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The interactive effects of parental knowledge with impulsivity and sensation seeking in adolescent substance use

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Compliance with Ethical Standards

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Abstract

This study examined whether interactions of parental knowledge of adolescent's whereabouts with impulsivity and sensation seeking in the prediction of adolescent substance use supported the diathesis-stress or differential susceptibility model in 230 15-year old adolescents (53% girls). Interactions between impulsivity and parental knowledge supported the diathesis-stress model with high impulsivity as a vulnerability factor: when impulsivity was higher, low levels of parental knowledge were associated with higher levels of substance use. Interactions between sensation seeking and parental knowledge supported differential susceptibility with low sensation seeking as a susceptibility factor; low parental knowledge was associated with higher substance use and high parental knowledge with lower substance use when sensation seeking was lower. Our results show that impulsivity and sensation seeking should be considered independently. Results support previous research suggesting that impulsivity in adolescence may act as a vulnerability factor and suggests that low sensation seeking may be a susceptibility factor.

Keywords: Personality, Monitoring, Alcohol, Drugs, Moderation

Adolescence is an important developmental period for the onset of substance use. In Québec (Canada), 63% of secondary 5 (grade 11) students had at least one binge drinking episode in the past year and 44% used drugs in the past year [1], with similar rates in the United States [2]. In addition to abuse, dependence and overdoses, short- and long-term consequences of substance use in adolescence include poor academic achievement, poor sleep quality, depressive symptoms, injuries, car accidents, teenage pregnancy and sexually transmitted diseases [3, 4]. Given these serious consequences, identifying factors associated with adolescent substance use is essential to develop evidence-based prevention and intervention programs. Among these factors, parental knowledge of their adolescent's whereabouts has been consistently associated with lower or delayed substance use in adolescents [5]. However, some theoretical models [6, 7] suggest that the association between parental knowledge and substance use would be strongest for adolescents with disinhibited traits, such as impulsivity and sensation seeking, which are also important correlates of substance use [8-11]. This presumed pattern of interaction would correspond to a diathesis-stress model if vulnerable disinhibited adolescents - who are high on impulsivity or sensation seeking - exhibit high substance use *only* when parental knowledge is low. In contrast, it would correspond to a differential susceptibility model if susceptible disinhibited adolescents *also* exhibit less substance use than their counterparts when parental knowledge is high [7, 12]. Accordingly, the purpose of this study is to examine interactions of parental knowledge with impulsivity and sensation seeking within a diathesis-stress versus differential susceptibility perspective. This will allow a better understanding of the interplay between parenting and personality in predicting adolescent substance use, as well as identification of adolescents who may benefit the most from targeted prevention and intervention programs.

Parental monitoring, parental knowledge and substance use

While parental monitoring comprises all parenting behaviors involving the surveillance and

tracking of a child [13], parental *knowledge* of their adolescent's whereabouts represents one specific dimension of parental monitoring [14]. Parental knowledge is obtained from three sources of information: adolescent disclosure (when adolescents disclose their whereabouts spontaneously), parental solicitation (when the parents ask their adolescent for information on their whereabouts) and parental control (when parents impose rules restricting their adolescent's whereabouts, limiting their ability to do things without disclosing them). Reports of parental knowledge may be obtained from the parents or the adolescents. However, it has been shown that parents may overestimate their knowledge regarding their child's whereabouts, making adolescent reports more accurate regarding parental knowledge [15]. Furthermore, these measures, asking adolescents to rate their parents' knowledge of their activities, have been shown to accurately represent the three sources of information. Indeed, adolescent reports not only measure adolescent disclosure, but also parental solicitation and parental control, although they are more strongly associated with adolescent disclosure [14, 16].

Parental knowledge is considered an important predictor of adolescent substance use and problem behavior, notably because it facilitates control of the adolescent's behavior by the parents, but also because it reflects the quality of parent-child relationship [14], which is also associated with delayed or low substance use [5]. Accordingly, parental knowledge has been consistently shown to be negatively associated with adolescent substance use in cross-sectional, prospective and longitudinal research [e.g., 17, 18, 19]. A meta-analysis also found that greater parental knowledge was associated with later alcohol initiation and lower levels of alcohol use [5].

Moderation of parental knowledge by impulsivity and sensation seeking

As mentioned earlier, the role of parental knowledge in predicting substance use may vary as a function of adolescents' personal characteristics, such as disinhibited traits, which have also been shown to be associated with substance use [8, 20]. This frames the problem in a person-

environment perspective [7, 12]. Person-environment interactions allow the identification of adolescents who may be more sensitive to their environment, and thus might benefit more from family interventions. In the present study, we examined parental knowledge as a key environmental influence. At the person level we examined disinhibition, which, although sometimes considered as a global trait, more likely consists of several independent dimensions [21, 22], with impulsivity and sensation seeking being particularly important with regards to substance use.

Impulsivity is generally defined as a tendency to react in a rapid and unplanned manner to stimuli, without thinking about potential negative consequences [23]. While an earlier study showed that temperamental impulsivity at 6 years did not interact with parental knowledge in adolescence to predict alcohol use [24], studies on the interaction between impulsivity and parental knowledge in adolescence in the prediction of substance use are lacking. However, one study examined these interactions in the prediction of antisocial behaviors in early adolescence, which often co-occur with substance use [25], and found that low levels of parental knowledge were associated with higher levels of antisocial behaviors only in girls high on impulsivity [26], suggesting that similar interactions could be expected for substance use.

Sensation seeking is generally defined as the tendency to seek new and intense sensations and experiences, and the willingness to take risks for those experiences [23, 27]. Similar to the results with impulsivity, a study of 13- to 17-year-old adolescents found a significant interaction of parental knowledge and rule setting with sensation seeking in the prediction of delinquency, another correlate of substance use [25, 28], which showed that low levels of parental knowledge and rule-setting were associated with higher levels of delinquency in high sensation seekers [29]. In contrast, a study found that between 13.4 and 16 years, low levels of parental knowledge and rule-setting were associated with higher levels of cannabis use for adolescents with *lower* levels of sensation seeking [30]. Thus, although high sensation seekers are generally more at risk for substance use, it

remains unclear whether parental knowledge will have more influence on adolescent substance use in high or low sensation seekers.

Models of person-environment interactions: Diathesis-stress and differential susceptibility

Research on person-environment interactions, such as those reviewed above, has recently focused on the comparison of two theoretical models which carry different implications for prevention and intervention. These models suggest that the environment would influence developmental outcomes for adolescents high in disinhibition, but not those low in disinhibition. In the past, research has mainly focused on one of these models, the *diathesis-stress model*, which posits that “vulnerable” individuals experience negative outcomes only when exposed to adverse environments [31]. Thus, according to this model, highly disinhibited adolescents would have higher levels of substance use than other adolescents when parental knowledge is low, but levels of substance use would be similar for adolescents low and high on disinhibition when parental knowledge is high. In contrast, the *differential susceptibility model* posits that “susceptible” individuals experience not only negative outcomes when exposed to adverse environments *but also* better-than-average outcomes when exposed to good environments [7, 12]. Thus, disinhibited adolescents would have higher levels of substance use than adolescents low on disinhibition when parental knowledge is low *and* lower levels of substance use than adolescents low on disinhibition when parental knowledge is high.

The diathesis-stress and differential susceptibility models can be distinguished by a careful analysis of patterns of interaction. Support for diathesis-stress comes from a pattern where the individual characteristic is associated with the outcome and an ordinal (fan-shaped) interaction is found. In contrast, support for differential susceptibility comes from a pattern where the individual characteristic is not associated with the outcome and a disordinal (crossover) interaction is found. Furthermore, for both models, the slope of the vulnerable or susceptible group (e.g., adolescents

high on disinhibition) has to be significantly different from zero and significantly steeper than the slope of the non-vulnerable or susceptible group (e.g., adolescents low on disinhibition). Although visual appraisal of the interaction was previously acceptable to determine whether it was ordinal or disordinal, further statistical testing is now required to do so [32]

Nevertheless, visual appraisal of the interaction plots remains a useful tool when examining the results of previous studies that did not test the models. This method was applied in a recent review of interactions between temperament and family factors in adolescent substance use and externalizing behaviors, and raised the hypothesis of a possible developmental shift: interactions of parenting with disinhibited traits in *childhood* supported differential susceptibility, whereas interactions between parenting and disinhibited traits in *adolescence* supported diathesis-stress [33]. However, because these results were post-hoc and based on the more liberal visual appraisal method, studies looking at the models a priori and conducting the required statistical tests are needed. Such studies could test the hypothesis that the diathesis-stress model and not the differential susceptibility hypothesis would be supported when these factors are measured in adolescence. Only Barker et al's (2011) study of antisocial behaviors at age 13 years mentioned above has tested this question a priori, showing that girls' impulsivity and parental knowledge at 12 years interacted in a diathesis-stress fashion [26]. Consequently, these hypotheses still need to be tested with substance use as an outcome, as well as with sensation seeking as a moderator.

The present study

As described in the previous sections, it is still unclear whether impulsivity and sensation seeking show a similar pattern of interaction with parental knowledge to predict substance use. While research suggests that interactions between parental knowledge and disinhibited traits in childhood support the differential susceptibility model and interactions between parental knowledge and disinhibited traits in adolescence support diathesis-stress, this is mostly based on visual

appraisal of interactions - and thus full statistical testing of the models is still needed to better support the hypothesis. Furthermore, the evidence suggesting support for diathesis-stress and differential susceptibility with predictors at different developmental periods came from different samples.

In the sample of the current study, it was previously found that impulsivity and coercive parenting in childhood follow a differential susceptibility pattern to predict alcohol use at 15 years [24]. Thus, evidence of differential susceptibility with childhood predictors was already found in this sample when predicting substance use in middle adolescence, at 15 years. In contrast, the present study examined whether the diathesis-stress model or the differential susceptibility model is supported, this time using mid-adolescence predictors of substance use in middle and late adolescence, i.e., at 15 years and 17 years. Specifically, the present study examined the interactions of parental knowledge with impulsivity and sensation seeking at 15 years in the prediction of substance use outcomes (binge drinking and drug use) at 15 and 17 years. Based on previous findings in adolescence [24, 26], it is hypothesized that a diathesis-stress pattern of interaction will be supported.

Methods

Participants

Participants come from a longitudinal study on the social, psychological and cognitive development of children in Québec, Canada [34]. One thousand families from urban areas and all socioeconomic backgrounds were randomly selected from the Québec birth registry in 1996-1997, with 572 francophone (90%) and anglophone (10%) families participating at the first assessment when the children were 5 months old. This urban sample differed slightly from a larger population-based sample of Québec 5-month-old children born 2 years later. Parents in the urban sample were significantly more likely to have finished high school (90% vs. 84%) or have postsecondary

education (57% vs. 50%) compared to parents in the larger population. Mothers in the sample were also significantly older than in the larger population at the birth of the participants (29.9 vs. 28.8 years). There were no significant differences between the urban and population samples regarding fathers' age (32.3 vs. 31.8 years) and proportion of family income under CAD\$30,000 (26% vs. 29%) [35].

The participants were followed annually. Informed parent consent was obtained at the first assessment and renewed at each follow-up. Child assent was obtained at 9 years of age and renewed at each subsequent assessment. Following attrition, loss to follow-up, and year-to-year variations in participation rates, the sample for this study consists of 230 participants (53% girls) with data between 15 ($M = 15.06$; $SD = 0.12$) and 17 years ($M = 17.18$; $SD = 0.10$). This subsample did not differ significantly from the remainder of the sample on sex, family income, impulsivity, coercive parenting and positive parenting at 6 years ($p = 0.10$ to 0.97). The University of Montreal and the CHU Ste-Justine Research Center ethics committees approved this project.

Measures

Substance use at 15 and 17 years. Substance use was assessed using items based on the Québec Survey on Tobacco, Alcohol, Drug Use and Gambling in Secondary School Students [1]. Binge drinking frequency was assessed asking participants how many times they had five or more drinks in one occasion in the last 12 months ($0 = none$ to $5 = five\ times\ or\ more$). Then, participants were asked at what frequency they had consumed the following drugs in the last 12 months: cannabis, cocaine, glue or solvents, hallucinogens, heroin, amphetamines and other drugs or medications taken without prescription ($0 = never$ to $7 = every\ day$). A sum of the scores on these variables was used to create a drug use frequency score, as, when analyzed separately, cannabis and other drugs were predicted by temperament and parenting variables in the same way.

Parental knowledge at 15 years. Adolescents answered two items on their parents'

knowledge of their whereabouts and activities; “Do your parents know where you are when you go out?” and “Do your parents know with whom you are when you go out?” These items were rated on a 5-point scale ranging from *never* to *always*, were highly correlated ($r = 0.67$, $p < .01$) and are frequently used to measure parental knowledge and found to be associated with a range of behavioral outcomes [e.g., substance use and externalizing behaviors; 24, 26, 36, 37].

Personality at 15 years. Adolescents completed the impulsivity (e.g., I usually act without stopping to think) and sensation seeking (e.g., I enjoy new and exciting experiences even if they are unconventional) subscales of the Substance Use Risk Profile Scale [38, 39], with five items each rated on a 4-point scale (*strongly disagree* to *strongly agree*; $\alpha = 0.73$ for impulsivity and $\alpha = 0.69$ for sensation seeking).

Data analysis

Linear regressions (path analyses) were conducted using Mplus 7.0 [40]. For each substance use outcome (i.e., binge drinking and drug use), three sets of analyses were conducted, i.e., (1) cross-sectional analyses with substance use variables at 15 years as outcomes; (2) prospective analyses with substance use variables at 17 years as outcomes; and (3) longitudinal analysis with substance use variables at 17 years as outcomes, controlling for substance use at 15 years. Sex, parental knowledge, impulsivity and sensation seeking were included in the first model and the interaction terms of parental knowledge with impulsivity and sensation seeking were added in the second model. Predictor and moderator variables were standardized before computing interaction terms and entering variables in the analysis. Maximum likelihood with robust standard errors (MLR) estimation, which is robust to deviations from normality [41], was used in all analyses and full information maximum likelihood (FIML) was used to account for missing data. As regression models were saturated, model fit indices were not calculated. When significant interactions were found, the effect of parental knowledge was plotted as a function of the moderator (impulsivity or

sensation seeking at ± 1 standard deviation) and followed by simple slope tests to determine the nature of the interaction.

To test for diathesis-stress and differential susceptibility, significant interactions were first examined according to the criteria previously mentioned. Following the examination of those criteria, the nature of the ordinal or disordinal interaction was formally tested. First, the “regions of significance” were identified using the Johnson-Neyman technique [42], which identifies the values of parental knowledge at which the moderator is associated with substance use. In other words, the regions-of-significance test identifies where in the parental knowledge continuum adolescents high and low on impulsivity/sensation seeking differ in their substance use. If they only differ at the low end of parental knowledge, results support an ordinal interaction and the diathesis-stress model. If they differ at both the low and high end of parental knowledge, results support a disordinal interaction and the differential susceptibility model. However, because region of significance testing is dependent on sample size, further quantification of the interaction has been proposed to confirm support for one or the other model [32]. Accordingly, the “proportion affected” (PA) index was computed. This index represents the proportion of participants who benefit from the positive environment, or the proportion of participants above the crossover point. Strong evidence for differential susceptibility would come from a PA index around 0.50 and clear support for diathesis-stress from a PA index of 0.00. Within the full continuum of values, a PA value below 0.16 is considered as indicative of diathesis-stress [32].

Results

Descriptive statistics

Prevalence for binge drinking was 43.4% at 15 years and increased to 77.7% at 17 years. For drug use, prevalence was 30.8% at 15 years (27.9% for cannabis use and 9.1% for other drugs) and 54.5% at 17 years (46.5% for cannabis use and 13.4% for other drugs). Table 1 presents

correlations and descriptive statistics for all variables. Impulsivity at 15 years was positively associated with substance use (binge drinking and drug use) at 15 and 17 years. Sensation seeking at 15 years was positively associated with binge drinking at 15 years and drug use at 15 and 17 years. Parental knowledge at 15 years was negatively associated with binge drinking at 15 and 17 years and drug use at 17 years. Testing for diathesis-stress and differential susceptibility requires the predictor and moderator to be independent from each other [7]. Because parental knowledge was mildly correlated with impulsivity ($r = -.14, p < .05$), parental knowledge was regressed on impulsivity and the parental knowledge residual score was used in analyses, as is often done in other studies testing the models [33].

Cross-sectional analyses at 15 years

Results of regression analyses are presented in Table 2, which shows that once effects of sex and all main predictors were taken into account, binge drinking and drug use frequencies were associated negatively with parental knowledge and positively with impulsivity, but were not associated with sensation seeking.

Interactions were found between parental knowledge and impulsivity for binge drinking and drug use frequencies. For these two interactions, plotted results and simple slope analyses showed that the effect of parental knowledge was not significant when impulsivity was lower, but it was significant and negative when impulsivity was higher (see Figure 1a-b). Regions-of-significance test indicated that the association between impulsivity and substance use was significant only at lower levels of parental knowledge, with a lower bound of significance at 1.1 for binge drinking and 1.0 for drug use. The proportion affected index was 0.00 for both binge drinking and drug use. Thus, these two interactions strongly supported the diathesis-stress model.

Interactions were also found between parental knowledge and sensation seeking for both binge drinking and drug use frequencies. The effect of parental knowledge was not significant when

sensation seeking was high, but was significant and negative when sensation seeking was low (see Figure 1c-d). Therefore, within these interaction models, results did not support the traditional conceptualization that high sensation seeking would be the risk or susceptibility factor for substance use. Rather, they supported the differential-susceptibility model with low sensation-seekers being more susceptible to parental knowledge than their high sensation-seeking counterparts: lower sensation-seekers had high levels of substance use when parental knowledge was low and low levels of substance use when knowledge was high. Although the regions-of-significance test for the interaction for binge drinking indicated that the association between sensation seeking and binge drinking was significant only at lower levels of parental knowledge, with a lower bound of significance at -1.3, the PA index was 54.5. The regions-of-significance test for the interaction for drug use indicated that the association between sensation seeking and drug use was significant at both lower and higher levels of parental knowledge, with a lower bound of significance at -1.8, a higher bound of significance at 0.8 and a PA index of 54.5.

Prospective and longitudinal analyses with substance use at 17 years

In prospective analyses, main effects in the prediction of substance use at 17 years (see Table 2) indicated that impulsivity at 15 years remained positively associated with both binge drinking and drug use frequencies at 17 years, but that there was no longer an association between those substances and parental knowledge. As with analyses for 15 years, sensation seeking was not significantly associated with substance use at 17 years.

There was no interaction of parental knowledge with impulsivity or sensation seeking at 15 years in the prediction of binge drinking frequency at 17 years, but interactions were found in the prediction of drug use frequency, which were similar to those found with drug use at 15 years. Indeed, an interaction between parental knowledge and impulsivity at 15 years was found in the prediction of drug use frequency at 17 years where the effect of parental knowledge was not

significant when impulsivity was lower, but was significant and negative when impulsivity was higher (see Figure 2a). The regions-of-significance test indicated that the association between impulsivity and substance use was significant only at lower levels of parental knowledge, with a lower bound of significance at 0.6. Furthermore, the proportion affected index was 0.00, which is indicative of strong support for the diathesis-stress model.

A second interaction was found between parental knowledge and sensation seeking at 15 years in the prediction of drug use frequency at 17 years. This interaction was comparable to the one found with drug use at 15 years, with the effect of parental knowledge being not significant when sensation seeking was high, but significant and negative when sensation seeking was low (see Figure 2b), supporting the differential susceptibility model, where low sensation seekers may be more susceptible to the effects of parental knowledge. Indeed, the regions-of-significance test indicated that the association between sensation seeking and substance use was significant at both lower and higher levels of parental knowledge, with a lower bound of significance at -1.0, a higher bound of significance at 1.5 and a PA index of 54.5.

In longitudinal analyses where substance use at 15 years was added as a covariate to the prospective model, all previous effects were no longer significant. Thus, parental knowledge, impulsivity, sensation seeking and their interaction did not predict an increase in substance use from 15 to 17 years.

Discussion

This study examined the unique contribution of impulsivity and sensation seeking at 15 years in predicting substance use at 15 and 17 years and their interaction with parental knowledge at 15 years. These interactions were then decomposed in order to test whether they supported the diathesis-stress or differential susceptibility models. The main findings of this study first indicate that parental knowledge and impulsivity in adolescence interact in a diathesis-stress fashion to

predict substance use, with adolescents high on impulsivity binge drinking and consuming drugs more frequently than their peers when parental knowledge is low. Second, this study found that parental knowledge and adolescent sensation seeking interacted in a differential susceptibility fashion to predict substance use, but that the more susceptible adolescents to parental knowledge were low in sensation seeking: parental knowledge was negatively associated with substance use when sensation seeking was low, but not when it was high.

Parental knowledge, personality and their interaction in the prediction of adolescent substance use

First, main effects of parental knowledge, impulsivity and sensation seeking in the prediction of binge drinking and drug use frequencies were examined. Parental knowledge and impulsivity predicted both binge drinking and drug use at 15 years, which is consistent with previous literature showing that these two variables are important correlates of adolescent substance use [5, 8]. An interaction between impulsivity and parental knowledge at 15 years predicted binge drinking and drug use at 15 years and only drug use at 17 years. These interactions showed that when impulsivity was higher, lower levels of parental knowledge were associated with higher levels of substance use, supporting the diathesis-stress model. This is of particular interest as previous analyses using this same sample showed that an interaction between impulsivity and coercive parenting, both measured at 6 years of age, was significantly associated with alcohol use at 15 years following a differential susceptibility pattern [24]. Accordingly, this suggests a potential developmental shift from differential susceptibility to diathesis-stress when looking at interactions between impulsivity and the familial environment, which will be discussed in more detail below.

Interactions were also found between sensation seeking and parental knowledge at 15 years in the prediction of binge drinking and drug use at 15 years and only drug use at 17 years, with the slopes being significant when sensation seeking was lower, but not when it was higher. Thus, in

contrast to what can be expected theoretically, these interactions supported the differential susceptibility model, but with low sensation seekers being more susceptible to parental knowledge. These results are not without precedent, as one of the two studies that examined interactions between sensation seeking and parental knowledge found that the association between parental knowledge and cannabis use between 13.4 and 16 years was greater in low sensation seekers [30]. These results suggest that although high sensation seekers are considered to be at greater risk for substance use independently from the environment, low sensation seekers may be more sensitive to some environmental influences, putting them at greater risk for substance use only under certain environmental conditions. What could make adolescents low on sensation seeking more likely to binge drink or use drugs compared to adolescents high on sensation seeking when their parents do not know about their whereabouts? One possible explanation for this unexpected result could involve lack of perseverance, which is the tendency not to finish tasks due to an inability to sustain attention, and is a disinhibitory trait that is also associated with substance use [43, 44]. Indeed, one study found that low parental knowledge was associated with higher levels of substance use in low sensation seekers, but only when lack of perseverance was high [45]. Another possible explanation could involve lower tolerance for arousal and higher stress response in low sensation-seekers [46]: for low sensation-seekers, an unsupportive familial environment may be associated with higher levels of anxiety [47], and this anxiety may, in turn, explain higher levels of substance use [48]. As low parental knowledge is associated with other aspects of the familial environment, including lower quality of the parent-child relationship [49], lower parent-child communication [50] and lower parent sensitivity [51], it may thus be indicative of a familial environment that could lead to higher anxiety in more susceptible adolescents. Future studies should examine the interaction between sensation seeking and parental knowledge to test whether it is replicated and explained by the aforementioned variables.

Our results have implications for the conceptualization of disinhibited traits. Research has shown that disinhibition is a multi-faceted trait [21, 22]. Although studies have shown some discrepancies in the number and nature of those traits, it is generally agreed upon that impulsivity and sensation seeking are among them [23]. While some studies combine impulsivity and sensation seeking into a global disinhibition score, the results of the present study showed that impulsivity and sensation seeking had different associations with substance use. Other studies have found differential effects for impulsivity and sensation seeking [e.g., 52, 53, 54], and recent research found that sensation seeking did not fit within the latent structure of impulsivity measures [55]. Thus, although they are both disinhibited traits and correlated measures, impulsivity and sensation seeking should be considered independently in order to fully comprehend their respective associations with developmental outcomes.

Results also have implications regarding the link between parental knowledge and substance use. Indeed, the association between parental knowledge and substance use was found to decrease over time [56]. In the present study, interactions with parental knowledge were found for both binge drinking and drug use at 15 years, but only for drug use at 17 years. This suggests that parental knowledge may be particularly important in reducing problematic behaviors in adolescents, but only when those behaviors are not normative developmentally. Indeed, by 17 years, the majority of adolescents have had episodes of binge drinking [1, 2], which may explain the decreased importance of parental knowledge for this behavior. However, although the prevalence of drug use is higher in late than in early adolescence, it is still less normative than alcohol use, and this may explain why parental knowledge would still be important for this behavior at 17 years. These results also suggest that research taking into account specific ages throughout adolescence instead of averaging across a wide age range may be more informative about adolescent development.

Support for the diathesis-stress and differential susceptibility models in adolescence

Interactions between impulsivity and parental knowledge supported the diathesis-stress model. This is consistent with previous findings showing that impulsivity-by-parenting interactions in the prediction of substance use support the diathesis-stress model when predictors were measured in adolescence [26, 33]. Indeed, a literature review of temperament-by-family interactions in the prediction of adolescent substance use and externalizing behaviors showed that studies measuring temperament and family variables in childhood supported the differential susceptibility model and studies measuring temperament and family variables in adolescence supported the diathesis-stress model [33]. However, these results were based on liberal re-analysis of published studies, and needed to be replicated by testing the models with the full criteria and statistical analyses. Furthermore, these effects were based on results from different samples, and thus the developmental change in model supported also needed to be shown within one sample. As mentioned previously, using the same sample as the present study, an interaction between impulsivity and coercive parenting at 6 years was shown to predict alcohol use at 15 years following a differential susceptibility pattern [24]. The present study showing support for diathesis-stress with impulsivity and parental knowledge at 15 years predicting binge drinking at 15 years and drug use at 15 and 17 years increases confidence in a developmental shift from differential susceptibility to diathesis-stress when looking at interactions between impulsivity and the familial environment. However, these differential effects could also be due to the different types of parenting practices examined, i.e., coercive parenting in childhood and parental knowledge in adolescence. Thus, future studies examining interactions between the same personality and parenting variables throughout development are needed to confirm this developmental shift from diathesis-stress to differential susceptibility.

In addition to replicating this finding, future studies should also examine potential

explanations for this shift from differential susceptibility to diathesis-stress. A possibility is that for susceptible individuals, childhood environment may influence later plasticity to the environment. For example, person-environment interactions could predict later personality [33]. Alternatively, individual characteristics and the environment may interact in childhood to predict susceptibility to environmental influences later in life. Thus, susceptible individuals exposed to adverse environments in childhood would be vulnerable to adverse environments in adolescence or adulthood, while susceptible individuals exposed to positive environments in childhood would be resilient to adverse environments later in life. This is supported by several studies examining gene-by-environment-by-environment interactions in the prediction of emotional and behavioral problems that found that individuals at higher genetic risk were more vulnerable to environmental adversity in adolescence and adulthood only when childhood adversity was high [57-60]; similar three-way interactions could be examined with substance use and personality variables such as impulsivity.

Still, although the diathesis-stress model was supported with impulsivity in interaction with the familial environment, other personal and environmental variables may capture plasticity and support differential susceptibility in adolescence. The present study suggests low sensation seeking may be such a variable, although replication of those interactions is needed before revising plasticity factors to include low sensation seeking instead of high sensation seeking. Furthermore, studies on sensory-processing sensitivity support differential susceptibility in adulthood [7, 61]. A study of interactions between “plasticity alleles” and parenting in adolescence also supported differential susceptibility in the prediction of parental stress in adulthood [62]. Thus, more research is needed to identify which model applies for specific developmental periods, personal characteristics, environmental variables and developmental outcomes.

Limitations

A first limitation of this study is that the sample was urban and mostly French-speaking Euro-Canadian, which limits the generalizability of results. Thus, more studies are needed to determine whether these findings apply to other populations. Second, attrition from infancy to adolescence may limit the generalizability to the originally sampled population. However, it has been shown that attrition has an influence mostly on means and not on the association between variables [63, 64] and, as shown, the initial childhood and final adolescent samples were comparable on childhood variables associated with the main variables of interest. Third, all measures were adolescent-reported, thus shared method variance may account for a portion of the associations. Although self-reports have been shown to be reliable in adolescence [65, 66], other informants and observations would clarify the robustness of these findings. Fourth, only parental knowledge of adolescents' whereabouts was examined, and future studies are needed to determine whether the effects found in the current study generalize to parental monitoring or are specific to parental knowledge. Finally, this study is correlational and therefore does not show causal relationships between parental knowledge, impulsivity, sensation seeking and substance use; randomized multimodal intervention studies could clarify the causal chain. Such intervention studies have already been used within the diathesis-stress versus differential susceptibility framework, looking at gene-intervention interactions in the prediction of substance use and externalizing behaviors [67], and looking at temperament-intervention interactions in the prediction of attachment security [68] and oppositional behaviors [69]. Thus, a parenting intervention could be delivered through randomization, and results examined according to levels of impulsivity and sensation seeking, which would be a fixed factor. Additionally, experimental manipulations may be used to test the models by exposing participants to a positive or negative feedback condition, and examining the effects of this manipulation depending on personal characteristics. For example, a

recent study found support for diathesis-stress by examining whether positive and negative feedback given to 4-6 year old children through puppet role-plays differentially affected changes in positive and negative affect and in prosocial and antisocial behavior as a function of children's negative emotionality [70].

Summary

The present study is the first to examine the moderating effect of both adolescent impulsivity and sensation seeking on the relationship between parental knowledge and substance use and to test those associations according to the diathesis-stress and differential susceptibility models. Results raise new questions regarding the role of sensation seeking in adolescent substance use by suggesting that low sensation seeking, but not high sensation-seeking, may reflect susceptibility to parental knowledge in adolescence. Furthermore, it was found that adequate parental knowledge may reduce vulnerability to substance use in impulsive adolescents, supporting previous findings on substance use suggesting that impulsivity in adolescence may act as a vulnerability factor, following a diathesis-stress pattern, rather than a susceptibility factor, following a differential susceptibility pattern [33]. This in turn provides further evidence for a developmental shift from childhood to adolescence since impulsivity in childhood was found in contrast to act as a susceptibility factor for adolescent substance use [24, 33].

References

1. Institut de la statistique du Québec (2014) Enquête québécoise sur le tabac, l'alcool, la drogue et le jeu chez les élèves du secondaire, 2013. Publications du Québec, Sainte-Foy, QC
2. Johnston LD, O'Malley PM, Miech RA, Bachman JG, Schulenberg JE (2016) Monitoring the Future national survey results on drug use, 1975-2015: Overview, key findings on adolescent drug use. Ann Arbor, Michigan
3. Newbury-Birch D, Walker J, Leah A, Beyer F, Brown N, Jackson K et al. (2009) Impact of Alcohol Consumption on Young People: A Systematic Review of Published Reviews. Research Report DCSF-RR067. Newcastle, UK
4. Odgers CL, Caspi A, Nagin DS, Piquero AR, Slutske WS, Milne BJ et al. (2008) Is It Important to Prevent Early Exposure to Drugs and Alcohol Among Adolescents? *Psychol Sci* 19: 1037-1044
5. Ryan SM, Jorm AF, Lubman DI (2010) Parenting factors associated with reduced adolescent alcohol use: a systematic review of longitudinal studies. *Aust N Z J Psych* 44: 774-783
6. Zuckerman M (1999) Vulnerability to psychopathology: A biosocial model. American Psychological Association, Washington, DC
7. Belsky J, Pluess M (2009) Beyond Diathesis Stress: Differential Susceptibility to Environmental Influences. *Psychol Bull* 135: 885-908
8. Stautz K, Cooper A (2013) Impulsivity-related personality traits and adolescent alcohol use: A meta-analytic review. *Clin Psychol Rev* 33: 574-592
9. Charles NE, Mathias CW, Acheson A, Dougherty DM (2017) Preadolescent sensation seeking and early adolescent stress relate to at-risk adolescents' substance use by age 15. *Addict Behav* 69: 1-7
10. Crawford AM, Pentz MA, Chou CP, Li CY, Dwyer JH (2003) Parallel developmental

- trajectories of sensation seeking and regular substance use in adolescents. *Psychol Addict Behav* 17: 179-192
11. Quinn PD, Harden KP (2013) Differential changes in impulsivity and sensation seeking and the escalation of substance use from adolescence to early adulthood. *Dev Psychopathol* 25: 223-239
 12. Belsky J, Pluess M (2013) Beyond risk, resilience, and dysregulation: Phenotypic plasticity and human development. *Dev Psychopathol* 25: 1243-1261
 13. Dishion TJ, McMahon RJ (1998) Parental monitoring and the prevention of child and adolescent problem behavior: a conceptual and empirical formulation. *Clinical child and family psychology review* 1: 61-75
 14. Stattin H, Kerr M (2000) Parental monitoring: A reinterpretation. *Child Dev* 71: 1072-1085
 15. Laird RD, Pettit GS, Bates JE, Dodge KA (2003) Parents' monitoring-relevant knowledge and adolescents' delinquent behavior: Evidence of correlated developmental changes and reciprocal influences. *Child Dev* 74: 752-768
 16. Kerr M, Stattin H (2000) What parents know, how they know it, and several forms of adolescent adjustment: Further support for a reinterpretation of monitoring. *Dev Psychol* 36: 366-380
 17. Abar CC, Jackson KM, Wood M (2014) Reciprocal Relations Between Perceived Parental Knowledge and Adolescent Substance Use and Delinquency: The Moderating Role of Parent-Teen Relationship Quality. *Dev Psychol* 50: 2176-2187
 18. Delforterie MJ, Verweij KJH, Creemers HE, van Lier PAC, Koot HM, Branje SJT et al. (2016) Parental solicitation, parental control, child disclosure, and substance use: native and immigrant Dutch adolescents. *Ethn Health* 21: 535-550
 19. DiClemente RJ, Wingood GM, Crosby R, Sionean C, Cobb BK, Harrington K et al. (2001)

- Parental monitoring: Association with adolescents' risk behaviors. *Pediatrics* 107: 1363-1368
20. Lauriola M, Panno A, Levin IP, Lejuez CW (2014) Individual Differences in Risky Decision Making: A Meta-analysis of Sensation Seeking and Impulsivity with the Balloon Analogue Risk Task. *J Behav Decis Mak* 27: 20-36
 21. Bevilacqua L, Goldman D (2013) Genetics of impulsive behaviour. *Philos Trans R Soc B-Biol Sci* 368: 12
 22. Dick DM, Smith G, Olausson P, Mitchell SH, Leeman RF, O'Malley SS et al. (2010) Understanding the construct of impulsivity and its relationship to alcohol use disorders. *Addict Biol* 15: 217-226
 23. Castellanos-Ryan N, Conrod P (2012) Personality and Substance Misuse: Evidence for a Four-Factor Model of Vulnerability. in *Drug Abuse and Addiction in Medical Illness*. Springer, New York
 24. Rioux C, Castellanos-Ryan N, Parent S, Vitaro F, Tremblay RE, Séguin JR (2016) Differential susceptibility to environmental influences: Interactions between child temperament and parenting in adolescent alcohol use. *Dev Psychopathol* 28: 265-275
 25. Castellanos-Ryan N, Struve M, Whelan R, Banaschewski T, Barker GJ, Bokde ALW et al. (2014) Neural and Cognitive Correlates of the Common and Specific Variance Across Externalizing Problems in Young Adolescence. *Am J Psychiat* 171: 1310-1319
 26. Barker ED, Trentacosta CJ, Salekin RT (2011) Are Impulsive Adolescents Differentially Influenced by the Good and Bad of Neighborhood and Family? *J Abnorm Psychol* 120: 981-986
 27. Zuckerman M (1979) *Sensation seeking: Beyond the optimal level of arousal*. Erlbaum, Hillsdale, NJ
 28. Armstrong TD, Costello EJ (2002) Community studies on adolescent substance use, abuse, or

- dependence and psychiatric comorbidity. *J Consult Clin Psychol* 70: 1224-1239
29. Mann FD, Kretsch N, Tackett JL, Harden KP, Tucker-Drob EM (2015) Person x environment interactions on adolescent delinquency: Sensation seeking, peer deviance and parental monitoring. *Personality and Individual Differences* 76: 129-134
 30. Epstein M, Hill KG, Roe SS, Bailey JA, Iacono WG, McGue M et al. (2017) Time-varying effects of families and peers on adolescent marijuana use: Person-environment interactions across development. *Dev Psychopathol* 29: 887-900
 31. Monroe SM, Simons AD (1991) Diathesis-Stress Theories in the Context of Life Stress Research: Implications for the Depressive Disorders. *Psychol Bull* 110: 406-425
 32. Roisman GI, Newman DA, Fraley RC, Haltigan JD, Groh AM, Haydon KC (2012) Distinguishing differential susceptibility from diathesis-stress: Recommendations for evaluating interaction effects. *Dev Psychopathol* 24: 389-409
 33. Rioux C, Castellanos-Ryan N, Parent S, Séguin JR (2016) The interaction between temperament and the family environment in adolescent substance use and externalizing behaviors: Support for diathesis-stress or differential susceptibility? *Dev Rev* 40: 117-150
 34. Santé Québec, Jetté M, Desrosiers H, Tremblay RE (1997) "En 2001... j'aurai 5 ans!", Enquête auprès des bébés de 5 mois. Rapport préliminaire de l'Étude longitudinale du développement des enfants du Québec (ÉLDEQ). Montréal
 35. Tremblay RE, Nagin DS, Séguin JR, Zoccolillo M, Zelazo PD, Boivin M et al. (2004) Physical aggression during early childhood: Trajectories and predictors. *Pediatrics* 114: E43-E50
 36. Brendgen M, Vitaro F, Tremblay RE, Lavoie F (2001) Reactive and proactive aggression: Predictions to physical violence in different contexts and moderating effects of parental monitoring and caregiving behavior. *J Abnorm Child Psychol* 29: 293-304
 37. Castellanos-Ryan N, Séguin JR, Vitaro F, Parent S, Tremblay RE (2013) Impact of a 2-year

- multimodal intervention for disruptive 6-year-olds on substance use in adolescence: randomised controlled trial. *Br J Psychiatry*: 188-195
38. Woicik PA, Stewart SH, Pihl RO, Conrod PJ (2009) The substance use risk profile scale: A scale measuring traits linked to reinforcement-specific substance use profiles. *Addict Behav* 34: 1042-1055
 39. Castonguay-Jolin L, Perrier-Menard E, Castellanos-Ryan N, Parent S, Vitaro F, Tremblay RE et al. (2013) SURPS French version validation in a Quebec adolescent population. *Can J Psychiat-Rev Can Psychiat* 58: 538-545
 40. Muthén LK, Muthén BO (1998-2012) *MPlus User's Guide*. Muthén & Muthén, Los Angeles
 41. Kaplan D, Kim J-S, Kim S-Y (2009) Multilevel latent variable modeling: Current research and recent developments. in *Handbook of quantitative methods in psychology*. Sage, Thousand Oaks, CA
 42. Kochanska G, Kim S, Barry RA, Philibert RA (2011) Children's genotypes interact with maternal responsive care in predicting children's competence: Diathesis-stress or differential susceptibility? *Dev Psychopathol* 23: 605-616
 43. Magid V, Colder CR (2007) The UPPS impulsive Behavior scale: Factor structure and associations with college drinking. *Personality and Individual Differences* 43: 1927-1937
 44. Coskunpinar A, Dir AL, Cyders MA (2013) Multidimensionality in Impulsivity and Alcohol Use: A Meta-Analysis Using the UPPS Model of Impulsivity. *Alcoholism-Clinical and Experimental Research* 37: 1441-1450
 45. Thompson K, Roemer A, Leadbeater B (2015) Impulsive Personality, Parental Monitoring, and Alcohol Outcomes From Adolescence Through Young Adulthood. *J Adolesc Health* 57: 320-326
 46. Roberti JW (2003) Biological responses to stressors and the role of personality. *Life Sci* 73:

2527-2531

47. Frojd S, Kaltiala-Heino R, Rimpela M (2007) The association of parental monitoring and family structure with diverse maladjustment outcomes in middle adolescent boys and girls. *Nord J Psychiatr* 61: 296-303
48. Lai HMX, Cleary M, Sitharthan T, Hunt GE (2015) Prevalence of comorbid substance use, anxiety and mood disorders in epidemiological surveys, 1990-2014: A systematic review and meta-analysis. *Drug Alcohol Depend* 154: 1-13
49. Malczyk BR, Lawson HA (2017) Parental monitoring, the parent-child relationship and children's academic engagement in mother-headed single-parent families. *Child Youth Serv Rev* 73: 274-282
50. Ying LH, Ma FL, Huang HH, Guo XL, Chen CS, Xu F (2015) Parental Monitoring, Parent-Adolescent Communication, and Adolescents' Trust in Their Parents in China. *PLoS One* 10: 9
51. Vaughn BE, Waters TEA, Steele RD, Roisman GI, Bost KK, Truitt W et al. (2016) Multiple domains of parental secure base support during childhood and adolescence contribute to adolescents' representations of attachment as a secure base script. *Attachment & Human Development* 18: 317-336
52. Castellanos-Ryan N, Conrod P (2011) Personality Correlates of the Common and Unique Variance Across Conduct Disorder and Substance Misuse Symptoms in Adolescence. *J Abnorm Child Psychol* 39: 563-576
53. Castellanos-Ryan N, Parent S, Vitaro F, Tremblay RE, Séguin JR (2013) Pubertal Development, Personality and Substance Use: A 10-Year Longitudinal Study from Childhood to Adolescence. *J Abnorm Psychol* 122: 782-796
54. Collado A, Felton JW, MacPherson L, Lejuez CW (2014) Longitudinal trajectories of sensation seeking, risk taking propensity, and impulsivity across early to middle adolescence. *Addict*

Behav 39: 1580-1588

55. MacKillop J, Weafer J, Gray JC, Oshri A, Palmer A, de Wit H (2016) The latent structure of impulsivity: impulsive choice, impulsive action, and impulsive personality traits. *Psychopharmacology* 233: 3361-3370
56. Van Ryzin MJ, Fosco GM, Dishion TJ (2012) Family and peer predictors of substance use from early adolescence to early adulthood: An 11-year prospective analysis. *Addict Behav* 37: 1314-1324
57. Starr LR, Hammen C, Conway CC, Raposa E, Brennan PA (2014) Sensitizing effect of early adversity on depressive reactions to later proximal stress: Moderation by polymorphisms in serotonin transporter and corticotropin releasing hormone receptor genes in a 20-year longitudinal study. *Dev Psychopathol* 26: 1241-1254
58. Keers R, Pluess M (2017) Childhood quality influences genetic sensitivity to environmental influences across adulthood: A life-course Gene \times Environment interaction study. *Dev Psychopathol* 29: 1921-1933
59. Kumsta R, Stevens S, Brookes K, Schlotz W, Castle J, Beckett C et al. (2010) 5HTT genotype moderates the influence of early institutional deprivation on emotional problems in adolescence: evidence from the English and Romanian Adoptee (ERA) study. *J Child Psychol Psychiatry* 51: 755-762
60. Grabe HJ, Schwahn C, Mahler J, Schulz A, Spitzer C, Fenske K et al. (2012) Moderation of adult depression by the serotonin transporter promoter variant (5-HTTLPR), childhood abuse and adult traumatic events in a general population sample. *Am J Med Genet B* 159B: 298-309
61. Aron EN, Aron A, Jagiellowicz J (2012) Sensory Processing Sensitivity: A Review in the Light of the Evolution of Biological Responsivity. *Pers Soc Psychol Rev* 16: 262-282
62. Beaver KM, Belsky J (2012) Gene-Environment Interaction and the Intergenerational

Transmission of Parenting: Testing the Differential-Susceptibility Hypothesis. *Psychiatr Q* 83: 29-40

63. Graham JW (2009) Missing Data Analysis: Making It Work in the Real World. *Annu Rev Psychol* 60: 549-576
64. Gustavson K, von Soest T, Karevold E, Roysamb E (2012) Attrition and generalizability in longitudinal studies: findings from a 15-year population-based study and a Monte Carlo simulation study. *BMC Public Health* 12: 918-928
65. Hagman BT, Cohn AM, Noel NE, Clifford PR (2010) Collateral Informant Assessment in Alcohol Use Research Involving College Students. *J Am Coll Health* 59: 82-90
66. Laforge RG, Borsari B, Baer JS (2005) The utility of collateral informant assessment in college alcohol research: Results from a longitudinal prevention trial. *Journal of Studies on Alcohol* 66: 479-487
67. Bakermans-Kranenburg MJ, van IJzendoorn MH (2015) The Hidden Efficacy of Interventions: Gene \times Environment Experiments from a Differential Susceptibility Perspective. *Annu Rev Psychol* 66: 381-409
68. Cassidy J, Woodhouse SS, Sherman LJ, Stupica B, Lejuez CW (2011) Enhancing infant attachment security: An examination of treatment efficacy and differential susceptibility. *Dev Psychopathol* 23: 131-148
69. Scott S, O'Connor TG (2012) An experimental test of differential susceptibility to parenting among emotionally-dysregulated children in a randomized controlled trial for oppositional behavior. *J Child Psychol Psychiatry* 53: 1184-1193
70. Slagt M, Dubas JS, van Aken MAG, Ellis BJ, Dekovic M (2017) Children's differential susceptibility to parenting: An experimental test of "for better and for worse". *J Exp Child Psychol* 154: 78-97

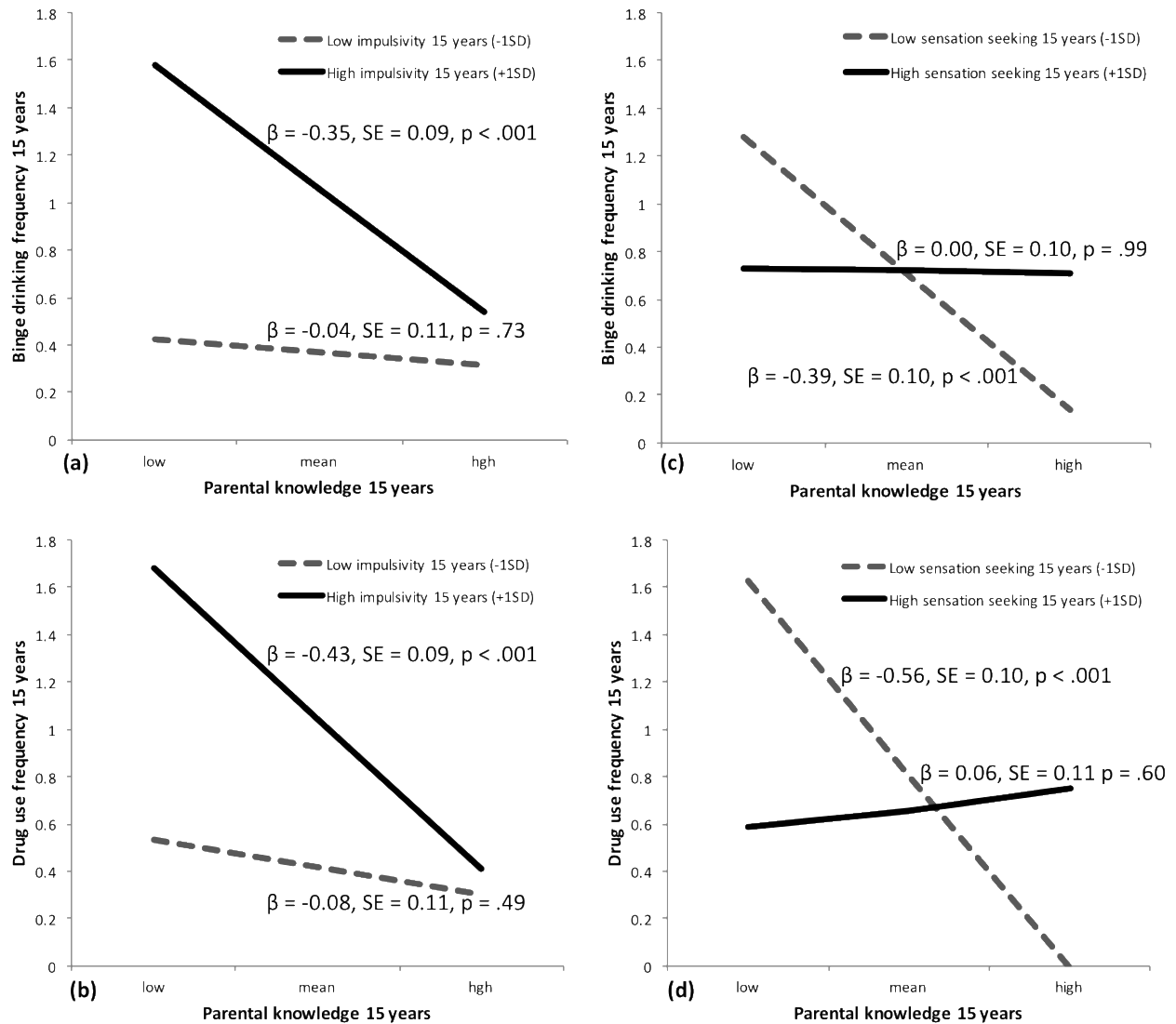


Figure 1. (a) Parental knowledge by impulsivity interaction predicting binge drinking frequency at 15 years; (b) parental knowledge by impulsivity interaction predicting drug use frequency at 15 years; (c) parental knowledge by sensation seeking interaction predicting binge drinking frequency at 15 years; and (d) parental knowledge by sensation seeking interaction predicting adolescent drug use frequency at 15 years. Sample distribution: low impulsivity (below -1SD) 15.8%, mean impulsivity (between -1SD and +1SD) 64.4%, high impulsivity (above +1SD) 19.6%; low sensation seeking 16.4%, mean sensation seeking 63.3%, high sensation seeking 20.3%.

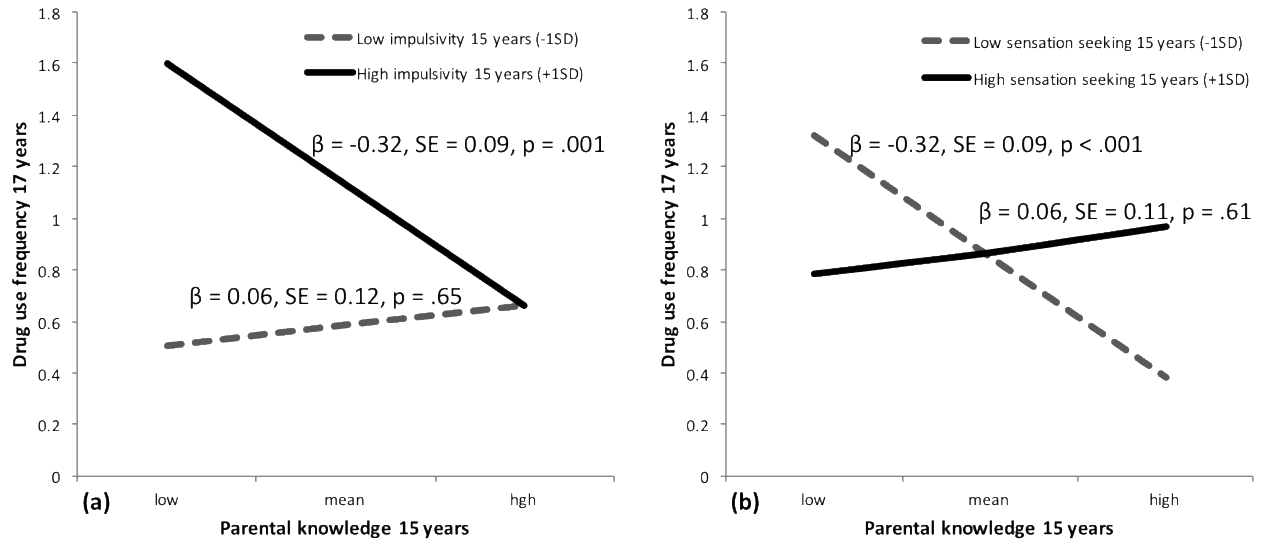


Figure 2. (a) Parental knowledge by impulsivity interaction and (b) parental knowledge by sensation seeking interaction predicting drug use frequency at 17 years.

Table 1. Correlations and descriptive statistics for study variables ^a

Variable	1	2	3	4	5	6	7
1. Binge drinking at 15	–						
2. Binge drinking at 17	.43**	–					
3. Drug use at 15	.53**	.32**	–				
4. Drug use at 17	.44**	.45**	.50**	–			
5. Impulsivity	.25**	.24**	.17*	.18*	–		
6. Sensation seeking	.17**	.26**	.08	.15*	.30**	–	
7. Parental knowledge	-.28**	-.13	-.29**	-.21**	-.14*	-.11	–
8. Sex	.05	.15*	-.05	.06	.09	.21**	-.20**
Mean	1.16	2.47	3.30	5.54	2.38	2.91	3.30
Standard deviation	1.67	2.01	5.41	5.55	0.65	0.65	0.69
Skewness	1.29	-0.22	1.55	0.41	-0.03	-0.49	-0.75
Kurtosis	0.30	-0.65	2.05	-0.83	-0.15	-0.03	0.01

^a * p < .05. ** p < .01.

Table 2. Main and interaction effects of parental knowledge, impulsivity and sensation seeking at 15 years on substance use at 15 and 17 years ^a

	Binge drinking		Drug use ^b	
Cross-sectional analyses at 15 years				
Main effects (model 1)	B (SE)	β	B (SE)	β
Sex	-0.08 (0.22)	-0.02	-1.31 (0.73)	-0.12
Parental knowledge	-0.35 (0.12)	-0.21**	-1.40 (0.45)	-0.26***
Impulsivity	0.55 (0.12)	0.33***	1.56 (0.37)	0.29***
Sensation seeking	0.09 (0.11)	0.05	-0.01 (0.38)	0.00
Interaction effects (model 2)				
Sex	-0.06 (0.22)	-0.02	-1.23 (0.71)	-0.11
Parental knowledge	-0.32 (0.11)	-0.19**	-1.36 (0.42)	-0.25***
Impulsivity	0.58 (0.12)	0.35***	1.69 (0.37)	0.31***
Sensation seeking	0.01 (0.12)	0.01	-0.41 (0.40)	-0.08
Impulsivity*Knowledge	-0.26 (0.13)	-0.16*	-0.95 (0.39)	-0.17*
Sensation seeking *Knowledge	0.33 (0.13)	0.19**	1.66 (0.45)	0.30***
Prospective analyses with predictors at 15 years and outcomes at 17 years				
Main effects (model 1)	B (SE)	β	B (SE)	β
Sex	0.42 (0.29)	0.10	0.21 (0.75)	0.02
Parental knowledge	-0.09 (0.16)	-0.04	-0.81 (0.43)	-0.15
Impulsivity	0.46 (0.16)	0.23**	1.50 (0.37)	0.27***
Sensation seeking	0.32 (0.17)	0.16	0.26 (0.38)	0.05
Interaction effects (model 2)				
Sex	0.43 (0.29)	0.11	0.27 (0.74)	0.02
Parental knowledge	-0.06 (0.15)	-0.03	-0.72 (0.40)	-0.13
Impulsivity	0.46 (0.16)	0.23**	1.52 (0.38)	0.27***
Sensation seeking	0.30 (0.18)	0.15	0.03 (0.38)	0.01
Impulsivity*Knowledge	-0.25 (0.17)	-0.12	-1.03 (0.43)	-0.18*
Sensation seeking *Knowledge	0.13 (0.18)	0.06	1.05 (0.37)	0.18**
Longitudinal analyses with predictors at 15 years and outcomes at 17 years, controlling for outcomes at 15 years				
Main effects (model 1)	B (SE)	β	B (SE)	β
Sex	0.50 (0.27)	0.12	0.90 (0.66)	0.08
Substance use at 15 ^c	0.46 (0.07)	0.38***	0.49 (0.08)	0.47***
Parental knowledge	0.09 (0.15)	0.05	0.03 (0.42)	0.01
Impulsivity	0.20 (0.15)	0.10	0.59 (0.43)	0.11
Sensation seeking	0.28 (0.16)	0.14	0.34 (0.33)	0.06
Interaction effects (model 2)				
Sex	0.50 (0.27)	0.13	0.89 (0.66)	0.08
Substance use at 15 ^c	0.45 (0.07)	0.38***	0.46 (0.08)	0.45***
Parental knowledge	0.10 (0.15)	0.05	0.04 (0.41)	0.01

Impulsivity	0.20 (0.15)	0.10	0.63 (0.43)	0.11
Sensation seeking	0.29 (0.16)	0.14	0.26 (0.34)	0.05
Impulsivity*Knowledge	-0.13 (0.16)	-0.06	-0.58 (0.44)	-0.10
Sensation seeking *Knowledge	0.02 (0.17)	0.01	0.37 (0.38)	0.07

^a * $p < 0.05$; ** $p < .01$; *** $p < .001$.

^b Results were the same for cannabis and other drugs when examined separately.

^c Analyses for each outcome at 17 years controlled for the corresponding variable at 15 years (e.g., binge drinking frequency at 15 years was used for analyses on binge drinking frequency at 17 years).