 |

***Note***. All coefficients significant at $p \leq .01$.

**Table 5**

Results from the predictive models tested in this study

| *Models* | $\chi^2$ | *dl* | *RMSEA (90% CI)* | *CFI* | *TLI* | *MDΔ$\chi^2$* | *Δdl* | *ΔRMSEA* | *ΔCFI* | *ΔTLI* |
|---|---|---|---|---|---|---|---|---|---|---|
| *Predictive models (total sample)* | | | | | | | | | | |
| P1. Autoregressive model | 11397.362* | 1265 | .088 (.087-.089) | .950 | .950 | --- | --- | --- | --- | --- |
| P2. P1 + Predictive invariance | 11094.861* | 1270 | .086 (.085-.088) | .952 | .952 | 5.471 | 5 | -.002 | +.002 | +.002 |
| P3. P2 + Cross lagged predictions | 2528.509* | 1254 | .031 (.030-.033) | .994 | .994 | 2455.291* | 16 | -.055 | +.042 | +.042 |
| P4. P3 + Predictive invariance | 2475.568* | 1264 | .030 (.029-.032) | .994 | .994 | 8.248 | 10 | -.001 | .000 | .000 |
| P5. Fully saturated model | 2506.061* | 1228 | .032 (.030-.034) | .994 | .994 | 50.05 | 36 | +.002 | .000 | .000 |
| *Predictive models (gender groups)* | | | | | | | | | | |
| P6. Autoregressive model | 11364.500* | 2567 | .081 (.080-.083) | .956 | .956 | --- | --- | --- | --- | --- |
| P7. P1 + Predictive invariance | 11159.596* | 2577 | .080 (.079-.082) | .957 | .958 | 21.772 | 10 | -.001 | +.001 | +.002 |
| P8. P2 + Cross lagged predictions | 3657.854* | 2545 | .029 (.027-.031) | .994 | .994 | 2837.598* | 32 | -.051 | +.037 | +.036 |
| P9. P3 + Predictive invariance | 3670.094* | 2565 | .029 (.027-.031) | .994 | .995 | 38.168* | 20 | .000 | .000 | +.001 |
| P10. Fully saturated model | 3600.870* | 2493 | .029 (.027-.031) | .994 | .994 | 121.358* | 72 | .000 | .000 | -.001 |

***Note***. $\chi^2$ = WLSMV chi square; *df*= degrees of freedom; *RMSEA* = Root mean square error of approximation; *90% CI* = 90% Confidence Interval for the RMSEA; *CFI* = Comparative fit index; TLI = Tucker-Lewis index; Δ since previous model; *MDΔ$\chi^2$*: chi square difference test based on the Mplus DIFFTEST function for WLSMV estimation.
* $p < .01$.

**Table 6**

Parameter estimates from the final autoregressive (P2) and predictive (P4) models

| *Predictors (t)* | *Outcomes (t +1)* | *Grade 7 → 8* *ß (E.S.)* | *Grade 8 → 9* *ß (S.E.)* | *Grade 9 → 10* *ß (S.E.)* | *Grade t → t+1* *b (S.E.)* |
|---|---|---|---|---|---|
| *Autoregressive paths from P2 (autoregressive model)* | | | | | |
| Academic achievement | Academic achievement | .869 (.019)** | .837 (.015)** | .845 (.017)** | .849 (.018)** |
| Frequency of substance use | Frequency of substance use | .847 (.022)** | .864 (.015)** | .889 (.019)** | .801 (.022)** |
| Substance use related problems | Substance use related problems | --- | .849 (.012)** | .849 (.013)** | .846 (.019)** |
| *Autoregressive paths from P4 (autoregressive cross lagged model)* | | | | | |
| Academic achievement | Academic achievement | .898 (.021)** | .869 (.015)** | .876 (.016)** | .886 (.015)** |
| Frequency of substance use | Frequency of substance use | .834 (.029)** | .780 (.053)** | .774 (.052)** | .730 (.041)** |
| Substance use related problems | Substance use related problems | --- | .233 (.037)** | .250 (.041)** | .237 (.040)** |
| *Cross lagged predictive paths from P4 (autoregressive cross lagged model)* | | | | | |
| Academic achievement | Substance use frequency | -.005 (.021) | -.006 (.022) | -.006 (.023) | -.005 (.018) |
| *Boys* | | *.068 (.026)*** | *.072 (.028)*** | *.081 (.031)*** | *.061 (.025)*** |
| *Girls* | | *-.073 (.029)** | *-.078 (.030)** | *-.081 (.032)** | *-.074 (.030)** |
| Academic achievement | Substance-related problems | .061 (.025)* | .059 (.025)* | .064 (.027)* | .091 (.039)* |
| *Boys* | | *.114 (.036)*** | *.115 (.037)*** | *.125 (.040)*** | *.174 (.058)*** |
| *Girls* | | *.015 (.033)* | *.014 (.031)* | *.014 (.033)* | *.021 (.047)* |
| Frequency of substance use | Academic achievement | .015 (.036) | .013 (.031) | .012 (.029) | .014 (.035) |
| Frequency of substance use | Substance use related problems | .760 (.029)** | .655 (.043)** | .647 (.044)** | 1.114 (.081)** |
| Substance use related problems | Academic achievement | --- | .019 (.034) | .019 (.034) | .013 (.013) |
| Substance use related problems | Frequency of substance use | --- | .105 (.045)* | .113 (.047)* | .059 (.025)* |

***Note***. The final model included invariant predictive paths, which explains why the non-standardized coefficients (*b*) are invariant across time periods. Conversely, the standardized coefficients (*ß*) are a function of the variances of latent constructs on which no constraints were imposed, and thus differ slightly across time periods. Gender-specific coefficients are marked in italics.
* $p < .05$; ** $p < .01$

## Appendix A

### Confirmatory Factor Analyses

**Analyses.** We first verified the adequacy of the a priori longitudinal factor model, including at each time point two a priori first-order factors reflecting drug use (Grade 7 to 10) and drug-related problems (grades 8 to 10). Students' GPA at each time point was also included in these models for comparison purposes with the main predictive model and specified as correlated with the latent variables. Thus, this model included a total of 11 correlated variables (7 latent factors + 4 observed GPA indicators). All factors were specified as congeneric, with each item allowed to load on a single factor, and all factors freely allowed to correlate within time-points as well as across time-points. Although ex post facto correlated uniquenesses should be avoided as a way to improve model fit, a priori correlated uniquenesses between matching indicators of the factors utilized at the different time-points need to be included in longitudinal models to avoid converging on inflated stability estimates (Jöreskog, 1979; Marsh, 2007). This inclusion reflects the fact that indicators' unique variance emerges in part from shared sources of influences over time.

Tests of measurement invariance across time points were first conducted to verify that the definition of the constructs has not changed over time. These tests were performed according to the classical sequential strategy devised by Meredith (1993; also see Millsap, 2011), adapted to the specificities of longitudinal research and WLSMV estimation (Millsap & Tein, 2004; Morin, Moullec, Maïano, Layet, Just, & Ninot, 2011): (i) configural invariance (same measurement model), (ii) weak invariance (invariance of the factor loadings); (iii) strong invariance (invariance of the loadings and item thresholds; with ordered categorical items, thresholds replace the intercepts and reflect the points at which the scores change from one category to another); (iv) strict invariance (invariance of the loadings, thresholds and uniquenesses), (v) invariance of the variances and within-time covariances between the constructs (invariance of the loadings, thresholds, uniquenesses, and variances-covariances), (vi) latent means invariance (invariance of the loadings, thresholds, uniquenesses, correlated uniquenesses, variances-covariances, and latent means). Whereas the first four steps directly assess whether the assessment of the constructs themselves can be considered to be equivalent across time points, the last two steps are not necessary and simply provide useful information regarding the equivalence of the variances, means, and correlations among constructs across time points. Tests of longitudinal invariance were first conducted on the total group. Then, tests of measurement invariance were conducted simultaneously across genders and time waves. To compare models including increasingly stringent invariance constraints, Chi square difference tests were first conducted using Mplus' DIFFTEST function (MD$\Delta\chi 2$; Asparouhov, & Muthén, 2006; Muthén, 2004).

However, as the $\chi2$, MD$\Delta\chi2$ tends to be oversensitive to sample size and to minor misspecifications. Thus, it is additional indices are generally used to complement MD$\Delta\chi2$ when comparing nested models, such as in a sequence of measurement invariance test (Chen, 2007; Cheung, & Rensvold, 2002). In these sequences, a CFI decline of .01 or less and a RMSEA increase of .015 or less between a model and the preceding model indicates that the measurement invariance hypothesis should not be rejected. However, there are still few investigation of the efficacy of these fit indices and cut-off scores based on the WLSMV estimator (e.g. Yu, 2002) or on complex models involving multiple factors and time points (Marsh, Hau, & Grayson, 2005; Marsh, Hau, & Wen, 2004). These cut-off scores thus only represent rough guidelines.

***Results.*** The goodness-of-fit results from the preliminary confirmatory factor analyses are reported in the top section of Table 3 in the main manuscript. These results confirm the adequacy of the a priori longitudinal model with indices indicating excellent fit (RMSEA $\leq$ .06; CFI and TLI $\geq$ .95). Detailed parameter estimates for this longitudinal model are reported in Appendix B and confirm the adequacy of the measurement model with strong and significant factor loadings in the expected direction (0.654 to 0.977; M = 0.867; SD = 0.105). Scale score reliability was calculated with McDonald's (1970) omega ($\omega$) coefficient, which is similar to alpha but has the advantage of taking into account the strength of association between items and constructs ($\lambda$i) as well as item-specific measurement errors ($\delta$ii) (see Sijtsma, 2009). Supporting the strength of the measurement model, these coefficients (see the online supplements) were all fully satisfactory ($\omega$ = .889 to .979; M = 0.936; SD = 0.041).

Latent correlations from this model are reported in Table 4 in the main manuscript. These show significant relations between constructs, and no apparent problem of multicollinearity; which was confirmed by a detailed examination of the later predictive models. Indeed, the highest correlations are between the constructs and themselves at later time points (|M| = .773, SD = .056; versus |M| = .540, SD = .255 for within-time correlations between different constructs and |M| = .459, SD = .202 for longitudinal correlations between different constructs), showing substantial longitudinal stability. This high longitudinal stability reinforces the need to rely on longitudinal models taking into account these autoregressive relations when the objective is to investigate the directionality of the association between constructs. Examination of these correlations show some preliminary support for our study hypotheses, showing mostly significant negative relations between GPA and both drug use (M = -.373, SD = .065) and drug-related problems (M = -.315, SD = .046), as well as substantial positive relations between drug use and drug-related problems (M = .787, SD = .092).

Tests of measurement invariance confirmed the complete measurement invariance of these models across time-point (configural, loadings, thresholds/intercepts, and uniquenesses) and the equivalence of the factor variances-covariances. Similarly, the second series of tests conducted across gender and times waves also supported the complete measurement invariance of the model and the equivalence of the factor variances-covariances over time. Indeed, none of the changes in fit indices showed any diminution in the relative fit of the model when these invariance constraints were imposed on the model, and some relative fit indices taking parsimony into account even showed an improvement. However, when the latent means where constrained to invariance over time, the results suggest that they might not be fully equivalent (as illustrated by the very large MD$\Delta\chi 2$ in relation to the differences in degrees of freedom, and by a slight decrease in the relative fit of the model). When mean differences over time where compared, they showed a slight increase over time in drug use (i.e. with the latent mean fixed to 0 in Grade 7 for comparisons purposes, the latent means are higher by .32 SD in Grade 8, .37 SD in grade 9, and .55 SD in Grade 10, all differences significant at $p < .01$) and drug related problems (i.e. with the latent mean fixed to 0 in Grade 8 for comparisons purposes, the latent means are higher by .11 SD in grade 9, and .24 SD in Grade 10, all differences significant at $p < .01$). In the context of the gender groups, the results showed that this pattern of increase over time was constant across genders.

**Appendix B**

**Standardized parameter estimates from the longitudinal confirmatory factor analytic model**

| | Frequency of Substance Use | | Substance Use Related Problems | |
|---|---|---|---|---|
| | λ | δ | λ | δ |
| Grade 7 | | | | |
| Indicator 1 | 0.825 | 0.320 | --- | --- |
| Indicator 2 | 0.741 | 0.451 | --- | --- |
| Indicator 3 | 0.836 | 0.301 | --- | --- |
| Indicator 4 | 0.830 | 0.311 | --- | --- |
| Indicator 5 | 0.976 | 0.048 | --- | --- |
| Indicator 6 | | | --- | --- |
| Indicator 7 | | | --- | --- |
| Indicator 8 | | | --- | --- |
| Indicator 9 | | | --- | --- |
| Reliability (ω) | 0.925 | | --- | |
| Grade 8 | | | | |
| Indicator 1 | 0.793 | 0.372 | 0.918 | 0.158 |
| Indicator 2 | 0.701 | 0.508 | 0.929 | 0.137 |
| Indicator 3 | 0.806 | 0.351 | 0.948 | 0.102 |
| Indicator 4 | 0.799 | 0.362 | 0.959 | 0.080 |
| Indicator 5 | 0.970 | 0.060 | 0.970 | 0.058 |
| Indicator 6 | | | 0.962 | 0.075 |
| Indicator 7 | | | 0.926 | 0.143 |
| Indicator 8 | | | 0.669 | 0.552 |
| Indicator 9 | | | 0.905 | 0.181 |
| Reliability (ω) | 0.909 | | 0.978 | |
| Grade 9 | | | | |
| Indicator 1 | 0.761 | 0.420 | 0.920 | 0.154 |
| Indicator 2 | 0.664 | 0.558 | 0.931 | 0.134 |
| Indicator 3 | 0.776 | 0.399 | 0.949 | 0.099 |
| Indicator 4 | 0.768 | 0.410 | 0.961 | 0.077 |
| Indicator 5 | 0.963 | 0.072 | 0.971 | 0.057 |
| Indicator 6 | | | 0.963 | 0.073 |
| Indicator 7 | | | 0.928 | 0.139 |
| Indicator 8 | | | 0.675 | 0.544 |
| Indicator 9 | | | 0.907 | 0.177 |
| Reliability (ω) | 0.893 | | 0.979 | |
| Grade 10 | | | | |
| Indicator 1 | 0.752 | 0.434 | 0.911 | 0.169 |
| Indicator 2 | 0.654 | 0.573 | 0.923 | 0.148 |
| Indicator 3 | 0.766 | 0.413 | 0.943 | 0.110 |
| Indicator 4 | 0.759 | 0.424 | 0.956 | 0.086 |
| Indicator 5 | 0.961 | 0.076 | 0.968 | 0.063 |
| Indicator 6 | | | 0.959 | 0.081 |
| Indicator 7 | | | 0.920 | 0.153 |
| Indicator 8 | | | 0.654 | 0.573 |
| Indicator 9 | | | 0.898 | 0.194 |
| Reliability (ω) | 0.889 | | 0.977 | |

***Note***. λ = standardized factor loadings; δ = standardized uniquenesses; Scale score reliability was computed from the standardized parameter estimates, using McDonald's (1970) omega coefficient:
$\omega = (\Sigma|\lambda i|)^2 / ([\Sigma|\lambda i|]^2 + \Sigma\delta ii)$ where $\lambda i$ are the factor loadings and $\delta ii$, the error variances. Compared with traditional scale score reliability estimates (e.g., alpha; see Sijtsma, 2009), $\omega$ has the advantage of taking into account the strength of association between items and constructs ($\lambda i$) as well as item-specific measurement errors ($\delta ii$).
All parameter estimates are significant at $p \leq .01$.

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