Université de Montréal

# De la sensibilité différentielle à la diathèse-stress dans la prédiction de la consommation de substances à l'adolescence: interactions entre l'environnement familial et le tempérament au cours du développement

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De la sensibilité différentielle à la diathèse-stress dans la prédiction de la consommation de substances à l'adolescence: interactions entre l'environnement familial et le tempérament au cours du développement

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# Résumé

Les interactions personne-environnement dans la prédiction de la consommation de substances peuvent être interprétées selon plusieurs modèles théoriques. Le modèle de la diathèse-stress propose que certains individus (p.ex., individus impulsifs) aient une consommation de substances plus élevée que leurs pairs lorsqu'exposés à des environnements négatifs. Le modèle de la sensibilité différentielle propose que ces mêmes individus aient *également* une consommation de substances plus faible que leurs pairs lorsqu'exposés à des environnements positifs. L'objectif principal de la présente thèse est d'examiner les modèles de la diathèse-stress et de la sensibilité différentielle dans le contexte d'interactions entre le tempérament et l'environnement familial dans la prédiction de la consommation de substances à l'adolescence. Elle comporte quatre articles, soit une recension systématique des écrits, deux articles empiriques et une perspective.

Le premier article présente une revue systématique de la littérature sur les interactions entre le tempérament et l'environnement familial dans la prédiction de la consommation de substances et des comportements extériorisés à l'adolescence. Les résultats montrent que les interactions entre le tempérament et l'environnement familial mesurés *à l'enfance* appuient le modèle de la sensibilité différentielle alors que les interactions entre ces facteurs mesurés *à l'adolescence* appuient le modèle de la diathèse-stress. Les analyses a posteriori concernant l'appui des modèles étant limitées sur le plan méthodologique, les deux articles suivants examinent ces effets a priori.

Le deuxième article examine les interactions entre le tempérament (impulsivité et contrôle inhibiteur à 6 ans) et les pratiques parentales (pratiques maternelles coercitives à 6 ans et supervision parentale à 14 ans) dans la prédiction de la fréquence de consommation d'alcool à

15 ans. Les résultats montrent qu'une interaction entre l'impulsivité et les pratiques coercitives appuie le modèle de la sensibilité différentielle, ce qui appuie les conclusions de la revue de littérature.

Le troisième article examine les interactions entre la personnalité (impulsivité et recherche de sensations à 15 ans) et la supervision parentale à 15 ans dans la prédiction de la fréquence de consommation d'alcool et de drogues à 15 et 17 ans. Les résultats montrent que les interactions entre l'impulsivité et la supervision parentale appuient le modèle de la sensibilité différentielle alors que les interactions entre la recherche de sensations et la supervision parentale appuient la diathèse-stress. Ainsi, le changement développemental observé dans la revue de littérature est appuyé avec l'impulsivité, mais la recherche de sensations pourrait s'avérer un facteur capturant la sensibilité aux environnements positifs et négatifs plus tard dans le développement.

Le quatrième article va au-delà des comportements extériorisés et de la consommation de substances et propose comment le modèle de la sensibilité différentielle pourrait s'appliquer à l'étiologie du trouble de la personnalité limite. L'article présente comment plusieurs caractéristiques personnelles associées au trouble de la personnalité limite (p.ex., réactivité émotionnelle, impulsivité) pourraient refléter une sensibilité aux environnements positifs et négatifs.

Suite à ces quatre articles, la discussion de la thèse aborde des points clés tels : une révision de la notion de vulnérabilité, l'importance de la prévention ciblée et l'importance d'analyser de façon détaillée les effets d'interaction.

**Mots clés :** Tempérament, personnalité, impulsivité, famille, pratiques parentales, environnement, alcool, drogues, comportements extériorisés, modération.

# Abstract

Person-environment interactions predicting substance use can be interpreted according to several developmental theoretical models. The diathesis-stress model suggests that certain individuals (e.g., impulsive individuals) would have higher substance use levels compared to their peers when they are exposed to negative environments. The differential susceptibility model suggests that these same individuals would *also* have lower substance use levels than their peers when exposed to positive environments. The main objective of this thesis is to examine the diathesis-stress and differential susceptibility models in the context of interactions between temperament and the familial environment when predicting adolescent substance use. It includes four articles, i.e., one systematic literature review, two empirical studies and one perspective paper.

The first article presents a systematic literature review on the interaction between temperament and the familial environment in the prediction of adolescent substance use and externalizing behaviors. Results show that interactions between temperament and the familial environment measured *in childhood* support the differential susceptibility model while interactions between temperament and the familial environment measured *in adolescence* support the diathesis-stress model. Since the a posteriori analyses for the models were limited methodologically, the next two articles examined the patterns of interactions a priori.

The second article examines the interaction between temperament (impulsivity and inhibitory control at 6 years) and parenting practices (maternal coercive parenting at 6 years and parental knowledge at 14 years) in the prediction of alcohol use frequency at 15 years. Results show that an interaction between impulsivity and coercive parenting supports the differential susceptibility model. Thus, results support the findings of the literature review.

The third article examines the interactions between personality (impulsivity and sensation seeking at 15 years) and parental knowledge at 15 years in the prediction of binge drinking frequency and drug use frequency at 15 and 17 years. Results show that the interactions between impulsivity and parental knowledge support the differential susceptibility model whereas the interactions between sensation seeking and parental knowledge support the diathesis-stress model. Thus, the developmental shift observed in the literature is supported for impulsivity, but sensation seeking could be a characteristic capturing sensitivity to positive and negative environments later in development.

The fourth article offers a perspective that goes beyond adolescent externalizing behavior and substance use and proposes how the differential susceptibility model could apply to borderline personality disorder. The article presents how several personal characteristics associated with borderline personality disorder (e.g., emotional reactivity, impulsivity) could be markers of a sensitivity to positive and negative environments.

Following these four articles, the discussion addresses key points such as: a revision of the notion of vulnerability, the importance of targeted prevention and the importance of thorough analyses of interaction effects.

**Keywords:** Temperament, personality, impulsivity, family, parenting, environment, alcohol, drugs, externalizing problems, moderation.

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# Liste des sigles

ANOVA: Analysis of variance

CBCL: Child Behavior Checklist

CBQ: Children's Behavior Questionnaire

CI: Confidence interval

CoBQ: Conflict Behavior Questionnaire

CRPR: Child-Rearing Practices Report

DAS: Dyadic Adjustment Scale

DOTS-R: Dimensions of Temperament Survey-Revised

EASI: Emotionality Activity and Sociability Inventory

EATQ-R: Early Adolescent Temperament Questionnaire-Revised

EHC: Event History Calendar

FES: Family Environment Scale

FIML: Full information maximum likelihood

GTS: General Temperament Survey

IFQ: Infant Characteristics Questionnaire

IPPA: Inventory for parent and peer attachment

MLR: Maximum likelihood with robust standard errors

NLSCY: National Longitudinal Survey of Children and Youth

NRI: Network Relationships Inventory

PA: Proportion affected index/Proportion affectée

PBI: Parental Behavior Inventory

PdI: Proportion de l'interaction

PPS: Parent Practices Scale

SD: Standard deviation

SDQ: Strengths and Difficulties Questionnaire

SE: Standard error

TCP: Teacher Checklist of Psychopathology

YSR: Youth Self-Report of the Child Behavior Checklist

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# 1. Introduction générale

Le débat sur l'origine innée ou acquise du comportement humain a longtemps caractérisé la recherche en psychologie. Alors que des visions purement génétiques ou environnementales ont dominé dans le passé, il est aujourd'hui généralement accepté qu'à la fois les gènes et l'environnement contribuent au développement du comportement et de la santé mentale (Lenroot et Giedd, 2011; Reiss et Neiderhiser, 2000; Rutter, Moffitt et Caspi, 2006; Schaffner, 2001). Cette vision s'appuie sur la notion importante qu'est la plasticité phénotypique, qui correspond à la possibilité d'un génotype produise différents phénotypes lorsque soumis à des conditions environnementales distinctes (Pigliucci, 2001), et ce dès le développement intra-utérin (Pluess & Belsky, 2011). En d'autres mots, il s'agit de la capacité d'un organisme (caractérisé par un code génétique) d'adapter ses caractéristiques observables (c.-à-d., son phénotype) en fonction des conditions environnementales dans lesquelles il se retrouve. Cependant, on retrouve des différences individuelles quant à la sensibilité aux influences environnementales, ce qui implique que les individus ne présentent pas tous la même plasticité phénotypique.

Le concept de différences individuelles quant à la sensibilité aux influences environnementales a traditionnellement été exprimé par le modèle de la *diathèse-stress* (Monroe et Simons, 1991; Zuckerman, 1999). Selon ce modèle, la sensibilité aux influences environnementales est une vulnérabilité menant à plus de problèmes développementaux en présence d'environnements adverses, mais il n'y a pas de sensibilité aux influences environnementales positives. Cette dernière est cependant incluse dans le modèle de la *sensibilité différentielle* (Belsky et Pluess, 2009, 2013a), qui propose que la sensibilité aux influences environnementales mène à plus de problèmes développementaux en présence

d'environnements adverses *et* à de meilleurs résultats développementaux que la moyenne en l'absence d'adversité ou en présence d'environnements favorables. Dans le cadre de la présente thèse, les modèles de la diathèse-stress et de la sensibilité différentielle seront examinés dans le contexte d'interactions entre le tempérament, la personnalité et l'environnement familial dans la prédiction de la consommation de substances à l'adolescence.

## 1.1. Les modèles de la diathèse-stress et de la sensibilité différentielle

Comme mentionné précédemment, les modèles de la diathèse-stress et de la sensibilité différentielle proposent que les individus présentent des niveaux différents de plasticité phénotypique. Ces deux modèles proposent ainsi qu'il y ait une modération biologique où des différences biologiques préexistantes augmentent ou diminuent les effets de l'environnement sur le développement. Ces différences peuvent être décrites par quatre niveaux hiérarchiques représentant chacun un niveau plus élevé de complexité biologique, soit (1) le comportement et le tempérament, (2) la réactivité autonomique et adrénocorticale, (3) la structure et responsivité neuronale et (4) les gènes et l'épigénome (Boyce, 2016). Des variables à ces quatre niveaux peuvent ainsi servir d'indicateurs de plasticité à l'environnement.

Le modèle de la diathèse-stress (Monroe et Simons, 1991; Salomon et Jin, 2013; Zuckerman, 1999) propose que certains individus vulnérables aient plus de chances d'être affectés négativement par un stresseur environnemental alors que des individus résilients (parfois nommés égo-résilients; Luthar, Cicchetti et Becker, 2000) ne seraient pas affectés par ces mêmes stresseurs. Ainsi, selon cette conception, les individus vulnérables présentant des facteurs de risque (p.ex., allèle de risque, tempérament difficile, réactivité cardiovasculaire élevée) auraient des niveaux plus élevés de problèmes développementaux (p.ex.,

psychopathologie) que les individus résilients lorsqu'ils sont exposés à un environnement adverse. Cependant, il n'y aurait pas de différences au niveau des problèmes développementaux entre les individus vulnérables et résilients en l'absence d'adversité. Il s'agit ainsi d'un risque inhérent à l'individu (la diathèse) qui interagit avec l'environnement adverse (le stress).

Le modèle de la sensibilité différentielle (Belsky, 1997, 2005; Belsky et Pluess, 2009, 2013a) peut être vu comme une extension du modèle de la diathèse-stress. Ainsi, selon ce modèle, les individus plus sensibles ont aussi plus de chances d'être affectés négativement par un stresseur environnemental, contrairement aux individus résilients. Cependant, ils ont également plus de chances d'être affectés positivement par un environnement enrichi, ou même simplement par l'absence d'adversité. Ainsi, selon cette conception, les individus sensibles auraient des niveaux plus élevés de problèmes développementaux que les individus résilients lorsqu'ils sont exposés à des environnements adverses *et* des niveaux plus faibles de problèmes développementaux que les individus résilients lorsqu'ils sont exposés à des environnements enrichis. Il est proposé que le mécanisme central de la sensibilité à l'environnement serait une sensibilité du système nerveux central; les structures cérébrales des individus plus sensibles enregistreraient les influences environnementales plus facilement et plus profondément (Boyce, 2016; Boyce et Ellis, 2005; Ellis, Boyce, Belsky, Bakermans-Kranenburg et van Ijzendoorn, 2011; Pluess, 2015).

### 1.1.1. Origines évolutionnistes du modèle de la sensibilité différentielle

L'élaboration du modèle de la sensibilité différentielle s'appuie sur un argument évolutionniste (Belsky, 1997, 2005). Selon le principe de sélection naturelle, les caractéristiques avantageuses augmentant les chances de survie d'une espèce sont reproduites

plus fréquemment et deviennent plus apparentes au fil des générations, alors qu'avec le temps les caractéristiques désavantageuses tendent à disparaître (Huneman, 2015). Ainsi, le modèle de la diathèse-stress aurait peu de sens selon ce principe. En effet, pourquoi des caractéristiques personnelles associées à une vulnérabilité seraient-elles demeurées avec l'évolution de l'espèce? La persistance de ces traits serait cohérente avec la théorie évolutionniste s'ils étaient aussi associés au développement positif dans certains environnements, tel que proposé dans le modèle de la sensibilité différentielle.

Ainsi, dans la formulation du modèle de la sensibilité différentielle, la proposition évolutionniste stipule que pour maximiser leur succès reproducteur, la sélection naturelle aurait mené les parents à avoir des enfants avec divers niveaux de sensibilité à l'environnement. En effet, face à un futur incertain, les parents ne pourraient pas savoir à l'avance quelle façon d'élever leurs enfants maximiserait le succès reproducteur de ceux-ci. Dans un contexte particulier, s'il s'avère que les influences parentales sont contre-productives au succès reproducteur, la reproduction serait maximisée chez les enfants résilients, qui ne sont pas affectés par ces influences environnementales. Cependant, s'il s'avère que les influences parentales sont productives pour le succès reproducteur, la reproduction serait maximisée chez les enfants plus sensibles aux influences environnementales. Il est à noter que bien que les effets de sensibilité différentielle soient d'abord conceptualisés avec les influences parentales, ils pourraient s'étendre aux influences environnementales de façon plus générale. Ainsi, on peut penser que le succès reproducteur est maximisé avec des enfants résilients lorsque l'environnement est adverse, alors que le succès reproducteur est maximisé avec des enfants sensibles ou plastiques en présence d'un environnement positif (Belsky,

1997, 2005; Belsky et Pluess, 2009; Ellis, Boyce, et al., 2011; Pluess, Stevens et Belsky, 2013).

### 1.1.2. Applications des modèles de la diathèse-stress et de la sensibilité différentielle

Les interactions personne-environnement proposées par les modèles de la diathèse-stress et de la sensibilité différentielle peuvent prédire une variété d'issues développementales. Par exemple, des études ont examiné ces interactions dans la prédiction du développement cognitif (Kegel, Bus et van Ijzendoorn, 2011; Raver, Blair, Willoughby et The Family Life Project Key Investigators, 2013), de la réussite scolaire (Belsky et al., 2014; Jaekel, Pluess, Belsky et Wolke, 2015; Kochanska, Kim, Barry et Philibert, 2011; Obradovic, Bush, Stamperdahl, Adler et Boyce, 2010), des habiletés sociales (Belsky et al., 2014; Belsky et Pluess, 2013b; Kochanska et al., 2011; Pluess et Belsky, 2009), du développement pubertaire (Ellis, Shirtcliff, Boyce, Deardorff et Essex, 2011) et de l'indice de masse corporelle (Anzman et Birch, 2009; Anzman-Frasca, Stifter, Paul et Birch, 2014; Wu, Dixon, Dalton, Tudiver et Liu, 2011). Deux des résultats développementaux les plus fréquemment examinés dans le cadre de ces modèles sont les problèmes intériorisés et extériorisés (Bakermans-Kranenburg et van IJzendoorn, 2015; Belsky et Pluess, 2009, 2013a). Les problèmes intériorisés sont davantage du domaine émotionnel et réfèrent à des problèmes « intérieurs » qui génèrent du malaise, de la tension et de la souffrance chez les individus eux-mêmes. Ils incluent des problèmes tels que la dépression et l'anxiété. De leur côté, les problèmes extériorisés sont davantage du domaine comportemental et réfèrent à des problèmes « extérieurs » impliquant un non-respect des normes sociales, générant un inconfort et des conflits chez les autres individus. Ils incluent des problèmes tels que l'agressivité et la délinquance (Achenbach,

1966; Forns, Abad et Kirchner, 2011). La consommation de substances, qui sera le sujet de la présente thèse, constitue également un type de problème extériorisé (Castellanos-Ryan et al., 2016; Castellanos-Ryan et al., 2014; Eaton, Rodriguez-Seijas, Carragher et Krueger, 2015; Krueger, 1999; Lahey et al., 2012).

## 1.2. La consommation de substances à l'adolescence

La consommation de substances débute à l'adolescence pour une majorité d'individus, la prévalence de la consommation de substances augmentant au cours de l'adolescence, incluant au Québec. L'alcool est la substance la plus consommée chez les jeunes québécois. Ainsi, 57% des jeunes québécois au secondaire ont consommé de l'alcool dans les 12 derniers mois. La consommation augmente au cours du secondaire, passant de 23% en secondaire 1 à 83% en secondaire 5. La consommation d'alcool s'avère ainsi normative à la fin du secondaire, la majorité des jeunes en consommant, et cette consommation n'est pas problématique la majorité du temps. Cependant, 14% des jeunes présentent une consommation régulière d'alcool, soit au moins une fois par semaine pendant au moins un mois, avec une évolution passant de 5% en secondaire 1 à 26% en secondaire 5. De plus, 34% des jeunes ont eu au moins un épisode de beuveries (cinq consommations ou plus lors de la même occasion) au cours des 12 derniers mois, avec une évolution passant de 7% en secondaire 1 à 63% en secondaire 5 (Institut de la statistique du Québec, 2014).

Malgré une plus faible prévalence que la consommation d'alcool, 24% des jeunes du secondaire ont consommé de la drogue au cours des 12 derniers mois, avec une évolution passant de 6% en secondaire 1 à 44% en secondaire 5. De plus, 10% des jeunes du secondaire ont eu au moins un épisode de consommation régulière de drogues, soit au moins une fois par

semaine pendant au moins un mois, avec une évolution passant de 2% en secondaire 1 à 21% en secondaire 5. La drogue la plus consommée au secondaire est le cannabis, avec 23% des jeunes qui en consomment, alors que les taux de consommation se situent entre 0.5% et 5% pour les autres drogues (c.-à-d., hallucinogènes, ecstasy, amphétamines ou métamphétamines, cocaïne, solvants ou colle, héroïne, médicaments pris sans prescription et autres drogues) (Institut de la statistique du Québec, 2014). Les taux de consommation d'alcool et de drogues à l'adolescence sont semblables dans les autres provinces canadiennes et aux États-Unis (Gouvernement du Canada, 2017; Johnston, O'Malley, Miech, Bachman et Schulenberg, 2016; Kann et al., 2016; Leatherdale et Burkhalter, 2012).

La consommation problématique d'alcool et de drogues à l'adolescence peut mener à la dépendance ou à l'abus de substances à l'âge adulte, les risques étant plus élevés lorsque l'âge de début de consommation est plus précoce (Behrendt, Wittchen, Hofler, Lieb et Beesdo, 2009; DeWit, Adlaf, Offord et Ogborne, 2000; Grant, Stinson et Harford, 2001; King et Chassin, 2007; Rioux et al., 2018; Scholes-Balog, Hemphill, Evans-Whipp, Toumbourou et Patton, 2016). La consommation problématique d'alcool peut avoir plusieurs conséquences néfastes. Les conséquences possibles de la consommation d'alcool chez les adolescents incluent des changements d'appétit, une perte de poids, de l'eczéma, des migraines, des troubles du sommeil, une augmentation des sentiments dépressifs et de la violence et une diminution de la performance scolaire. De plus, lorsque sous influence de l'alcool, il y a une augmentation des probabilités d'accidents de voiture et de comportements sexuels à risque, augmentant du fait même les risques de grossesse non désirée et d'infections transmises sexuellement. À long terme, la consommation d'alcool peut également mener à des maladies du foie et au cancer. Finalement, l'intoxication à l'alcool peut mener à des vomissements et au

coma éthylique (de Carvalho et al., 2017; Marshall, 2014; Newbury-Birch et al., 2009; Scoccianti, Staif et Romieu, 2013). Des études ont permis de détecter des différences au niveau du cerveau, mais ne permettent pas de déterminer si ces différences viennent avant ou après la consommation. Comparés aux non-consommateurs, les jeunes consommateurs d'alcool ont un volume plus faible de matière grise et une moins bonne intégrité de la matière blanche dans plusieurs régions préfrontales associées au contrôle exécutif ainsi que dans le système de récompense mésocorticolimbique (Feldstein Ewing, Sakhardande et Blakemore, 2014).

La consommation problématique de drogues est également associée avec la possibilité de plusieurs conséquences négatives, dont les accidents de voiture, une plus faible réussite scolaire, la violence, les problèmes de conduite et plusieurs problèmes psychiatriques, dont la dépression, les pensées et tentatives suicidaires, les problèmes anxieux et les troubles psychotiques (Brook, Richter et Rubenstone, 2000; Degenhardt et Hall, 2012; Macleod et al., 2004). Plusieurs complications médicales sévères peuvent aussi être associées à la prise de drogues, dont des problèmes respiratoires (cocaïne et cannabis), des douleurs thoraciques et problèmes cardiovasculaires (cocaïne, cannabis et amphétamines), des convulsions, pertes de conscience et coma (cocaïne, amphétamines, opioïdes, benzodiazépines, ecstasy), l'hyperthermie (cocaïne, ecstasy) et la rhabdomyolyse (toutes les drogues) (Devlin et Henry, 2008). Pour ce qui est du cerveau, des études ont trouvé des altérations au niveau des lobes frontaux, pariétaux et temporaux chez les adolescents consommateurs de cannabis; des altérations au niveau de l'hippocampe chez les consommateurs d'ecstasy; des altérations au niveau du striatum chez les consommateurs de métamphétamines; et des altérations au niveau

du thalamus chez les consommateurs d'inhalants (Silveri, Dager, Cohen-Gilbert et Sneider, 2016).

Il est à noter que la littérature sur les impacts de la consommation problématique de substances à l'adolescence est limitée méthodologiquement, ce qui ne permet pas d'être certain de la causalité des effets pour toutes ces conséquences, notamment en ce qui a trait aux effets psychosociaux et sur le développement du cerveau. En effet, la majorité des études s'intéressent à la consommation à la fin de l'adolescence, avec peu d'études portant sur la consommation au début de l'adolescence. De plus, la majorité des études sont transversales et peu d'études prospectives et longitudinales à long terme ont été conduites. Finalement, peu d'études contrôlent pour une variété de variables confondantes (Castellanos-Ryan, Rioux et London-Nadeau, accepté; Degenhardt et Hall, 2012; Feldstein Ewing et al., 2014; Marshall, 2014; Newbury-Birch et al., 2009). Des études plus rigoureuses méthodologiquement permettront une meilleure confiance dans la direction des effets énumérés, mais ne permettront pas d'effectuer des conclusions causales.

Malgré les limites de la littérature, la consommation problématique de substances est considérée comme un des facteurs de mortalité et d'invalidité les plus importants chez les adolescents (Degenhardt, Stockings, Patton, Hall et Lynskey, 2016; Gore et al., 2011). La consommation problématique de substances a également des impacts importants sur les dépenses de l'État, les coûts de l'abus de substances pour la société canadienne ayant été estimés à près de 40 milliards de dollars (Rehm et al., 2007), un fardeau économique qui est aussi présent à l'international (Rehm et al., 2009). Il est donc important d'identifier les facteurs personnels et environnementaux augmentant les probabilités de consommation problématique de substances à l'adolescence. En effet, l'identification de ces facteurs

permettra d'informer le développement de programmes de prévention efficaces, qui à leur tour pourront permettre de diminuer la consommation de substances problématique et ses conséquences physiques, psychologiques, sociales, et économiques.

## 1.3. Tempérament, personnalité et environnement familial

Parmi les facteurs personnels, le tempérament et la personnalité constituent des cibles de prévention potentielles permettant de dépister les jeunes à risque qui seraient plus sensibles aux effets de l'alcool (Comeau, Stewart et Loba, 2001; Conrod, Castellanos-Ryan et Mackie, 2011; Lammers et al., 2015). Le tempérament et la personnalité sont parfois difficiles à distinguer dans la littérature. Alors qu'il existe plusieurs définitions du tempérament, la majorité des chercheurs s'entendent sur le fait que le tempérament consiste en une prédisposition qui apparaît tôt dans la vie, qui a une origine partiellement génétique, qui est relativement stable, et qui comprend plusieurs traits associés à l'activité, l'autorégulation, l'affectivité et l'attention (De Pauw et Mervielde, 2010; Goldsmith et al., 1987; Henderson et Wachs, 2007; Rothbart et Bates, 2006; Shiner et al., 2012). Plusieurs auteurs proposent que le tempérament, en interaction avec l'environnement, forme la base de la personnalité, ou que le tempérament constitue une partie des traits de personnalité, soit ceux qui sont associés à l'activité, l'autorégulation, l'affectivité et l'attention (De Pauw et Mervielde, 2010; Rothbart, 2011). En plus de ces traits, la personnalité comprend des différences individuelles plus complexes associées avec les valeurs, les croyances et les cognitions (Evans et Rothbart, 2007). Ainsi, la personnalité est habituellement définie de façon générale comme représentant un patron de pensées, émotions et comportements qui sont stables dans le temps et dans diverses situations (Allport, 1937; Rothbart, 2011). Le tempérament et la personnalité ont tous

deux été montrés comme étant associés à la consommation de substances à l'adolescence (Belcher, Volkow, Moeller et Ferre, 2014; Castellanos-Ryan et Conrod, 2012; Sanson, Hemphill et Smart, 2004; Stautz et Cooper, 2013; Wills et Dishion, 2004).

Du côté environnemental, la famille constitue une influence importante pouvant constituer une cible d'intervention (Dishion et Kavanagh, 2000; Sanders, 2012; Thorell, 2009; Webster-Stratton et Reid, 2003). L'environnement familial comprend plusieurs facteurs associés à la consommation de substances à l'adolescence. D'abord, les pratiques parentales, c'est-à-dire les stratégies utilisées pour élever l'enfant, ont été montrées comme étant associées avec la consommation d'alcool et d'autres substances dans plusieurs revues systématiques de la littérature (Cablova, Pazderkova et Miovsky, 2014; Sharmin et al., 2017; Yap, Cheong, Zaravinos-Tsakos, Lubman et Jorm, 2017) et constituent une cible d'intervention dans plusieurs programmes de prévention et d'intervention pour la consommation de substances (Allen et al., 2016; Kuntsche et Kuntsche, 2016; Thomas, Baker et Thomas, 2016). Ensuite, la qualité de la relation parent-enfant, qui comprend les comportements du parent et de l'enfant, ainsi que les sentiments et les attentes qu'ils ont un envers l'autre, est également associée avec la consommation de substances (Johnson, McBride, Hopkins et Pepper, 2014; Visser, de Winter et Reijneveld, 2012). Enfin, le conflit marital, soit les disputes entre les parents, ainsi que la séparation et le divorce, est également associé à la consommation de substances des enfants à l'adolescence et à l'âge adulte (Schiff et al., 2014; Troxel et Matthews, 2004; Turner, Irwin Jr et Millstein, 2014; Vanassche, Sodermans, Matthijs et Swicegood, 2014).

## 1.4. Objectifs et structure de la présente thèse

Alors que le tempérament/la personnalité et l'environnement familial sont associés à la consommation de substances à l'adolescence, il est également possible que ces facteurs interagissent entre eux. En effet, tel que proposé par les modèles de la diathèse-stress et de la sensibilité différentielle, les facteurs individuels, comme le tempérament et la personnalité, ainsi que les facteurs environnementaux, comme l'environnement familial, peuvent interagir pour prédire le développement humain (Belsky et Pluess, 2009, 2013a; Monroe et Simons, 1991; Zuckerman, 1999). La présente thèse vise à examiner ces interactions à l'enfance et à l'adolescence dans la prédiction de la consommation de substances à l'adolescence. Spécifiquement:

Le premier article de thèse constitue une revue systématique de la littérature portant sur l'interaction entre le tempérament et l'environnement familial dans la prédiction de la consommation de substances et des comportements extériorisés à l'adolescence. Toutes les études revues ont été examinées en fonction des modèles de la diathèse-stress et de la sensibilité différentielle afin de déterminer lequel des deux modèles recevait le plus de soutien. Les comportements extériorisés en général ont été examinés en plus de la consommation de substances afin de maximiser le nombre d'études incluses.

Le deuxième article de thèse est un article empirique qui examine les interactions entre le tempérament (impulsivité et contrôle inhibiteur à 6 ans) et les pratiques parentales (pratiques maternelles coercitives à 6 ans et supervision parentale à 14 ans) dans la prédiction de la fréquence de consommation d'alcool à 15 ans, et ce selon les modèles de la diathèse-stress et de la sensibilité différentielle.

Le troisième article de thèse est un article empirique qui examine les interactions entre la personnalité (impulsivité et recherche de sensations à 15 ans) et la supervision parentale à 15 ans dans la prédiction de la fréquence de consommation d'alcool et de drogues à 15 et 17 ans, et ce selon les modèles de la diathèse-stress et de la sensibilité différentielle.

Finalement, le quatrième article de thèse va au-delà des comportements extériorisés et de la consommation de substances, visant à élargir le champ d'application du modèle de la sensibilité différentielle. Alors que le modèle de sensibilité différentielle a gagné en popularité en psychologie développementale, il demeure peu connu dans d'autres domaines dominés surtout par le modèle de la diathèse-stress. Le quatrième article de thèse constitue ainsi une perspective présentant comment le modèle de la sensibilité différentielle pourrait s'appliquer au trouble de personnalité limite. L'article présente comment plusieurs caractéristiques personnelles associées au trouble de la personnalité limite (p.ex., réactivité émotionnelle, impulsivité) pourraient refléter une sensibilité aux environnements positifs et négatifs plutôt que seulement une vulnérabilité aux environnements négatifs.

# 2. Méthodologie et résultats

## Articles de recherche

## 2.1. Premier article

# The interaction between temperament and the family environment in adolescent substance use and externalizing behaviors: Support for diathesis-stress or differential susceptibility?

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Objectifs spécifiques de cet article: Analyser toutes les études publiées sur l'interaction entre le tempérament et l'environnement familial dans la prédiction de la consommation de substances et des comportements extériorisés à l'adolescence selon les modèles de la diathèse-stress et de la sensibilité différentielle.

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## Contribution des auteurs

**Charlie Rioux:** Conceptualisation de l'article, recherche systématique des articles, ré-analyse des résultats des articles, synthèse des articles, rédaction des différentes sections de l'article, préparation des tableaux et graphiques.

**Natalie Castellanos-Ryan:** Soutien à la conceptualisation de l'article, à l'analyse des articles et à l'interprétation des résultats, correction du manuscrit et révision de l'article.

**Sophie Parent:** Soutien à l'interprétation des résultats, correction du manuscrit et révision de l'article.

**Jean Séguin:** Soutien à la conceptualisation de l'article et à l'interprétation des résultats, correction du manuscrit et révision de l'article.

Abstract

Both individual and environmental factors predict externalizing behaviors and substance use; however different patterns of interaction among these factors may have different implications. This review first examines how temperament and the family environment interact in the prediction of adolescent externalizing behaviors and substance use. Second, studies are reviewed according to two theoretical models: (1) diathesis-stress, i.e., certain individual characteristics are linked to vulnerability and later problems in adverse environments; (2) differential susceptibility, i.e., these characteristics are linked to susceptibility, predicting problems in adverse environments, but *also* better than average outcomes in good environments. Fourteen studies focusing on the prediction of externalizing behaviors and substance use at ages 12-18 were selected through a literature search. Results showed that certain temperament traits (high levels of impulsivity and disinhibition; low levels of effortful control, negative affect, fearfulness and shyness), hereby designated as "adventurous" disposition, were associated with higher levels of externalizing behaviors and substance use in adverse family environments. Some studies also showed that children with "adventurous" temperament traits in positive environments had the lowest levels of externalizing behaviors and substance use. This suggests that prevention of externalizing behaviors and substance use might target family factors such as parenting and focus on children with "adventurous" temperament traits. Further, studies that supported the differential susceptibility model were those assessing temperament and the family environment in childhood and studies that supported the diathesis-stress model assessed these variables in adolescence. It is thus possible that some of these "adventurous" temperament traits, with regards to externalizing behaviors and substance use, would be indicators of susceptibility to both enriched and adverse

environments in childhood but no longer in adolescence, when they would only be indicators of vulnerability to adverse environments.

*Keywords:* Diathesis-stress, Differential susceptibility, Temperament, Family, Externalizing, Moderation.

## The interaction between temperament and the family environment in adolescent substance use and externalizing behaviors: Support for diathesis-stress or differential susceptibility?

Adolescent substance use has several potential adverse short- and long-term consequences, including addiction, poor academic achievement, sleep disturbances, depression, suicidal behavior, injuries, overdoses, car accidents, teenage pregnancy, sexually transmitted diseases and liver disease (Newbury-Birch et al., 2009; Single, Rehm, Robson, & Van Truong, 2000; Stolle, Sack, & Thomasius, 2009). Correlates of substance use in adolescence include both individual and environmental characteristics (Chartier, Hesselbrock, & Hesselbrock, 2010; Patrick & Schulenberg, 2013). While internalizing problems are more strongly associated with substance use in adulthood (Chan, Dennis, & Funk, 2008; Grant et al., 2004; King, Iacono, & McGue, 2004), a history of externalizing behaviors beginning in early childhood is more likely to be observed in adolescents using substances (Chan et al., 2008; Jester et al., 2008; Pingault et al., 2013; Zucker, Heitzeg, & Nigg, 2011). Furthermore, since adolescent substance use and externalizing behaviors share common variance and developmental predictors (Castellanos-Ryan & Conrod, 2011; Castellanos-Ryan et al., 2014; Krueger, Markon, Patrick, Benning, & Kramer, 2007; Vrieze, Perlman, Krueger, & Iacono, 2012), substance use may be considered a form of externalizing behavior. Thus, examining the predictors of adolescent externalizing behaviors can also provide insights into the development of substance use problems.

Two sets of predictors reflecting the child's early predisposition and its environment have shown promise in understanding the development of externalizing behaviors and substance use. Most researchers agree that temperament consists of individual differences in behavior-influencing traits which appear early, are relatively stable across situations and time,

and are thought to have some biological foundation (De Pauw & Mervielde, 2010; Goldsmith et al., 1987; Henderson & Wachs, 2007; Rothbart & Bates, 2006; Shiner et al., 2012). Historically, temperament research has allowed to study the potential influence of children's early characteristics to their social development and began after the publication of the New York Longitudinal Study by Thomas, Chess, Birch, Hertzig, and Korn (1963). Until then, most studies focused on the influence of the environment on children's development, including the family environment, such as parenting practices, the quality of the parent-child relationship and marital conflict (Sanson, Hemphill, & Smart, 2004; Schaffer, 1999; Thomas et al., 1963). Still, most studies of temperament and the family environment have focused on the direct associations with children's development (Sanson et al., 2004), and both have been found to be associated with substance use and externalizing behaviors (Barnes, Reifman, Farrell, & Dintcheff, 2000; Kitzmann, Gaylord, Holt, & Kenny, 2003; Teerikangas, Aronen, Martin, & Huttunen, 1998; Willem et al., 2011). Some studies have also examined how they may interact with each other. This is important since the impact of temperament on children's development has long been considered to be dependent on their environment (Thomas & Chess, 1977; Wachs, 2000). However, specific information regarding their pattern of interaction is lacking. Accordingly, the present study will systematically review studies on the interactions between temperament and the family environment in the prediction of adolescent substance use and externalizing behaviors and examine the pattern of these interactions according to two theoretical models.

To complete this introduction, we will now clarify the concepts of temperament and family environment, examine the associations they each have with substance use and

externalizing behaviors, and consider why and how we could study their interaction in the prediction of substance use and externalizing behaviors.

**Temperament, substance use and externalizing behaviors**

Researchers usually either study specific temperament dimensions or cluster temperamental dimensions into overarching temperament profiles, with few indications that one method would have specific advantages over the other. Although the most common overarching temperament profile for which questionnaires were developed is difficult temperament, researchers have proposed different combinations of temperament dimensions, based on theory or through factor analysis. Overarching temperament profiles observed in this review are defined in Table 1.

Regarding more specific temperament dimensions, the number and nature of these behavior-influencing traits is still debated and there are several theoretical and measurement traditions in the temperament literature, the most common being the theories of Thomas and Chess (1977), Buss and Plomin (1975, 1984) and Rothbart (1981) (see Zentner and Bates (2008), for a review on temperament theories).

Rothbart (1981) defined temperament as constitutionally based individual differences in two broad categories: reactivity and self-regulation. Reactivity refers to the speed and intensity of responses, which includes dimensions related to motor activation, surgency and negative affectivity. Self-regulation refers to the strategies that modulate reactivity, which includes dimensions related to attentional control and the inhibition of dominant responses. Because this theory is the broadest and most inclusive (Shiner et al., 2012), and we note that most temperamental dimensions proposed by Thomas and Chess (1977) and Buss and Plomin (1975, 1984) can be theoretically classified within the reactivity and self-regulation categories,

the Rothbart classification will serve to organize the results presented in this review. Table 1 also provides a list of temperament dimensions observed in the current review, classified within the reactivity or self-regulation categories, along with their definition.

Table 1
*Classification and definition of observed temperament overarching profiles and dimensions*

| |
|---|
| **Overarching temperament profiles** |
| Difficult temperament<br>*Various characteristics making the child more difficult to handle* (Goldsmith et al., 1987).<br>General characteristics (characteristics vary among studies): *Irregular eating and sleeping daily routines, withdrawal from people and novel stimuli, low adaptability or inflexibility to changes in the environment, high intensity responses and irritable mood quality* (Thomas & Chess, 1977) |
| Protective temperament<br>*Tendency to focus on tasks, persist until finished, have a cheerful mood and smile frequently* (Wills et al., 2001) |
| Extravert/aggressive<br>*In a doll-play situation: High amount of bodily movement, easily roused to excite behavior, low tendency to stick with one activity, tendency to respond, show aggression, be rough and show nonrealistic fantasy* (Score based on factor analysis; Wennberg & Bohman, 2002). |
| Extravert/outgoing<br>*In a doll-play situation: attempts to change occupation/terminate the play, low concern for neatness, low concerns regarding getting dirty, tendency to seek attention from the examiner, shows high degree of pleasure* (Score based on factor analysis; Wennberg & Bohman, 2002). |
| **Temperament dimensions** |
| **Reactivity** |
| Activity level<br>*Gross motor activity, including rate and extent of locomotion* (Rothbart et al., 2001). |
| Impulsivity<br>*Speed of response initiation* (Rothbart et al., 2001). |
| Approach<br>*Amount of excitement and anticipation for expected pleasurable activities* (Rothbart et al., 2001). |
| Sociability<br>*Enjoyment derived from social interaction and preference for being in the presence of others rather than being alone* (Evans & Rothbart, 2009; Goldsmith et al, 1987). |
| Disinhibition<br>*Combination of activity level and approach* (Burk et al. 2011; Armstrong et al., 2013). |

Negative affectivity (Synonyms: negative mood, negative emotionality)
*Distress; proneness to negative emotional experiences such as frustration, fear and shyness* (Ellis, 2002)

- Fearfulness
  *Negative affectivity, including unease, worry, or nervousness, which is related to anticipated pain or distress and/or potentially threatening situations* (Rothbart et al., 2001).
- Shyness
  *Slow or inhibited speed of approach and discomfort in social situations* (Rothbart et al., 2001).
- Frustration (synonym: anger)
  *Negative affect related to interruption of ongoing tasks or goal blocking* (Rothbart et al., 2001).

**Self-Regulation**

Effortful control
*Combination of volitional skills, including attentional, inhibitory, and activational control that allow the inhibition of a dominant response in order to perform a subdominant response.* (Ellis, 2002).

Attentional control

- Attentional focusing
  *Capacity to maintain attentional focus on task-related channels* (Rothbart et al., 2001).
- Duration of orienting (Synonym: persistence)
  *The child's vocalization, looking at, and/or interaction with a single object for extended periods of time when there has been no sudden change in stimulation* (Rothbart, 1981).

Inhibition of dominant responses

- Inhibitory control
  *Capacity to plan and suppress inappropriate approach responses under instructions or in novel or uncertain situations* (Rothbart et al., 2001).

Several studies have documented direct associations between temperament and developmental outcomes (Sanson et al., 2004), including substance use and externalizing behaviors. Some of these studies have examined how overarching temperament profiles are associated with substance use and externalizing behaviors. Windle (1991) measured temperament in adolescence (average age 15.7 years) with a questionnaire evaluating ten dimensions and summarized the scores by computing an overarching profile of the number of difficult temperament dimensions (activity level-general, activity level-sleep, approach-withdrawal, flexibility, rhythmicity-sleep, rhythmicity-eating, rhythmicity-daily habits,

distractibility, persistence). A significant linear trend was found in which the number of difficult temperament dimensions predicted higher cigarette, alcohol and hard drugs use as well as delinquency. In a longitudinal study of adolescents (average age 15.5 at time one) whose temperament (categorized as not difficult, somewhat difficult and difficult) and substance use were assessed twice one year apart, Tubman and Windle (1995) found that cigarette and alcohol use, averaged across the two time points, were higher for adolescents who showed stable difficult temperament across both time points. Finally, Wennberg and Bohman (2002) showed that participants scoring high on the overarching temperament profile extravert/aggressive at age 4 years had a higher frequency of intoxication at age 25 years whereas those who scored high on the dimension extravert/outgoing at age 4 years had more lifetime alcohol problems at age 25 years.

With regards to reactivity dimensions of temperament, high levels of impulsivity have also been shown to accompany high levels of externalizing behaviors in a study of 11-year-old children (Oldehinkel, Hartman, De Winter, Veenstra, & Ormel, 2004), and high levels of alcohol use in 12 to 18 year-old adolescents (Colder & Chassin, 1997). Similarly, in a cross-sectional study of 14 to 18 year-old participants, Willem et al. (2011) compared a clinical group of adolescents recruited from a specialized inpatient unit for substance use disorders to a control group recruited through schools. They found that the clinical youth had higher levels of impulsivity compared to the school group. Finally, Oldehinkel et al. (2004) found that high levels of frustration were concurrently associated with externalizing behaviors at 11 years.

Some studies have also examined self-regulatory dimensions of temperament. The study by Oldehinkel et al. (2004) also found that low levels of effortful control were concurrently associated with externalizing behaviors at 11 years. Effortful control at 14 years

was also concurrently and negatively associated with delinquency and aggression (van der Voort, Linting, Juffer, Bakermans-Kranenburg, & van Ijzendoorn, 2013) and effortful control at 54 months was negatively associated with externalizing behaviors at 15 years (Honomichl & Donnellan, 2012). Also, in a longitudinal study of participants who reported on their age of substance use initiation at 19.5 years, lower duration of orienting at 14.5 years was found to be associated with earlier initiation of cigarette smoking, but was not associated with alcohol and illicit drug initiation (Hartman, Hopfer, Corley, Hewitt, & Stallings, 2013).

Finally, in a cross-sectional study (mean age 11 years), Muris, Meesters, and Blijlevens (2007) examined interactions between reactive and self-regulatory temperament dimensions and found that high levels of frustration were associated with high levels of externalizing behaviors when inhibitory control was low. They also found that the more general temperament dimension of negative affectivity was associated with externalizing behaviors when effortful control was low. Because the previously mentioned study by Oldehinkel et al. (2004) found that high levels of frustration and low levels of effortful control were associated with externalizing behaviors, it is possible that a test for interactions would have yielded an interaction similar to those found in the study by Muris et al. (2007).

In summary, and examining temperament alone, difficult temperament and temperament dimensions including high impulsivity, high negative affectivity, low effortful control and low duration of orienting were found in some studies to be directly associated with externalizing behaviors and substance use.

**The family environment, substance use and externalizing behaviors**

Among the most studied environmental factors conveying risk for externalizing behaviors and substance use are those related to the family environment. Family factors

highlighted as important univariate predictors of externalizing behaviors and substance use include parenting practices (i.e., child rearing strategies; see Table 2 for definitions of parenting variables observed in the present review), quality of the parent-child relationship (i.e., parent and child behaviors, feelings and expectations towards each other) and marital conflict (i.e., disagreements and/or arguments between the father and the mother).

Table 2
*Definition of observed parenting variables*

- **Parental control**
  *Consistent discipline, monitoring of activities and enforcement of consequences* (Stice & Gonzales, 1998).
- **Appropriateness**
  *Adolescents' perception of how well their parent's reactions fit the situation* (Padilla-Walker and Nelson, 2010)
- **Coercive parenting**
  *Use of harsh physical and/or verbal discipline, from over-reacting to relatively extreme forms of physical and verbal punishment* (Leve et al., 2005; Rioux et al., 2015).
- **Monitoring**
  *Parenting behaviors involving attention to and track of the child's whereabouts, activities, and adaptations* (Dishion & McMahon, 1998).
- **Authoritative parenting**
  *Parenting style characterized by clear rules and monitoring and efforts to foster openness, support exploration and respond non-punitively* (Armstrong et al., 2013; Baumrind, 1971).
- **Authoritarian parenting**
  *Parenting style characterized by control, criticism and punishment* (Armstrong et al., 2013; Baumrind, 1971).

Problematic parenting practices, including high coercive parenting, low parental control and low parental monitoring in childhood (Fergusson & Lynskey, 1997; Hayatbakhsh et al., 2008), preadolescence (Burnette, Oshri, Lax, Richards, & Ragbeer, 2012; Buschgens et al., 2010) and in adolescence (Abar, Jackson, Colby, & Barnett, 2014; Aquilino & Supple, 2001; Barnes & Farrell, 1992; Barnes et al., 2000; Clark, Shamblen, Ringwalt, & Hanley, 2012; DiClemente et al., 2001; Duncan, Duncan, Biglan, & Ary, 1998; Kaynak et al., 2013;

Tornay et al., 2013) have been associated with substance use and other externalizing behaviors in adolescence and young adulthood. High levels of parent-child conflict and poor parent-child relationship quality in preadolescence (Burt, McGue, Krueger, & Iacono, 2005) and adolescence (Duncan et al., 1998; Koh & Rueter, 2011; Loke & Mak, 2013; Marsiglia, Kulis, Parsai, Villar, & Garcia, 2009; McKinney & Renk, 2011; Yeh, 2011) have also been shown to contribute to adolescent substance use and externalizing behaviors. Finally, marital conflict and divorce in childhood (Dube et al., 2006; Sourander & Helstela, 2005) and adolescence (Barnett, Rowley, Zimmerman, Vansadia, & Caldwell, 2011; Cui, Donnellan, & Conger, 2007; Fletcher & Sindelar, 2012; Grych, Raynor, & Fosco, 2004; Kristjansson, Sigfusdottir, Allegrante, & Helgason, 2009; Roustit, Chaix, & Chauvin, 2007; Vanassche, Sodermans, Matthijs, & Swicegood, 2014) have also been associated with heightened externalizing behaviors and alcohol use in adolescents.

**The interplay between temperament and family environments**

Although various studies have examined temperament and the family environment separately as predictors of substance use and externalizing behaviors, models taking into account their joint effects are needed to explain the development of adolescent substance use and externalizing behaviors (Sanson et al., 2004). These include but are not restricted to moderation effects, which will be the focus of the present review. Examining these interactions is important because the impact of temperament on developmental outcomes is often considered to be dependent on the child's environment (Thomas & Chess, 1977; Wachs, 2000) and it has been suggested that temperament is involved in children's responsiveness to environmental stressors (Rothbart, 2004). Furthermore, developmentally, and in interaction with the family environment, temperament could be associated with substance use and

externalizing behaviors in adolescence through its influence on self-control abilities (Wills & Dishion, 2004), which are a complex set of attributes involved in the control of cognition, emotion, and behavior including self-monitoring, planning, future orientation, delay of gratification, and emotional regulation (Barkley, 1997; Mischel, Shoda, & Rodriguez, 1989; Wills & Dishion, 2004; Wills, Sandy, & Yaeger, 2000).

Within this context, a primary goal of this review is to examine how temperament and family factors such as those just reviewed interact in the prediction of adolescent substance use and externalizing behaviors. This could inform prevention and early intervention efforts by helping identify which children could benefit most from targeted interventions, and what aspects of family life could be targeted by these interventions. A second goal is to review studies according to two theoretical models that address how children's individual characteristics can interact with the family environment and convey risk or advantage to the child.

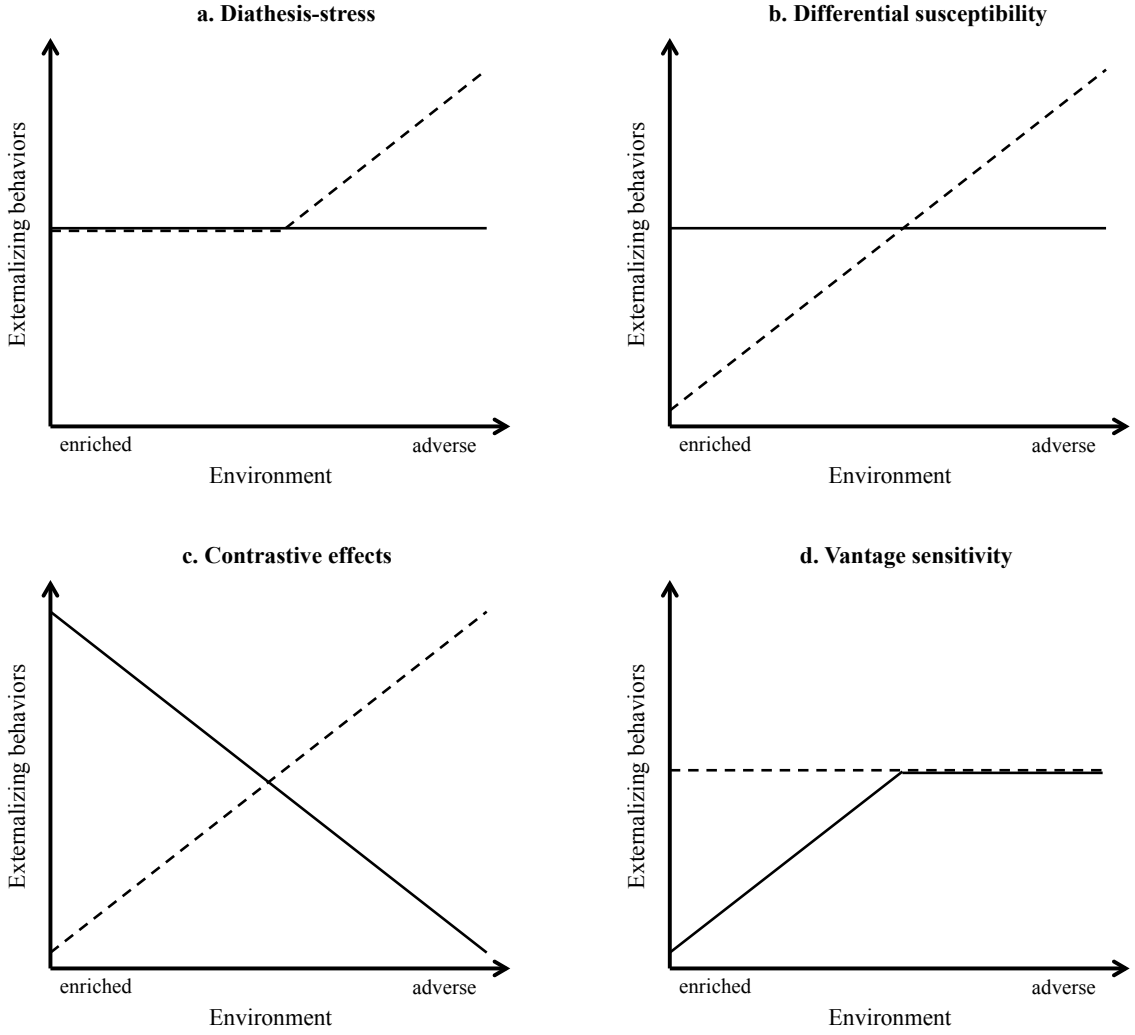
**Patterns of person-environment interactions**

There are several patterns of person-environment interactions that have different theoretical and methodological implications. The diathesis-stress model (Monroe & Simons, 1991) suggests that vulnerable individuals with certain characteristics exhibit worse outcomes in adverse environments (see Figure 1a). The differential susceptibility model (Belsky & Pluess, 2009) posits that these individuals also benefit more from enriched environments (see Figure 1b). A pattern of contrastive effects (see Figure 1c) suggests that individuals high on an individual characteristic and those low on the same characteristic are both affected by environmental variables, but in opposite directions (Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2007). Finally, the vantage sensitivity model (Pluess & Belsky, 2013) suggests

that individuals with certain characteristics can benefit more from positive environmental influences (see Figure 1d).

Figure 1

*Graphical representation of different moderation models. The lines depict high or low levels of an individual characteristic: for example, continuous lines represent an easy temperament and dashed lines represent a difficult temperament.*




Since the diathesis-stress model has guided most research on person-environment interactions and the differential susceptibility model can provide an alternative interpretation for some results interpreted according to the diathesis-stress model (Belsky & Pluess, 2009), the present review will focus on these two models, which are described in more detail below.

**The diathesis-stress and differential susceptibility models**

Research on interactions between individual characteristics and the environment has been primarily guided by the diathesis-stress model (Gottesman & Shields, 1967; Monroe & Simons, 1991; Zuckerman, 1999). According to this model (see Figure 1a), some individuals are disproportionately likely to be affected adversely by an environmental stressor due to an individual vulnerability factor (e.g., difficult temperament). This model purports that "vulnerable" and "resilient" individuals develop differently primarily when exposed to adverse environmental conditions. That is, "vulnerable" individuals will experience worse outcomes than "resilient" individuals when exposed to environmental stress or negative environmental factors, whereas they will develop more or less similarly in the absence of adversity.

The differential susceptibility model (Belsky, 2005; Belsky et al., 2007; Belsky et al., 2014; Belsky & Pluess, 2009; B. J. Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2011) is more recent and posits that individuals with certain characteristics, such as difficult temperament, are not only adversely affected by environmental stressors, but also reap the most benefits from good environmental conditions (see Figure 1b), because they are more sensitive to environmental influences. That is, the differential susceptibility model does not consider these individuals as "vulnerable", but as "susceptible" to input from environmental factors, whether positive or negative. Thus, from a developmental-psychopathology perspective, the main implication of the differential susceptibility model is that more susceptible individuals would have an increased tendency to experience good outcomes in positive environments in addition to their increased likelihood of bad outcomes in negative environments (B. J. Ellis et al., 2011). As such, susceptibility factors would no longer be conceptualized exclusively as a risk.

**Statistical testing of the diathesis-stress and differential susceptibility models**

Interactions are usually tested using moderation analyses. These analyses can be conducted using ANOVA techniques when the two predictors are categorical, but multiple regression techniques with continuous predictors are recommended because they are more flexible (J. Cohen, Cohen, West, & Aiken, 2013). When one or both predictors are continuous, multiple regression techniques (multiple linear regression for continuous outcomes and multiple logistic regression for categorical outcomes) should be used, where the interaction between the individual and environmental factors is tested after taking into account their main effects. The main concern with moderation analysis is that it tends to lack power. The three most common problems leading to lack of power in moderation analysis include small sample size, with effect sizes for interactions that are often small (Aguinis, Beaty, Boik, & Pierce, 2005; Chaplin, 1991), low reliability of the predictor and/or moderator which dramatically reduces the reliability of the interaction term, and restriction in range, where individuals in the studied population do not have the same probabilities of being selected for the sample (Aguinis, 1995; Aguinis & Stone-Romero, 1997; Aiken & West, 1991; McClelland & Judd, 1993).

Once a significant interaction is found, the diathesis-stress and differential susceptibility models may be distinguished empirically by evaluating the pattern of the interaction. Statistical support for the diathesis-stress model comes from a pattern where an individual characteristic is related to an outcome and an ordinal (fan-shaped, without a crossover point) interaction is found (Belsky et al., 2007). To support the differential susceptibility model, a disordinal (with a crossover point) interaction must be found, where the slope of the susceptible group (e.g., children with difficult temperament) is significantly

different from zero and significantly steeper than the slope of the non-susceptible group (e.g., those with easy temperament). Also, the susceptibility variable should ideally not be significantly correlated to the environmental factor or to the outcome (Belsky et al., 2007; Belsky & Pluess, 2009). However, when the environmental and individual variables are mildly correlated, the residual score from the environmental variable on the individual characteristic can be used (e.g., Nederhof, Belsky, Ormel, & Oldehinkel, 2012; Ramchandani, van IJzendoorn, & Bakermans-Kranenburg, 2010; Rioux et al., 2016).

While these criteria were previously considered sufficient to distinguish the two models, additional statistical tests have now been proposed to differentiate ordinal from disordinal interactions. The first option would be to conduct a *region-of-significance* analysis (Aiken & West, 1991; Preacher, Curran, & Bauer, 2006), which was suggested by Kochanska, Kim, Barry, and Philibert (2011) in the context of a test of the differential susceptibility model. Roisman et al. (2012) also suggested two additional metrics that can be used to supplement the region-of-significance analysis. Another procedure can statistically differentiate ordinal from disordinal interactions by estimating the crossover point and its confidence interval (Widaman et al., 2012). Finally, a model fitting approach can also be used to directly test the two models without using multiple regression to test for significant interactions (Belsky, Pluess, & Widaman, 2013).

**Objectives of the present review**

The first objective of this review was to synthesize the findings of studies examining the interactions between temperament and the family environment in the prediction of adolescent substance use and externalizing behaviors. The second objective was to re-examine

the results of relevant studies according to the diathesis-stress and differential susceptibility models by qualitatively examining the plotted interactions (see methods section for details).

## Methods

We included studies identified through a systematic literature search using Web of Science™, PsycINFO® and Medline®. Journal articles in English or French (French keywords not listed) were searched using the following keywords in a Boolean search: adolescen* AND externalizing OR "substance use" OR alcohol OR drug OR tobacco OR cannabis OR marijuana AND parent* OR famil* OR paternal OR maternal OR mother OR father AND temperament* OR emotionality OR "emotional reactivity" OR "negative affect*" OR "positive affect*" OR "activity level" OR "distress to limitations" OR approach/withdrawal OR impulsivity OR "behavioral undercontrol" OR "behavioural undercontrol" OR "motor activation" OR inhibition OR "inhibitory control" OR "effortful control" OR "attention* focus*" OR "attention* shift*" OR sociability OR persistence OR "duration of orienting" AND moderat* OR interact*. Specific family variables were not specified in the search in order to include all environmental family variables that could be identified through the primary search criteria. No date restrictions were applied to the selection of literature and articles were searched up to May 4th, 2015. Searches in PsycINFO® and Medline® were also limited to human studies. The retrieved titles and abstracts from the literature search were screened for relevance. For every abstract that was identified as potentially relevant, the full-text article was retrieved for evaluation. The reference lists of relevant articles were also searched.

To be included in the review, studies had to meet the following eligibility criteria: (1) substance use or externalizing behaviors were assessed as outcomes; (2) substance use or

externalizing behaviors were measured in adolescence, between 12 and 18 years of age; (3) the family variables were environmental - for example, heritability variables were excluded; (4) the individual characteristics studied were temperament and not related characteristics such as personality - the authors' definitions and the questionnaires used were used to determine whether the variable fit the definition of temperament outlined above, and (5) the study examined moderation effects between temperament and the family environment (studies examining mediation only were excluded).

**Effect sizes**

Effect sizes are provided to facilitate comparison across studies and because of the power issues that can arise when testing interactions (Aguinis et al., 2005; Chaplin, 1991). When articles did not provide standardized results, the information was requested from authors via electronic mail. Electronic mail addresses were obtained from the articles' contact information or from a Google search. The corresponding authors of eight articles were contacted. Of those, three provided the requested data, three did not have access to the information and two could not be reached.

Standardized regression coefficients (standardized betas) are provided as effect size estimates (Nieminen, Lehtiniemi, Vähäkangas, Huusko, & Rautio, 2013; Rosenthal & DiMatteo, 2001). Standardized coefficients of 0.10, 0.30 and 0.50 were considered small, medium and large effect sizes respectively (J. Cohen, 1988, 1992). These coefficients represent the effect size of the interaction between temperament and family variables on substance use or externalizing behaviors while controlling for the other variables included in the tested model of the various studies. Because control variables and other predictors differ

between studies, the coefficients are not equivalent (Lipsey & Wilson, 2001), which is a limitation. However, they still provide useful information about the size of the effect.

**Comparing the Diathesis-Stress and Differential Susceptibility models**

The statistical approaches previously described should be applied when conducting analyses and comparing differential susceptibility from diathesis-stress models. However, most studies to date were conducted within a diathesis-stress frame of reference and do not report the statistical information necessary for rigorously testing the differential susceptibility model (Belsky & Pluess, 2009). Thus, the following more liberal criteria were used in this review. The first criterion for either model was to find a significant interaction. Plotted results of the significant interactions were then qualitatively examined as either ordinal (fan-shaped), which is consistent with the diathesis-stress model, or disordinal (crossover), which is consistent with the differential susceptibility model. Specifically, when the crossover point was in the middle range of the family variable, the interaction was considered disordinal. When the crossover point was in the lower/higher range of the family variable or outside of the observable data, the interaction was considered ordinal. When plots were not included in the articles, results were plotted using the coefficients provided and following the guidelines of Frazier, Tix, and Barron (2004) and W. B. Cohen, Maiersperger, Gower, and Turner (2003). When significance of simple slopes were provided in the article, they were also used to interpret the findings, i.e., to determine whether the slope for the susceptible group was significantly different from zero and significantly steeper than the slope for the non-susceptible group. One criterion for supporting the differential susceptibility model requires that the susceptibility variable not be significantly correlated to the environmental factor. This criterion was not applied because it can be controlled for statistically when formally testing the

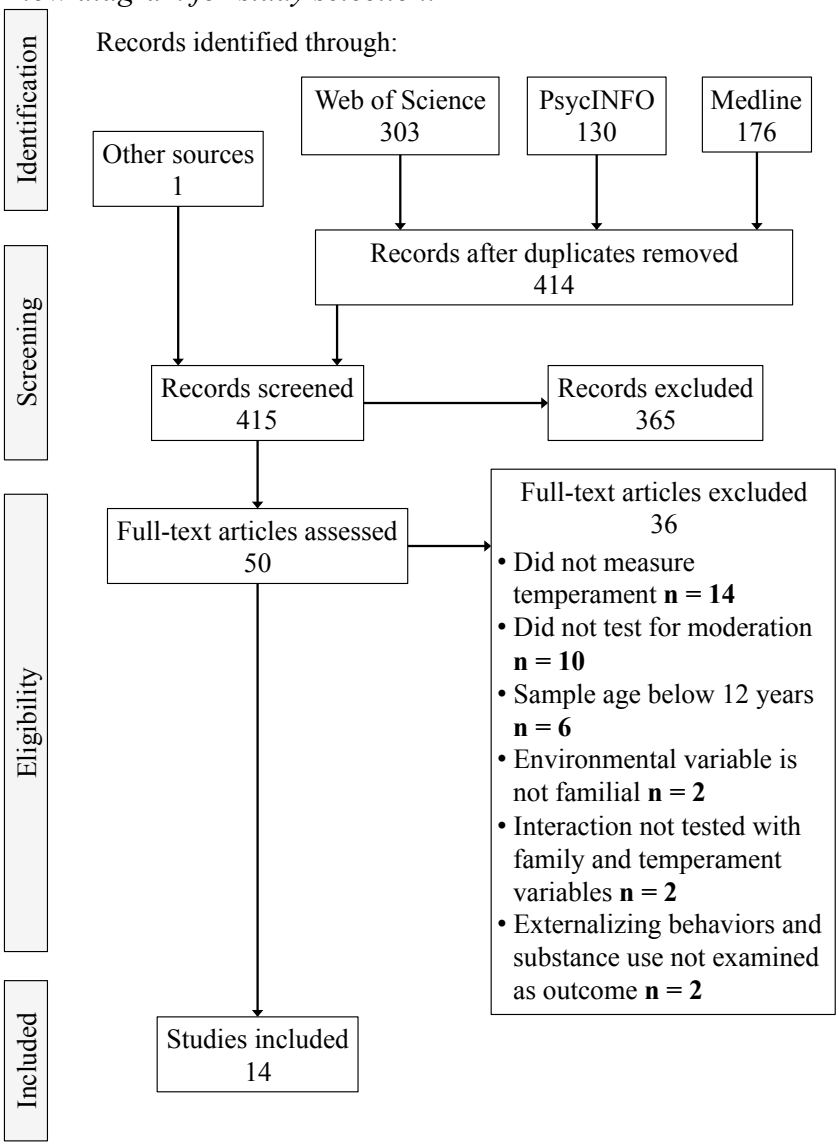
model by using residual scores, a procedure which does not seem to have a significant impact on results (Ramchandani et al., 2010; Rioux et al., 2016). Importantly, since the criteria applied are more liberal when re-examining previously published studies, results should be seen as indicative of support for one or the other model rather than as providing clear support. Plotted results of significant interactions from included studies that were not plotted in the original studies are provided in supplementary material.

## Results

Figure 2 summarizes the results of the different steps of the literature search. The Boolean search (N=414) and a search through other sources (N=1) resulted in identifying 415 articles. Screening of the titles and abstracts resulted in the exclusion of 365 articles that did not meet inclusion criteria. This left 50 full-text articles out of which 36 were further excluded because they did not meet eligibility criteria. The review will therefore include 14 studies. Among these 14 studies, we retained the study that had been identified in the first step through other sources than search engines, which was from our laboratory (Rioux et al., 2016). Temperament variables examined in the reviewed studies include overarching temperament profiles, reactivity measures and self-regulation measures. The family environment variables examined in the studies fell within these three broad categories: parent-child relation (e.g., parental support, parent-child conflict), parenting practices (e.g., parental control, coercive parenting) and home environment (e.g., familial stress, parent separation). Details regarding the design, measures and results of all reviewed studies are summarized in Table 3. Results of

Figure 2

*Flow diagram for study selection.*




reviewed studies are presented separately in subsections for a) overarching temperament profiles, b) reactivity dimensions and c) self-regulation dimensions. Within subsections, cross-sectional studies are covered before prospective and longitudinal studies and organized chronologically. Cross-sectional studies had data at only one time point, prospective studies had data at several time points with no repeated measures and longitudinal studies had data at several time points with repeated measures of substance use or externalizing behaviors.

Table 3

*Studies examining the interaction of temperament and family factors in the prediction of substance use and externalizing behaviors*

| | | | Measures | | | |
|---|---|---|---|---|---|---|
| Design | Author, Year | Sample | Temperament | Family | Outcome | Findings (effect sizes) *supported model* |
| Cross-sectional | Windle, 1992 | 975 (53% girls) - mean age 15.5 - from the USA | **Overarching profiles** - Difficult temperament, **Reactivity** - Activity level and **Self-regulation** - Duration of orienting and Attentional focusing with the DOTS-R. *Self-Report*. | **Parent-child relation** - Parental support (from Procidano and Heller, 1983). *Self-report*. | **Externalizing behaviors** - Delinquency with 19 items extracted from previous research. *Self-report*. | **Non-significant interactions**<br>Difficult temperament*Support – Females (β = 0.04)<br>Activity level*Support – Males (β = -0.03)<br>Activity level*Support – Females (β = -0.06)<br>Attentional focus*Support – Males (β = -0.02)<br>Duration of orienting*Support – Females (β = 0.01)<br>**Significant interactions** [a]<br>Difficult temperament*Support – Males (β = -0.13)<br>Parental support negatively associated with delinquency when difficult temperament is high, but not when it is low. *Diathesis-stress*<br>Attentional focus*Support – Females (β = 0.11)<br>Parental support negatively associated with delinquency when attentional focus was low, but not when it was high. *Diathesis-stress*<br>Duration of orienting*Support – Males (β = 0.13)<br>Parental support negatively associated with delinquency when duration of orienting was low, but not when it was high. *Diathesis-stress* |
| | Carlo, Roesch & Maelby, 1998 | 80 (51% girls) - mean age 14 - from the USA | **Reactivity** - Anger and Sociability with the EASI. *Parent report*. | **Parent-child relation** - Parental support with items from the NRI and additional items designed to be consistent with the instrument. *Parent report*. | **Externalizing behaviors** - Antisocial behaviors with the YSR. *Self-report*. | **Non-significant interactions**<br>Anger*Father support (β = -0.04)<br>Anger*Mother support (β = 0.07)<br>Sociability*Father support (β = -0.01)<br>Sociability*Mother support (β = 0.14) |
| | Stice & Gonzales, 1998 | 631 (51% girls) - 16-19 years - from the USA | **Reactivity** - Impulsivity and Negative affectivity with the GTS. *Self-report*. | **Parent-child relation** - Parental support with items from the NRI and **Parenting practices** - Parental control with | **Externalizing behaviors** - Antisocial behavior with items from the National Longitudinal Youth Survey Delinquency | Antisocial behavior<br>**Non-significant interactions**<br>Negative affect*Mother control (β = 0.02)<br>Negative affect*Mother support (β = 0.00)<br>Impulsivity*Father support (β = -0.03)<br>Negative affect*Father control (β = 0.01) |

| Design | Author, Year | Sample | Measures | | | Findings (effect sizes) *supported model* |
|---|---|---|---|---|---|---|
| | | | Temperament | Family | Outcome | |
| | | | | item from the PBI. *Self-Report*. | Scale.<br>**Substance use** - Alcohol use and Illicit Substance use frequency in the last 6 months. *Self-report.* | Negative affect*Father support (β = 0.04)<br>**Significant interactions**<br>Impulsivity*Mother control (β = -0.08)<br>Maternal control negatively associated with antisocial behaviors when impulsivity is high, but not when it is low. *Diathesis-stress*<br>Impulsivity*Mother support (β = -0.08)<br>Maternal support negatively associated with antisocial behaviors when impulsivity is high, but not when it is low. *Diathesis-stress*<br>Impulsivity*Father control (β = -0.08)<br>Paternal control negatively associated with antisocial behaviors when impulsivity is high, but not when it is low. *Diathesis-stress*<br><br><u>Alcohol use</u><br>**Non-significant interactions**<br>Impulsivity*Mother control (β = 0.01)<br>Impulsivity*Mother support (β = 0.01)<br>Negative affect*Mother control (β = 0.05)<br>Negative affect*Mother support (β = 0.03)<br>Impulsivity*Father control (β = -0.02)<br>Impulsivity*Father support (β = 0.02)<br>Negative affect*Father control (β = -0.01)<br>**Significant interaction**<br>Negative affect*Father support (β = 0.10)<br>Paternal support negatively associated with alcohol use when negative affect is low, but not when it is high. *Diathesis-stress*<br><br><u>Illicit substance use</u><br>**Non-significant interactions**<br>Impulsivity*Mother control (β = -0.05)<br>Impulsivity*Mother support (β = 0.00)<br>Impulsivity*Father control (β = -0.04)<br>Negative affect*Father control (β = 0.01) |

| Design | Author, Year | Sample | Measures | | | Findings (effect sizes) *supported model* |
|---|---|---|---|---|---|---|
| | | | Temperament | Family | Outcome | |
| | | | | | | Negative affect*Father support (β = 0.03)<br>**Significant interactions**<br>Negative affect*Mother control (β = 0.09)<br>Maternal control negatively associated with illicit substance use when negative affect is high and when it is low, with a stronger effect when it is low. *Diathesis-stress*<br>Negative affect*Mother support (β = 0.13)<br>Maternal support negatively associated with illicit substance use when negative affect is low, but not when it is high. *Diathesis-stress*<br>Impulsivity*Father support (β = -0.08)<br>Paternal support negatively associated with illicit substance use when impulsivity is high, but not when it is low. |
| | Padilla-Walker & Nelson, 2014 | 134 (54% girls) - mean age 16.2 - from the USA | **Reactivity** - Fearfulness with an adaptation of the CBQ. *Self-report* | **Parent-child relation** - Maternal support with the IPPA and **Parenting practices** - Maternal appropriateness (from Padilla-Walker & Carlo, 2004). *Self-report.* | **Externalizing behaviors** - Antisocial behaviors with the YSR. *Self-report*. | **Non-significant interactions**<br>Fearfulness*Support (β = 0.15)<br>Fearfulness*Support*Gender (β = -0.04)<br>Fearfulness*Appropriateness (β = 0.07)<br>**Significant interaction**<br>Fearfulness*Appropriateness*Gender (β = -0.34)<br>Maternal appropriateness negatively associated with antisocial behaviors for boys low in fearfulness, but not boys high in fearfulness. Not significant for girls. *Diathesis-stress*. |
| Prospective | Olson, Bates, Sandy & Lanthier, 2000 | 116 (43% girls) - followed from 6 months to 17 years - from the USA | **Self-regulation** - Inhibitory control with the IFQ. *Mother report, 6, 13 and 24 months.* | **Parent-child relation** - Mother-infant affectionate contact: *Home observation at 6 months.* | **Externalizing behaviors** - Aggression and Attention problems subscales of the YSR. *Self-report, assessed at 17 years.* | **Non-significant interaction**<br>Inhibitory control*affection ($\Delta R^2 = 0.02$) |

| Design | Author, Year | Sample | Measures: Temperament | Measures: Family | Measures: Outcome | Findings (effect sizes) *supported model* |
|---|---|---|---|---|---|---|
| | Rioux, Castellanos-Ryan, Parent, Vitaro, Tremblay & Séguin. under review | 209 (52% girls) - followed from 6 to 15 years - from Canada | **Reactivity** - Impulsivity and **Self-Regulation** - Inhibitory control with the CBQ. *Mother report, assessed at 6 years*. | **Parenting practices** - Coercive parenting: Items from the PPS and the NLSCY. *Mother report, assessed at 6 years*. Parental monitoring: 2 items used in previous studies. *Adolescent report, assessed at 14 years.* | **Alcohol use** - Alcohol use frequency in the last year. *Self-report, assessed at 15 years.* | **Non-significant interactions**<br>Impulsivity*Monitoring (β = 0.07)<br>Inhibitory control*Coercive parenting (β = 0.15)<br>Inhibitory control*Monitoring (β = 0.44)<br>**Significant interaction**<br>Impulsivity*Coercive parenting (β = 0.16)<br>Coercive parenting positively associated with alcohol use when impulsivity was high, but not when it was low. *Differential susceptibility* |
| Longitudinal | Wills, Sandy, Yaeger & Shinar, 2001 | 1269 (50% girls) - followed 3 years, mean age 11.5 at onset - from the USA | **Overarching profiles** - Protective temperament: task attentional orientation and positive emotionality subscales of the DOTS-R. Difficult temperament: physical activity level subscale of the DOTS-R, and negative emotionality subscale of the EASI. *Teacher and self-report, assessed at 12, 13 an 14 years.* | **Parent-child relation** - Parent-child conflict: 3 item scale derived from research by Barrera, Chassin & Rogosch (1993). *Self-report, assessed at 12, 13 and 14 years.* | **Substance use** - Typical frequency of cigarette, alcohol and marijuana use. *Self-report, assessed at 12, 13 and 14 years.* | Substance use intercept (12 years)<br>**Non-significant interaction**<br>Self-reported difficult temperament*Conflict<br>**Significant interactions**<br>Teacher-reported difficult temperament*Conflict<br>Parent-child conflict more strongly positively associated with substance use for children with high difficult temperament. *Diathesis-stress*<br>Self-reported protective temperament*Conflict<br>Teacher-reported protective temperament*Conflict<br>Parent-child conflict more strongly positively associated with substance use for children with low protective-temperament. *Diathesis-stress*<br><br>Substance use slope<br>**Non-significant interactions**<br>Self-reported difficult temperament*Conflict<br>Teacher-reported difficult temperament*Conflict<br>Self-reported protective temperament*Conflict<br>Teacher-reported protective temperament*Conflict |
| | Leve, Kim & Pears, 2005 | 337 (48% girls) - followed from 5 to 17 | **Reactivity** - Impulsivity and fearfulness/shyness with the CBQ. *Mother* | **Parenting practices** - Coercive parenting: | **Externalizing behaviors** with the CBCL. *Mother and* | Externalizing behaviors intercept (17 years)<br>**Non-significant interactions**<br>Impulsivity*Coercive parenting - Boys (β = 0.05)<br>Fear/shyness*Coercive parenting - Boys (β = 0.07) |

| Design | Author, Year | Sample | Measures: Temperament | Measures: Family | Measures: Outcome | Findings (effect sizes) *supported model* |
|---|---|---|---|---|---|---|
| | | years - from the USA | *and father report, assessed at 5 years.* | Interview regarding discipline practices | *father report at 5, 7, 10, 14 and 17 years.* | **Significant interactions**<br>Impulsivity*Coercive parenting - Girls (β = 0.23)<br>Coercive parenting positively associated with externalizing behaviors when impulsivity was high, but not when it was low. *Differential susceptibility*<br>Fear/shyness* Coercive parenting - Girls (β = -0.21)<br>Coercive parenting positively associated with externalizing behaviors when fear/shyness was low, but not when it was high. *Differential susceptibility*<br><br><u>Externalizing behaviors slope</u><br>**Non-significant interactions**<br>Impulsivity* Coercive parenting - Boys (β = -0.02)<br>Fear/shyness* Coercive parenting - Boys (β = 0.01)<br>**Significant interactions**<br>Impulsivity* Coercive parenting - Girls (β = 0.24)<br>Coercive parenting positively associated with increases in externalizing behaviors when impulsivity was high, but not when it was low. *Differential susceptibility*<br>Fear/shyness* Coercive parenting - Girls (β = -0.28)<br>Coercive parenting positively associated with increases in externalizing behaviors when fear/shyness was low, but not when it was high. *Differential susceptibility* |
| | Loukas & Roalson, 2006 | 459 (53% girls) - followed 1 year, mean age 11.7 at onset - from the USA | **Self-regulation** - <u>Effortful control</u> with the EATQ-R. *Self-report, assessed at 12 years.* | **Parent-child relation** - <u>Parent-child conflict</u> with the CoBQ and **Home environment** - <u>Negative family relations</u> with the FES. *Self-report, assessed at 12 years.* | **Externalizing behaviors** - <u>Conduct problem</u> subscale of the SDQ. *Self-report, assessed at 12 (control) and 13 years (outcome).* | **Non-significant interaction**<br>Effortful control*Parent-child conflict (β = -0.06)<br>**Significant interactions**<br>Effortful control*Negative relations (β = -0.10)<br>Effortful control*Negative relations* Ethnicity (β = -0.11)<br>Negative family relations positively associated with conduct problems when effortful control was low, but not when it was high. Significant for Caucasian adolescents, but not for Latino adolescents. *Diathesis-stress* |

| Design | Author, Year | Sample | Measures: Temperament | Measures: Family | Measures: Outcome | Findings (effect sizes) *supported model* |
|---|---|---|---|---|---|---|
| | Measelle, Stice & Springer, 2006 | 493 girls - followed 4 years, mean age 13 at onset - from the USA | **Reactivity** - Negative affectivity with the EASI. *Self-report, assessed at 13 years.* | **Parent-child relation** - Parental support with the NRI. *Self-report, assessed at 13 years.* | **Substance use** - Scale assessing DSM-IV symptoms of general substance abuse, including both alcohol and illicit substances. *Self-report, assessed at 13, 14, 15, 16 and 17 years.* | **Non-significant interaction**<br>Negative affect*Support |
| | Bakker, Ormel, Verhulst & Oldehinkel, 2011* | 2230 (51% girls) - followed from 11 to 16 years - from Netherlands | **Self-regulation** - Effortful control with the EATQ-R. *Parent report, assessed at 11 years.* | **Home environment** - Family adversity with the EHC. *Adolescent report, assessed at 16 years (asking about events between 11 and 16 years).* | **Externalizing behaviors** with the CBCL (*parent report*), the YSR (*adolescent report*) and the TCP (*teacher report*), *assessed at 11 (control) and 16 years (outcome), mean from three respondents.* | **Significant interaction**<br>Effortful control*Adversity (β = -0.05)<br>Family adversity positively associated with externalizing behaviors when effortful control was low, but not when it was high. *Diathesis-stress* |
| | Sentse, Ormel, Verhulst, Veestra & Oldehinkel, 2011* | 1274 (51% girls) - followed from 11 to 16 years - from Netherlands | **Reactivity** - Fearfulness and **Self-regulation** - Effortful control with the EATQ-R. *Parent report, assessed at 11 years.* | **Home environment** - Parent separation: EHC adapted into an interview. *Self-report, assessed at 16 years (asking about events between 11 and 16 years).* | **Externalizing behaviors** with the CBCL (*parent report*), the YSR (*self-report*) and the TCP (*teacher report*). *Assessed at 11 (control) and 16 years (outcome), mean from three respondents.* | **Non-significant interaction**<br>Fearfulness*Separation (β = -0.05)<br>**Significant interaction**<br>Effortful control*Separation (β = -0.16)<br>Parent separation positively associated with externalizing behaviors when effortful control was low, but not when it was high. *Diathesis-stress* |
| | Burk, Armstrong, Goldsmith, Klein, Strauman, | 362 (53% girls) - followed from birth to age 16 - | **Reactivity** - Disinhibition: Activity Level and Approach scales from the CBQ. Negative affectivity: Anger, Fear and Sadness | **Parenting practices** - Authoritative parenting with the CRPR and **Home environment** - Familial stress: composite of depression, | **Alcohol use** - Typical Number of Alcoholic Drinks consumed per drinking occasion in the last 30 days and asking about lifetime | **Non-significant interactions**<br>Negative affect*Authoritative parenting<br>Disinhibition*Authoritative parenting<br>Negative affect*Familial stress<br>Disinhibition*Familial stress |

| Design | Author, Year | Sample | Measures: Temperament | Measures: Family | Measures: Outcome | Findings (effect sizes) *supported model* |
|---|---|---|---|---|---|---|
| | Costanzo & Essex, 2011° | from the USA | scales of the CBQ. *Mother report, assessed at 3 1/2 and 4 1/2 years.* | expressed anger (e.g., marital conflict), parenting stress, role overload and financial stress. *Mother and father report, assessed at 1, 4 and 12 months, 3 1/2 and 4 1/2 years and in grade 3.* | abstinence. *Self-report, assessed at 15 (control) and 16 years (outcome).* | **Significant interaction**<br>Disinhibition*Familial stress*Gender<br>Familial stress positively associated with girls' alcohol use when disinhibition was high, but not when it was low. Non-significant for boys. *Differential susceptibility* |
| | Armstrong, Ruttle, Burk, Costanzo, Strauman & Essex, 2013° | 374 boys and girls (followed from 3.5 years to Grade 12) from the USA | **Reactivity** - Disinhibition: Activity Level and Approach scales from the CBQ. *Mother report, assessed at 3.5 and 4.5 years.* | **Parenting practices** - Authoritative and authoritarian parenting with the CRPR. *Mother and father report, assessed at 4.5 years and in Grade 3.* | **Alcohol use** - Typical Number of Alcoholic Drinks consumed per drinking occasion in the last 30 days and asking about lifetime abstinence. *Self-report, assessed in Grades 9, 10, 11 and 12.* | Alcohol use intercept<br>**Non-significant interaction**<br>Disinhibition*Authoritatian<br>**Significant interaction**<br>Disinhibition*Authoritative<br>Authoritative parenting negatively associated with alcohol use when disinhibition was high, but not when it was low. *Differential susceptibility*<br><br>Alcohol use slope and quadratic<br>**Non-significant interaction**<br>Disinhibition*Authoritative<br>**Significant interaction**<br>Disinhibition*Authoritarian<br>For children low in disinhibition, low authoritarian parenting is associated with a steeper slope that levels off by the end of high school and high authoritarian parenting is associated with a steeper increase at the end of high school. Parenting not significant for high disinhibition. *Neither model*<br>Disinhibition*Authoritarian*Gender<br>For girls low in disinhibition, pattern was as described above. For girls high in disinhibition, low authoritarian parenting is associated with a linear increase and high authoritarian parenting is associated with a steeper slope that levels off by the end of high school. *Neither model* |

*Note*. Sample sizes are analyzed (final) samples.
° * Indicates same sample in multiple studies.
[a] Interpretation of significant interactions were not provided and is based on visual interpretation of plotted results.
CBCL = Child Behavior Checklist (Achenbach & Edelbrock, 1983); CBQ = Children's Behavior Questionnaire (Rothbart, Ahadi, Hershey, & Fisher, 2001); CoBQ = Conflict Behavior Questionnaire (Prinz, Foster, Kent & O'Leary, 1979); CRPR = Child-Rearing Practices Report (Block, 1965); DAS = Dyadic Adjustment Scale (Spanier, 1976); DOTS-R = Dimensions of Temperament Survey-Revised (Windle & Lerner, 1986); EASI = Emotionality Activity and Sociability Inventory (Buss & Plomin, 1984); EATQ-R = Early Adolescent Temperament Questionnaire-Revised (Ellis, 2002; Ellis & Rothbart, 2001); EHC = Event History Calendar (Caspi et al., 1996); FES = Family Environment Scale (Moos & Moos, 1986); GTS = General Temperament Survey (Watson & Clark, 1993); IFQ = Infant Characteristics Questionnaire (Bates, Freeland, & Lounsbury, 1979); IPPA = Inventory for parent and peer attachment (Armsden & Greenberg, 1987); NLSCY = National Longitudinal Survey of Children and Youth (Statistics Canada, 1995); NRI = Network Relationships Inventory (Furman & Buhrmester, 1985); PBI = Parental Behavior Inventory (Schaefer, 1965); PPS = Parent Practices Scale (Strayhorn & Weidman, 1988); SDQ = Strengths and Difficulties Questionnaire (Goodman, 1997); TCP = Teacher Checklist of Psychopathology (Huisman et al., 2008); YSR = Youth Self-Report of the CBCL (Achenbach, 1991).

**Overarching temperament profiles**

In a first early study, Windle (1992) conducted a cross-sectional study with 975 participants averaging 15.5 years (range not provided). In that study, the interaction between parental support and difficult temperament was not significant for girls, with an effect size close to zero ($\beta = 0.04$), but it was significant for boys, with a small effect size ($\beta = -0.13$). Low parental support was associated with higher delinquency levels for boys with a higher score of difficult temperament, but not for boys with a lower score. Plotting the coefficients provided revealed a fan-shaped interaction, supporting the diathesis-stress model (see supplementary materials figure 1a).

In a second study, Wills, Sandy, Yaeger, and Shinar (2001) followed 1269 adolescents assessed three times, at 12, 13 and 14 years of age. They assessed protective temperament, defined as high levels of task attentional orientation and positive emotionality, and difficult temperament, defined as high levels of physical activity and negative emotionality. Results showed that the association between parent-child conflict and substance use at 12 years was low among participants with higher levels of self-reported and teacher-reported protective temperament between 12 and 14 years. The association between parent-child conflict and substance use at 12 years was also high among participants with a higher level of teacher-reported difficult temperament, but the interaction with self-reported difficult temperament was not significant. Effect sizes could not be obtained for this study. Plotting the coefficients provided revealed fan-shaped interactions, supporting the diathesis-stress model (see supplementary materials figures 7a-c). The interaction between parent-child conflict and temperament (self-reported and teacher-reported protective and difficult temperament) did not predict change in substance use from 12 to 14 years.

In summary, only two studies examined interactions between the family environment and overarching temperament profiles, with one predicting delinquency (Windle, 1992) and one predicting substance use (Wills et al., 2001). Both studies collected data exclusively during adolescence and the significant interactions in both studies supported the diathesis-stress model.

**Reactivity**

In addition to using a difficult temperament score (see overarching temperament profiles section), the cross-sectional study of 15.5 year-old adolescents by Windle (1992) also examined interactions with activity level. No significant interactions were found between activity level and parental support in the prediction of boys' and girls' delinquency and effect sizes were close to zero ($\beta = -0.03$ for boys; $\beta = -0.06$ for girls).

A second cross-sectional study conducted by Carlo, Roesch, and Melby (1998) with 80 participants averaging 14 years found no significant interactions between anger, sociability and maternal and paternal support in the prediction of antisocial behaviors, most likely due to the very small sample size; whereas some effect sizes were close to zero ($\beta = -0.01$ to 0.07), there was a small effect size ($\beta = 0.14$) for the interaction between sociability and maternal support.

A third cross-sectional study conducted by Stice and Gonzales (1998) with 631 participants aged 16-19 years examined interactions of impulsivity and negative affectivity with maternal and paternal control and support in the prediction of antisocial behaviors, alcohol use and illicit substance use. They found three significant interactions in the prediction of antisocial behaviors. These results showed that low levels of maternal control, maternal support and paternal control were associated with higher levels of antisocial behaviors when

impulsivity was higher, but not when it was lower. One significant interaction was found in the prediction of alcohol use, showing that low levels of paternal control were associated with higher levels of alcohol use when negative affect was low, but not when it was high. Finally, three interactions were found in the prediction of illicit substance use. Low levels of maternal control and support were associated with higher levels of illicit substance use when negative affect was lower and low levels of paternal support were associated with higher levels of illicit substance use when impulsivity was higher, but not when it was lower. Plotting the coefficients provided revealed fan-shaped interactions, supporting the diathesis-stress model (see supplementary materials figures 3a-g). Non-significant interactions had effect sizes close to zero ($\beta = 0.00$ to $0.05$) whereas significant interactions had small effect sizes ($\beta = 0.08$ to $0.13$).

A fourth cross-sectional study conducted by Padilla-Walker and Nelson (2010) with 134 participants averaging 16 years found no significant interaction with fearfulness and maternal support, for which the effect size was small ($\beta = 0.15$). However, a significant three-way interaction was found between sex, fearfulness and maternal appropriateness, with a moderate effect size ($\beta = -0.34$). Although the two-way interaction was not significant for girls, it was significant for boys: low levels of maternal appropriateness were associated with higher levels of antisocial behaviors for boys who reported lower levels of fearfulness, but not boys reporting higher levels of fearfulness. Plotting the coefficients provided revealed a fan-shaped interaction, supporting the diathesis-stress model (see supplementary materials figure 4).

One prospective study conducted by Rioux et al. (2016) followed 209 participants from 6 to 15 years, and assessed the interactions of impulsivity at 6 years with coercive

parenting at 6 years and parental monitoring at 14 years in the prediction of alcohol use frequency at 15 years. The interaction between impulsivity and parental monitoring was not significant and had an effect size close to zero ($\beta = 0.07$). A significant interaction with a small effect size ($\beta = 0.16$) was found between impulsivity and coercive parenting, showing that higher levels of coercive parenting at 6 years were associated with more frequent alcohol use at 15 years for children higher on impulsivity at 6 years, but not children lower in impulsivity. Furthermore, children higher in impulsivity also showed lower alcohol use frequency compared to children lower in impulsivity when coercive parenting was low. This study further examined the interaction using the crossover point estimation method (Widaman et al., 2012, see introduction - statistical testing of the diathesis-stress and differential susceptibility models) and found that it supported the differential susceptibility model.

A first longitudinal study conducted by Leve, Kim, and Pears (2005) followed 337 participants from 5 to 17 years and modeled externalizing behaviors across these years with linear growth curves with the intercept centered at 17 years. Models were tested separately for boys and girls and they examined the interactions of impulsivity and fearfulness/shyness with coercive parenting and marital adjustment. No significant interactions were found for boys and effect sizes were close to zero ($\beta = 0.01$ to $0.07$), but interactions were found in the prediction of girls' intercept and slope, with small to moderate effect sizes ($\beta = 0.21$ to $0.28$). Higher levels of coercive parenting at 5 years were associated with higher levels of externalizing behaviors at 17 years for girls with higher levels of impulsivity and lower levels of fear/shyness at 5 years, but not for girls with lower levels of impulsivity and higher levels of fear/shyness. Higher levels of coercive parenting at 5 years were also associated with higher increases in externalizing behaviors from 5 to 17 years for girls with higher levels of

impulsivity and lower levels of fear/shyness at 5 years. Plotted results provided in the article showed a crossover interaction where girls with higher levels of impulsivity and lower levels of fear/shyness also decreased more in externalizing behaviors from 5 to 17 years when exposed to lower levels of coercive parenting, supporting the differential susceptibility model. Coefficients for the effects on the intercept at 17 years were in the same direction and magnitude, suggesting the same pattern of interaction.

A second longitudinal study conducted by Measelle, Stice, and Springer (2006) followed 493 girls from 13 to 17 years and found no significant interaction between negative affect and parental support in the prediction of substance abuse initiation. Effect sizes could not be obtained for this study. Similarly, a third longitudinal study conducted by Sentse, Ormel, Veenstra, Verhulst, and Oldehinkel (2011) followed 1274 participants from 11 to 16 years and found no significant interaction between fearfulness at 11 years and parental separation between 11 and 16 years in the prediction of externalizing behaviors at 16 years, with an effect size close to zero ($\beta = -0.05$).

A fourth longitudinal study conducted by Burk et al. (2011) followed 362 participants from birth until the age of 16. They assessed disinhibition, an average of activity level and approach, familial stress and authoritative parenting. No significant interactions were found between negative affect and authoritative parenting or familial stress in childhood in the prediction of alcohol use at 16 years or between disinhibition and authoritative parenting. However, a three-way interaction between sex, disinhibition and familial stress was found. The two-way interaction was significant for girls, but not for boys. High levels of familial stress in childhood were associated with higher levels of alcohol use at 16 years for girls with higher levels of disinhibition in childhood, but not for girls with lower levels of disinhibition.

Effect sizes could not be obtained for this study. Plotting the coefficients provided revealed a crossover interaction, where girls with higher levels of disinhibition also showed lower levels of alcohol use when familial stress was low, supporting the differential susceptibility model (see supplementary materials figure 13).

A fifth longitudinal study conducted by Armstrong et al. (2013) and using the same sample as Burk et al. (2011) followed 374 participants from 3.5 years until Grade 12 and modeled alcohol use quantity from grades 9 to 12 with a quadratic growth curve and the intercept centered at Grade 9. They assessed disinhibition, authoritative parenting and authoritarian parenting in childhood. Although the interaction between authoritative parenting and disinhibition in childhood was not significant in the prediction of growth in alcohol use quantity between Grades 9 and 12 (neither linear or quadratic slopes), it was significant in the prediction of alcohol use quantity at Grade 9 (intercept). Lower levels of authoritative parenting were associated with higher levels of alcohol use in Grade 9 when disinhibition was higher in childhood, but not when it was lower. Effect sizes could not be obtained for this study. Plotting the coefficients provided revealed a crossover interaction where children higher in disinhibition also had lower levels of alcohol use when authoritative parenting was higher, supporting the differential susceptibility model (see supplementary materials figure 14a). Regarding authoritarian parenting, the interaction between disinhibition and authoritarian parenting in childhood was not significant in the prediction of the alcohol use quantity in grade 9 (intercept), but was significant in the prediction of growth in alcohol use quantity across time (both linear and quadratic slope factors). For children lower in disinhibition, low authoritarian parenting was associated with a steeper slope that leveled off by the end of high school and high authoritarian parenting was associated with a steeper increase at the end of

high school. A three-way interaction with sex showed that the effect of authoritarian parenting was not significant for boys with high levels of disinhibition, but was significant for girls high on disinhibition. For these girls, low authoritarian parenting was associated with a linear increase in alcohol use and high authoritarian parenting was associated with a steeper slope that leveled off by the end of high school. The interactions predicting the alcohol use slope did not support the diathesis-stress or differential susceptibility models and the pattern for girls was more consistent with contrastive effects (see supplementary materials figure 14b).

In summary, negative affect was examined in three studies (Burk et al., 2011; Measelle et al., 2006; Stice & Gonzales, 1998), with small significant interactions in the prediction of alcohol and illicit substance use found in one study only (Stice & Gonzales, 1998), which was the better powered study of the three (N=631 vs N=493 and N=280), raising the possibility that non-significant moderation effects in the Burk et al. (2011) and Measelle et al. (2006) studies may be due to lack of power. Furthermore, the participants in the study by Stice and Gonzales (1998) were assessed in late adolescence while the other samples were assessed in early to middle adolescence. Fearfulness assessed in adolescence was examined in two studies (Padilla-Walker & Nelson, 2010; Sentse et al., 2011), with only one study showing a medium sized significant interaction with maternal appropriateness in the prediction of externalizing behaviors, supporting the diathesis-stress model (Padilla-Walker & Nelson, 2010). A study assessing a combination of fearfulness and shyness in childhood (Leve et al., 2005) found small interactions with coercive parenting supporting the differential susceptibility model in the prediction of externalizing behaviors. Impulsivity was examined in three studies. The first of these three studies found small interactions supporting the diathesis-stress model with parental control and support assessed in adolescence in the prediction of antisocial behaviors,

alcohol use and illicit substance use (Stice & Gonzales, 1998). The two other studies found interactions between impulsivity and coercive parenting assessed in childhood predicting adolescent externalizing behaviors (Leve et al., 2005) and alcohol use frequency (Rioux et al., 2016), reporting small effect sizes and supporting the differential susceptibility model. Finally, two studies using the same sample examined disinhibition with family stress, authoritative and authoritarian parenting assessed in childhood in the prediction of alcohol use, with two significant interactions supporting the differential susceptibility model and one interaction that did not support either model (Armstrong et al., 2013; Burk et al., 2011).

**Self-regulation**

In addition to examining overarching temperament profiles and reactivity measures, the cross-sectional study of 15.5 year-old adolescents by Windle (1992) reviewed earlier also examined interactions between parental support and duration of orienting, as well as attentional focusing. The interaction between duration of orienting and parental support was not significant for girls, with an effect size close to zero ($\beta = 0.01$), but it was significant for boys, with a small effect size ($\beta = 0.13$): lower levels of parental support were associated with higher levels of delinquency when boys had lower duration of orienting. Conversely, the interaction between attentional focusing and parental support was not significant for boys, with an effect size close to zero ($\beta = -0.02$), but it was significant for girls, with a small effect size ($\beta = 0.11$): lower levels of parental support were associated with higher levels of delinquency when girls had lower attentional focusing. Plotting the coefficients provided revealed fan-shaped interactions, supporting the diathesis-stress model (see supplementary material figures 1b-c).

A prospective study of self-regulation conducted by Olson, Bates, Sandy, and Lanthier (2000) followed 116 participants from 6 months until 17 years and found no significant interaction between inhibitory control and mother-infant affectionate contact in infancy in the prediction of externalizing behaviors at 17 years. Standardized coefficients could not be obtained for this study. However, the interaction had a $R^2$ change statistic of 0.02, which represents a small portion of variance explained (J. Cohen, 1992).

In addition to examining reactivity measures, the prospective study by Rioux et al. (2016) reviewed in the previous section also examined a measure of inhibitory control in the prediction of alcohol use frequency at 15 years. In that study, no significant interaction was found between inhibitory control at 6 years and coercive parenting at 6 years and the effect size was small ($\beta = 0.15$). The interaction between inhibitory control at 6 years and parental monitoring at 14 years was also not significant, but the effect size was moderate in magnitude ($\beta = 0.44$).

A longitudinal study conducted by Loukas and Roalson (2006) followed 459 participants, averaging 12 years of age at baseline (ranging from 10 to 14 years), for one year. There was no significant interaction between effortful control and parent-child conflict assessed at 12 years in the prediction of conduct problems one year later and the effect size was close to zero ($\beta = -0.06$). A small interaction between effortful control and negative family relations was significant ($\beta = -0.10$) and a three-way interaction with ethnicity was found ($\beta = -0.11$): the interaction was not significant for Latino adolescents, but was significant for Caucasian adolescents. Higher levels of negative family relations at 12 years were associated with higher levels of conduct problems at 13 years for Caucasian adolescents with lower levels of effortful control at 12 years, but not for those with higher levels of

effortful control. Plotted results provided in the article showed a fan-shaped interaction, supporting the diathesis-stress model.

In addition to examining reactivity measures, the longitudinal study by Sentse et al. (2011) reviewed in the previous section also examined a measure of effortful control and found a small significant interaction ($\beta = -0.16$). Parental separation between 11 and 16 years was associated with higher levels of externalizing behaviors at 16 years when effortful control at 11 years was low, but not when it was high. Plotted results provided in the article showed a fan-shaped interaction, supporting the diathesis-stress model.

Finally, a last longitudinal study conducted by Bakker, Ormel, Verhulst, and Oldehinkel (2011) used the same sample as Sentse et al. (2011), following 2230 participants from 11 to 16 years. In that study, higher levels of family adversity between 11 and 16 years were associated with higher levels of externalizing behaviors at 16 years when effortful control at 11 years was low, but not when it was high. The effect size was very small ($\beta = -0.05$). Plotted results provided in the article showed a fan-shaped interaction, supporting the diathesis-stress model.

In summary, six studies examined self-regulatory measures of temperament. Two studies used a measure of inhibitory control and did not find significant interactions (Olson et al., 2000; Rioux et al., 2016). Effect sizes were small when the interaction involved coercive parenting and mother-infant affectionate contact, but it was of medium magnitude when the interaction involved parental monitoring. Conversely, three studies examined effortful control and found significant interactions that supported the diathesis-stress model (Bakker et al., 2011; Loukas & Roalson, 2006; Sentse et al., 2011), all with small effect sizes and large sample sizes. These three studies used data exclusively in adolescence and two of them used

data from the same sample (Bakker et al., 2011; Sentse et al., 2011). The last study examined duration of orienting and attentional focus, and also found interactions with small effect sizes that supported the diathesis-stress model using a cross-sectional design (Windle, 1992).

## Discussion

The aim of this review was first to examine how temperament and the family environment interact in the prediction of adolescent substance use and externalizing behaviors and second to determine if studies supported the diathesis-stress or differential susceptibility models as this may be helpful for research into prevention and early intervention. Evidence for the interactions between temperament and various family factors was found in the studies reviewed. Support for the differential susceptibility model was found in studies examining temperament and the family environment in childhood, which mostly examined reactivity dimensions of temperament. Support for the diathesis-stress model was found in studies examining temperament and the family environment in adolescence, which examined both reactivity and self-regulatory dimensions of temperament.

### Interactions between temperament and the family environment

The studies reviewed examined overarching temperament profiles, reactivity measures and self-regulation measures. Two studies assessed overarching temperament profiles and found significant interaction effects (Wills et al., 2001; Windle, 1992). Six of the ten studies assessing reactivity measures found significant interactions (Armstrong et al., 2013; Burk et al., 2011; Leve et al., 2005; Padilla-Walker & Nelson, 2010; Rioux et al., 2016; Stice & Gonzales, 1998), with four of the six studies showing a further moderating effect of sex (Armstrong et al., 2013; Burk et al., 2011; Leve et al., 2005; Padilla-Walker & Nelson, 2010). Results for self-regulatory measures of temperament were consistent, although based on only a

few studies. Two studies examined inhibitory control and did not find significant interactions (Olson et al., 2000; Rioux et al., 2016) and three studies examined effortful control, finding significant interactions (Bakker et al., 2011; Loukas & Roalson, 2006; Sentse et al., 2011). One additional cross-sectional study examined duration of orienting and attentional focus and found significant interactions (Windle, 1992).

The majority of significant interactions had small effect sizes, while the majority of non-significant interactions had effect sizes close to zero. There were some exceptions where non-significant interactions had small to medium effect sizes (Carlo et al., 1998; Padilla-Walker & Nelson, 2010; Rioux et al., 2016), but these effects were found in studies with relatively small samples (n = 80 to 209). Whereas most significant interaction effects were small in size, larger effect sizes were found in studies with relatively homogeneous samples. For example, participants in the Rioux et al. (2016) study came from a mostly Caucasian and French-speaking urban sample and participants in the Padilla-Walker and Nelson (2010) study were sampled from one high school. Small effect sizes found in most studies reviewed, which are usually the norm in moderation studies (Aguinis et al., 2005), along with some findings showing further moderating effects of sex and ethnicity, highlight the need for large sample sizes when testing these effects.

Overall, the significant interactions reported in most studies reviewed showed higher levels of substance use and externalizing behaviors in adolescence when more adverse family environments were combined with high levels of impulsivity and disinhibition, which includes activity level and approach, as well as low levels of effortful control, negative affect, fearfulness and shyness. Certain studies also showed that children with some of these temperament traits had lower levels of substance use and externalizing behaviors in

adolescence compared to children without those temperament traits when exposed to positive family environments. These temperament traits are similar, but sufficiently different from what is usually described as a difficult temperament, for which negative affect and its subcomponents fearfulness and shyness are high. Although high levels of negative affectivity are associated with some developmental problems, including internalizing problems, the guilt and anxiety associated with negative affectivity has been considered to be a protective factor for later externalizing behaviors (Kochanska, 1993). Furthermore, other individual traits associated with externalizing behaviors are associated with lower negative affect. Notably, children and adolescents with callous-unemotional traits, which are strongly associated with antisocial behaviors and conduct problems (Frick, Ray, Thornton, & Kahn, 2014; Frick & White, 2008), tend to have lower levels of fearfulness (Barker, Oliver, Viding, Salekin, & Maughan, 2011; Pardini, Lochman, & Frick, 2003; Roose, Bijttebier, Van der Oord, Claes, & Lilienfeld, 2013). Overall, this indicates that specific temperament traits or dimensions may provide more comprehensive information than prevailing overarching temperament profiles such as difficult temperament regarding susceptibility to specific problematic developmental outcomes.

As a whole, these temperament traits (i.e., high levels of impulsivity, disinhibition, activity level and approach; low levels of effortful control, negative affect, fearfulness and shyness) could be considered more indicative of an "adventurous" tendency or disposition, rather than of a difficult temperament. It should be noted that while these traits show a similar pattern of associations with substance use and externalizing behaviors, they are also different and there may be different unique mechanisms underlying these different associations. Nevertheless, to simplify the discussion, and for the sake of clarity, the term "adventurous"

will be used throughout the discussion. Since "adventurous" temperament characteristics were not examined as a composite score in the studies reviewed, future studies could examine whether some children show an overarching "adventurous temperament profile", and whether this hypothetical profile is associated with specific developmental outcomes such as externalizing behaviors. Indeed, such a temperamental profile may be more strongly associated with an increased risk for externalizing behaviors and substance use compared to difficult temperament traits (when exposed to an adverse family environment) because impulsive traits are here combined with an absence of negative emotional states, which serve to inhibit behaviors when faced with real or imagined punishment (Rothbart, Ahadi, & Hershey, 1994). Because it has been previously found that temperament dimensions interacted with each other (Muris et al., 2007), future studies could also examine three-way interactions between two "adventurous" temperament traits and the family environment.

Similar "adventurous" temperament traits have been identified previously in adults. A study of parents whose daughters had eating disorders identified an "explosive/adventurous temperament" characterizing mothers who were notably high in impulsivity and novelty seeking, but low in shyness, anxiety, depression and sentimentality (Amianto, Daga, Bertorello, & Fassino, 2013). Furthermore, "adventurous" temperament traits could be associated with specific personality profiles later in life. The "adventurous" temperament traits identified in this review have been associated with high extraversion and agreeableness and low neuroticism and conscientiousness using the Big Five personality approach (De Pauw & Mervielde, 2010). Specifically, a) high activity level was associated with high extraversion (Hagekull & Bohlin, 2003), b) low effortful control and high impulsivity were associated with low conscientiousness (Digman & Shmelyov, 1996; Grist & McCord, 2010; Shafer, 2001) and

c) low negative affectivity was associated with low neuroticism (Grist & McCord, 2010; Hagekull & Bohlin, 2003; Shafer, 2001; Watson & Clark, 1992), low conscientiousness (Farrell, Brook, Dane, Marini, & Volk, 2015; Grist & McCord, 2010) and high agreeableness (Farrell et al., 2015; Shafer, 2001). Besides one study which was prospective (Hagekull & Bohlin, 2003), other studies were concurrent. Future studies could examine concurrently or prospectively whether "adventurous" temperament traits are associated with other personality measures in addition to those of the Big Five. For example, the temperamental dimensions of impulsivity and inhibitory control may be associated with the personality dimension of impulsivity, and temperamental disinhibition shares some similarities with the personality dimension of sensation seeking/venturesomeness (Eysenck & Eysenck, 1978). Since personality has been shown to be associated with externalizing behaviors and substance use (Castellanos-Ryan & Conrod, 2012; DeYoung, Peterson, Séguin, & Tremblay, 2008; Mezquita et al., 2015; Zvolensky, Taha, Bono, & Goodwin, 2015), future longitudinal studies could test a mediated moderation model (Muller, Judd, & Yzerbyt, 2005) examining whether the interaction between temperament and the family is mediated by personality in the prediction of externalizing behaviors and substance use. Other variables than personality that could potentially mediate the association include peer affiliation (Dishion & Tipsord, 2011; Leung, Toumbourou, & Hemphill, 2014; Marschall-Lévesque, Castellanos-Ryan, Vitaro, & Séguin, 2014), self-control abilities (Wills & Dishion, 2004) as well as the internalization of social norms and positive morals and the effectiveness of socialization (Kochanska, 1993; Kochanska & Aksan, 2006).

**Support for the differential susceptibility model and implications**

Support for the differential susceptibility model was found in four studies (Armstrong et al., 2013; Burk et al., 2011; Leve et al., 2005; Rioux et al., 2016), all assessing reactivity measures of temperament. In those studies, in addition to higher levels of externalizing behaviors or alcohol use in adverse family environments, more impulsive and disinhibited children as well as those low in fearfulness/shyness had lower levels of externalizing behaviors and alcohol use in positive family environments or in the absence of adversity compared to children lower in impulsivity and disinhibition and higher in fearfulness/shyness. Prospective interactions with reactivity measures other than impulsivity, disinhibition and fearfulness/shyness (e.g., anger, or activity level and approach alone as opposed to combined in a disinhibition score) should be examined to help determine whether the effects are specific to these measures or more generalizable across reactivity measures.

Importantly, all the studies that showed support for the differential susceptibility model were prospective in nature with temperament and the family environment being assessed in childhood, whereas studies supporting the diathesis-stress model assessed all of these variables in adolescence. Thus, although support for the differential susceptibility model was only found with reactivity measures of temperament, the dearth of prospective studies assessing overarching temperament profiles and self-regulation in childhood could explain the lack of support for the differential susceptibility model using these other measures of temperament. More long-term prospective studies are needed to determine whether overarching temperament profiles and self-regulatory measures are also susceptibility factors in childhood.

The fact that the interaction between temperament and family variables in childhood predicted outcomes in adolescence following a differential susceptibility pattern is compatible

with the suggestion that enhanced susceptibility should lead to developmental changes that are sustained in time (B. J. Ellis et al., 2011). Furthermore, our finding that only studies using predictors in childhood support the differential susceptibility model is consistent with Belsky and Pluess' (2009) observation that evidence for temperamental differential susceptibility comes from research showing that it is temperament in childhood, and not later in development, that moderates the effect of environmental factors on behavioral development. Thus, "adventurous" temperament traits could be indicators of susceptibility to both positive and negative environments in childhood but no longer in adolescence. Indeed, the mechanisms underlying adventurous temperament traits may not be the same in childhood and adolescence, with temperament being primarily under genetic influence in infancy and increasingly reflecting an influence of the environment over time. Within a differential susceptibility framework, when temperament traits are measured later in development, the measure of temperament traits themselves could already reflect the interaction between being more susceptible and the environment. Future studies could clarify this developmental process explicitly by assessing whether an interaction between "adventurous" temperament traits and the family environment in childhood predicts "adventurous" temperament traits in adolescence, and examining whether this differs among temperament traits. Furthermore, studies could assess "adventurous" temperament traits and the family environment across development and examine if the pattern of their interaction in the prediction of externalizing behaviors and substance use changes from a differential susceptibility to a diathesis-stress pattern as participants go from childhood into adolescence.

It is generally assumed by developmentalists that plasticity is greatest in infancy and childhood. However, it has been suggested that, although on average plasticity might be

greater earlier in development, some individuals might show greater plasticity later in life. Thus, individuals of all ages might vary in their susceptibility, with individual variations in terms of when children and adults show greater plasticity (Belsky & Pluess, 2013; B. J. Ellis et al., 2011). Furthermore, plasticity has also been observed in adolescence, with important neurobiological changes occurring during this period (Spear, 2000, 2013; Steinberg, 2008). Thus, while temperament assessed early in development may be more strongly associated with plasticity than when assessed later in development, variability in susceptibility at later ages may still be captured using other measures. For example, measures of individual differences in the reactivity of neurobiological stress response systems, highlighted in the biological sensitivity to context literature, may be better indices of susceptibility later in development than more behavioral temperament measures (Blandin, 2013; Boyce & Ellis, 2005). One of these individual characteristics is referred to as sensory-processing sensitivity in the personality literature, or sometimes more generally as high sensitive personality (Aron & Aron, 1997). While related to temperament, this personality trait is broader, encompassing a sensitive nervous system, awareness of subtle stimuli, a tendency to be easily over-stimulated by the environment and a deep processing of novel situations, leading these individuals to reexamine their cognitive maps following some experiences. An important element of sensory-processing sensitivity is the depth of emotional and mental processing. Evidence of differential susceptibility from studies examining this trait (Aron, Aron, & Jagiellowicz, 2012; Belsky & Pluess, 2009) suggests it may be a good index of susceptibility in adolescence and adulthood.

An important limitation of the current literature is that the authors of most studies examined and interpreted their results explicitly or implicitly within a diathesis-stress frame of

reference in mind. Notably, the only study that explicitly compared the models using childhood predictors showed support for the differential susceptibility model (Rioux et al., 2016). Other studies were re-examined using a more "qualitative" appraisal of plotted results. The criteria applied when using the coefficients in published studies to see if they support the differential susceptibility model are liberal compared to the analyses that should be conducted with the full data, making our results only indicative regarding the support of both models. Thus, more long-term prospective studies that specifically compare the two models are needed to help determine which temperamental characteristics are vulnerability or susceptibility factors, under which environmental conditions, and at what age.

Clarifying those issues is important because accrued support for the differential susceptibility model would suggest that the conception of some individual "vulnerability" factors needs revising. Although both models support targeting children with "adventurous" temperament traits early for interventions, adopting the differential susceptibility model could lead to a change in the expectations of parents, teachers and clinicians regarding what could be achieved by these children. Indeed, considering these temperament traits as risk factors and children with these temperament traits as "vulnerable" could misrepresent their malleable nature and deflect from the fact that their temperament could also be an asset in the right environment (Belsky & Pluess, 2009). This would keep the focus on a need for screening children (in order to identify the most vulnerable or susceptible), but clearly shift the intervention content to focus on the environment. Furthermore, the common term "difficult" temperament itself may then no longer be appropriate due to its negative connotation and its implied vulnerability, a point already raised when research on temperament was in its beginning stages (Rothbart, 1982).

Experimental research is also needed for testing these models. Studies evaluating whether the impact of interventions targeting the family environment (e.g., improving parenting practices, parent-child relationship or marital relationship) on substance use and externalizing behaviors is moderated by temperament could be conducted. To test the differential susceptibility model, these studies would have to randomize the familial intervention, whereas temperament would be a fixed factor (Bakermans-Kranenburg & van IJzendoorn, 2015). This review would suggest the hypothesis that interventions in childhood might be more effective because temperament in childhood, but not in adolescence, might be a susceptibility factor. For example, parents exhibiting adverse parenting practices with their children could be randomized to a parenting intervention and control condition to examine whether the intervention effects observed on externalizing behavior outcomes in adolescence differ between the children with "non-adventurous" temperament traits and those with "adventurous" temperament traits. If the children with "adventurous" temperament traits benefit more from interventions than children without those temperament traits and thus have better outcomes, it would demonstrate susceptibility to positive family environments. This, in combination with findings showing that control participants with "adventurous" temperament traits and adverse family environment have worse outcomes than participants with "non-adventurous" temperament traits and adverse family environment, as supported by the literature, would provide support for the differential susceptibility model.

**Integrating findings into prevention programs**

There are already a variety of evidence-based interventions that could be used in experimental studies to test the hypotheses raised above by examining whether their positive impact on substance use and externalizing behaviors is greater for children with "adventurous"

temperament traits compared with those with "non-adventurous" temperament traits. Interventions on parenting practices can be especially useful, particularly since they can be delivered early in child development. Parenting programs can support parents in monitoring their children's behavior and establishing a strong parent-child relationship by teaching them how to model healthy behaviors, communicate effectively with their children, develop problem-solving skills and provide appropriate reinforcement (Essau, 2004). A recent meta-analysis showed that parenting interventions based on social learning and cognitive-behavioral principles are effective in reducing problem behaviors (Dretzke et al., 2009). A low cost group-based parenting intervention developed using cognitive-behavioral theories is the Webster-Stratton parenting program (Webster-Stratton, 1998; Webster-Stratton & Herbert, 1994; see incredibleyears.com), which employs a collaborative approach building on parents' strengths and expertise. Other programs have used the media (e.g., Triple P program; Sanders, 1999) and schools (e.g., Adolescent Transitions Program; Dishion & Kavanagh, 2000, 2003) to decrease the costs of the intervention and reach more parents. In programs such as the Triple P and Adolescent Transitions Program, general interventions are delivered to the majority of the population through the media or through schools, but regular practitioner interventions are also delivered to higher-risk families. Since children with "adventurous" temperament traits exposed to dysfunctional parenting practices have the highest risk for externalizing behaviors and substance use, identifying children with "adventurous" temperament traits could be an important factor when selecting high-risk families in need of the practitioner-delivered interventions.

## Conclusion

This review showed that the recent literature supports an interaction between temperament and the family environment in the prediction of externalizing behaviors and substance use, at least for certain dimensions. Most significant interactions showed that "adventurous" temperament traits combined with adverse family environments predicted higher levels of substance use and externalizing behaviors in adolescence. These temperament traits included high levels of impulsivity and disinhibition, as well as low levels of effortful control, negative affect, fearfulness and shyness, a combination that differs from the most common overarching temperament profile labeled as difficult temperament. Support for the differential susceptibility model was found in studies assessing temperament (specifically those assessing reactivity) and family environments in childhood while studies assessing them in adolescence supported the diathesis-stress model. It is thus possible that "adventurous" temperament traits would be indicators of susceptibility to both enriched and adverse environments in childhood but no longer in adolescence, when it would only be an indicator of vulnerability to adverse environments.

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## Supplementary material

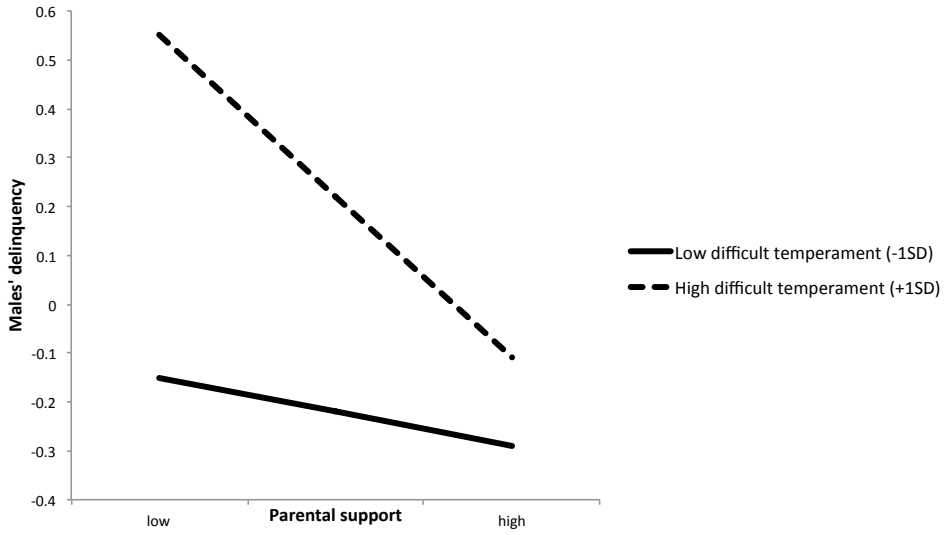
**To accompany:**

**Rioux, C., Castellanos-Ryan, N., Parent, S. & Séguin, J. R. The interaction between temperament and the family environment in adolescent substance use and externalizing behaviors: Support for diathesis-stress or differential susceptibility?**

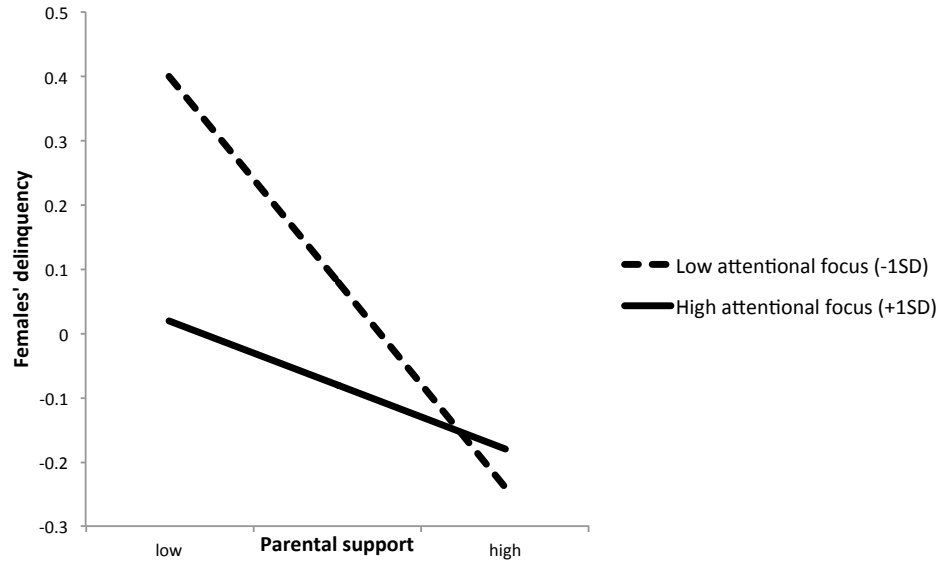
Most interactions were estimated using hierarchical regression. These interactions were plotted following recommendations by Frazier, Tix & Barron (2004) and Cohen, Maiersperger, Gower, and Turner (2003). When enough information was provided, temperament slopes were plotted at +/- 1 standard deviation, which is indicated in parenthesis. When standard deviations are not indicated in parenthesis, only unstandardized coefficients were available and standard deviations were not provided. In those cases, data was still plotted using +/-1, but it is impossible to know what this represents in terms of standard deviations. In all cases, zero was used as a constant. Crossover points in the middle range of the familial variable were considered consistent with a disordinal interaction (differential susceptibility). Crossover points in the lower/higher range of the familial variable or outside of the observable data range were considered consistent with an ordinal interaction (diathesis-stress).

## 1. WINDLE, 1992

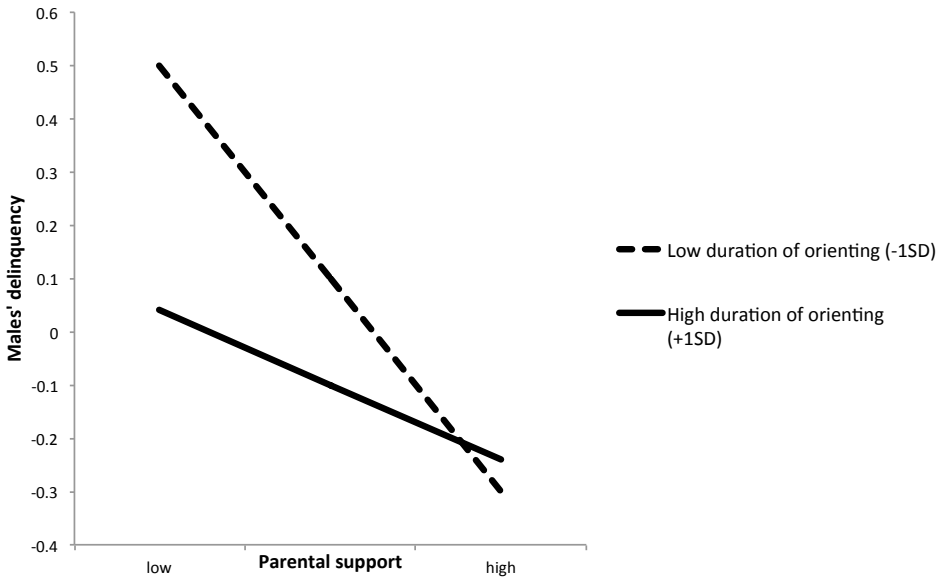
a. Difficult temperament*Parental support → Delinquency (Males)




b. Attentional focus*Parental support → Delinquency (Females)



c. Duration of orienting*Parental support → Delinquency (Males)




## 2. CARLO, ROESCH & MAELBY, 1998

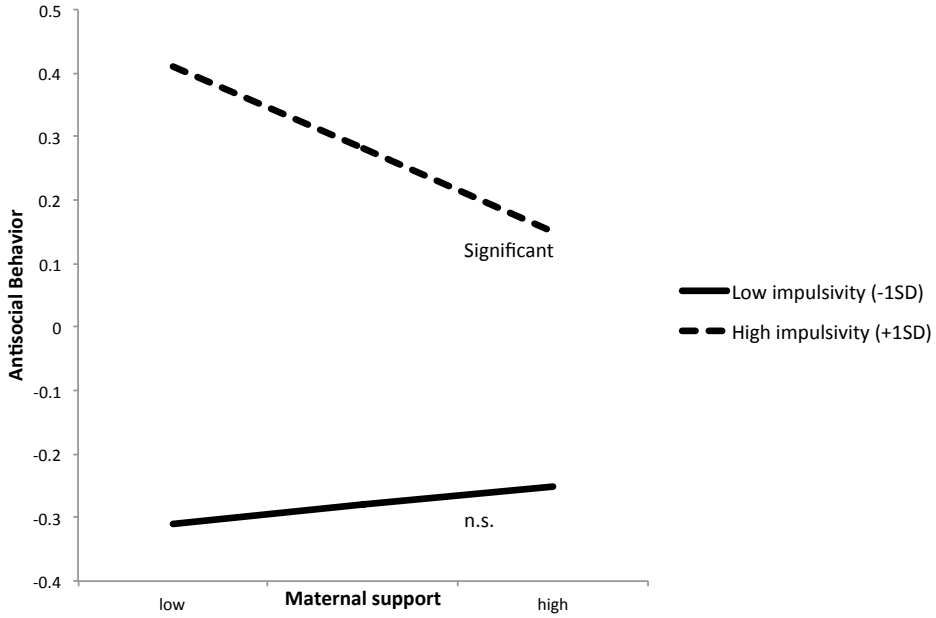
No significant interactions reported.

## 3. STICE & GONZALES, 1998

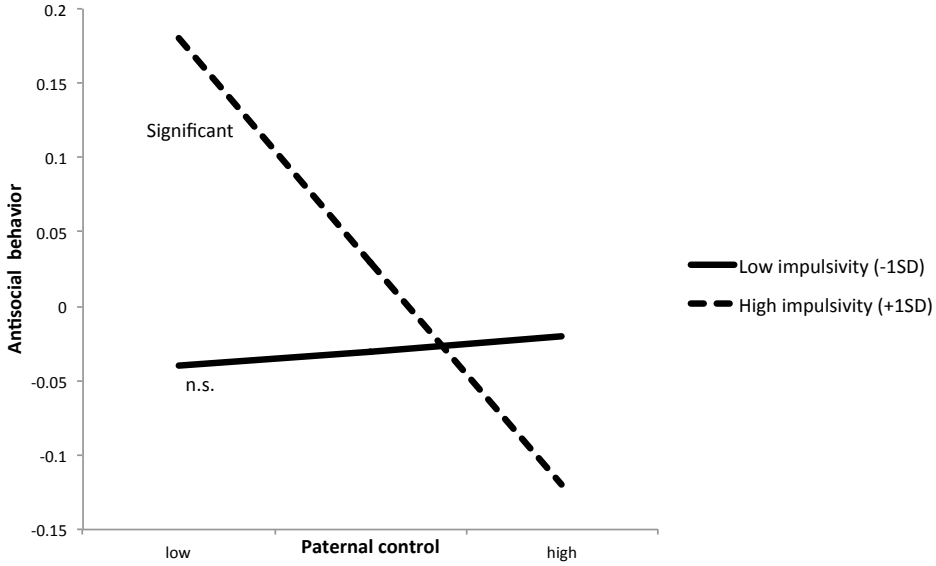
a. Impulsivity*Mother control → Antisocial behavior

Plot provided in article.

b. Impulsivity*Mother support → Antisocial behavior



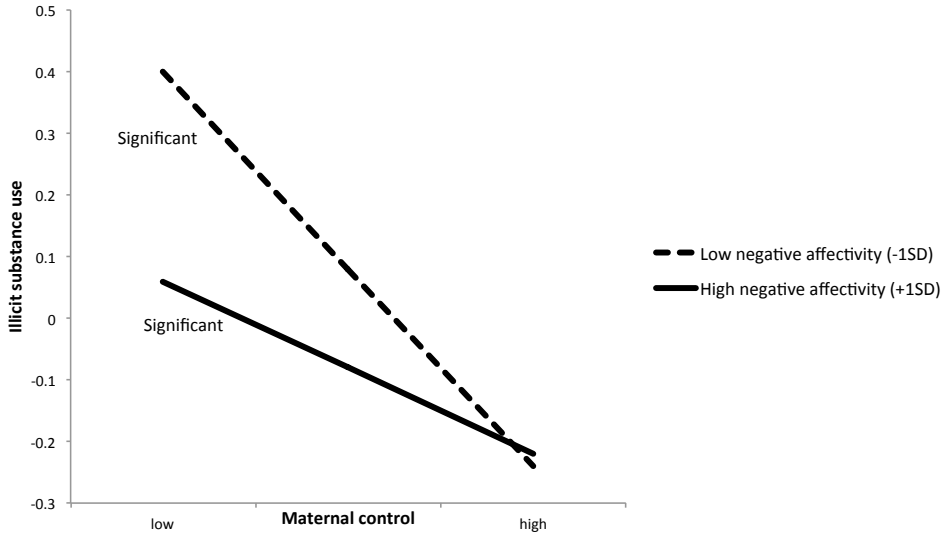

c. Impulsivity*Father control → Antisocial behavior



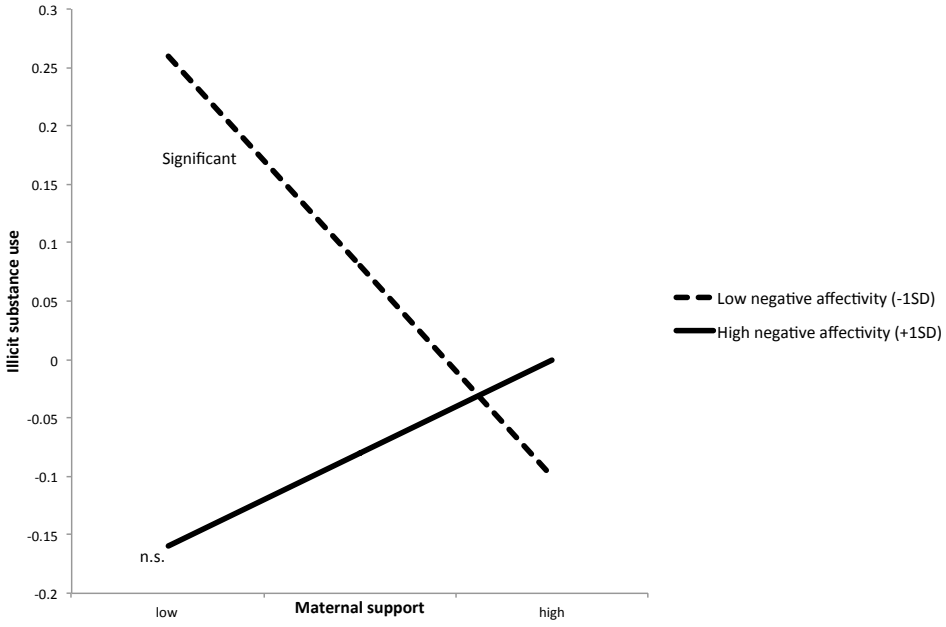

d. Negative affect*Father support → Alcohol use

Plot provided in article.

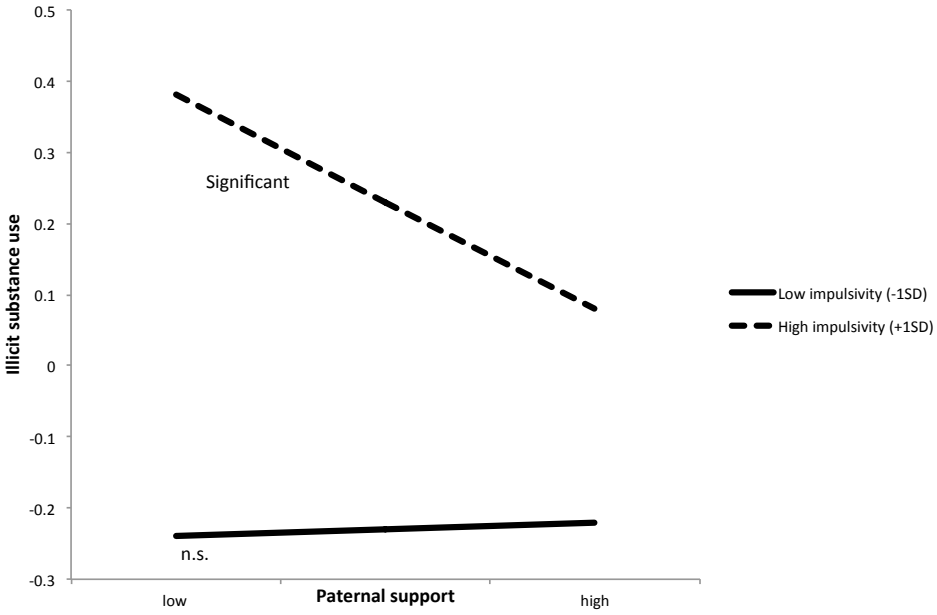
e. Negative affect*Mother control → Illicit substance use




f. Negative affect*Mother support → Illicit substance use



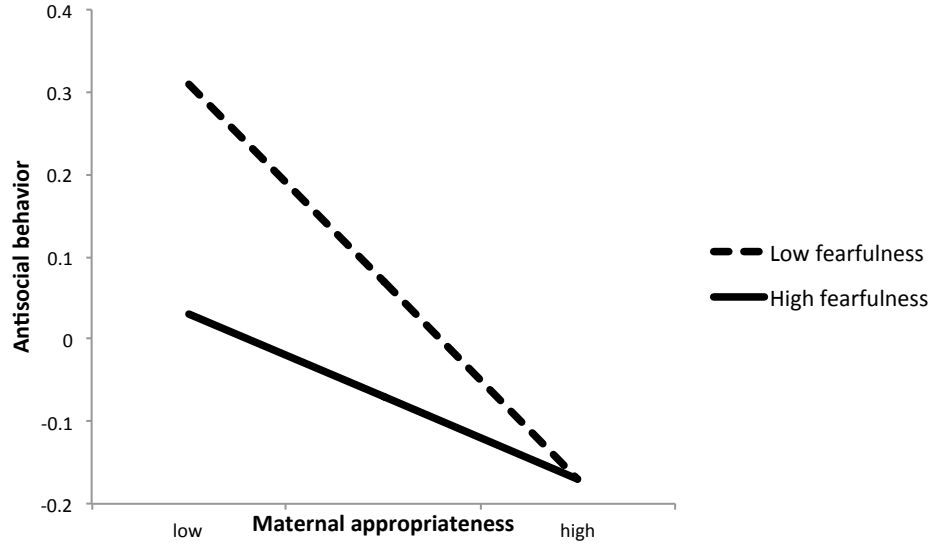
g. Impulsivity*Father support → Illicit substance use




## 4. PADILLA-WALKER & NELSON, 2014

Fearfulness*Maternal appropriateness → Antisocial behaviors

Note: Interaction was only significant for boys, but available information only permitted plotting the interaction for the whole sample.



## 5. OLSON, BATES, SANDY & LANTHIER, 2000

No significant interaction reported.

## 6. RIOUX ET AL., IN PRESS

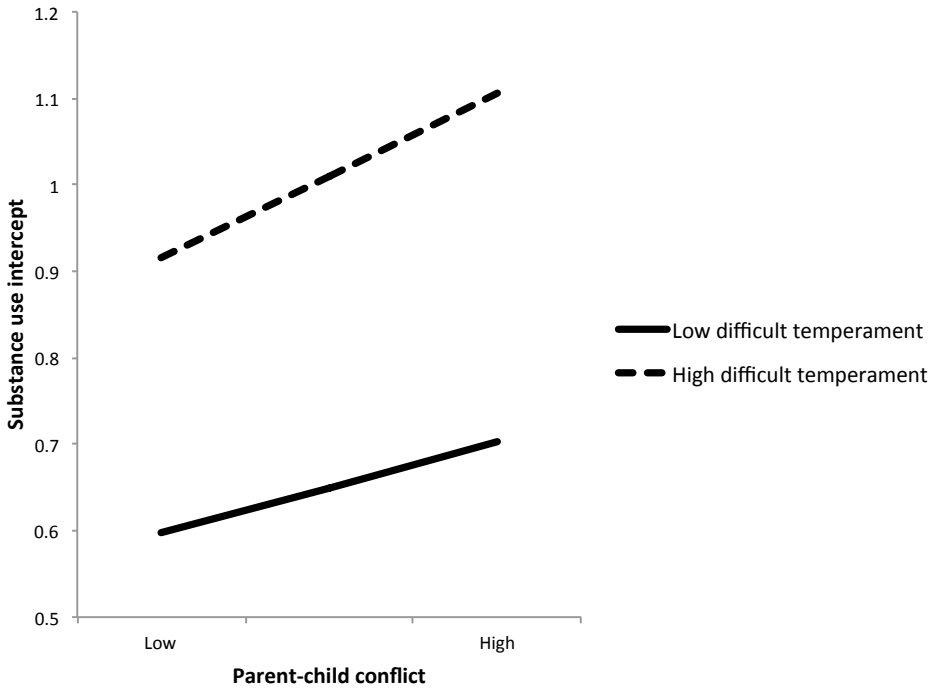
Impulsivity*Coercive parenting → Alcohol use

Plot provided in article.

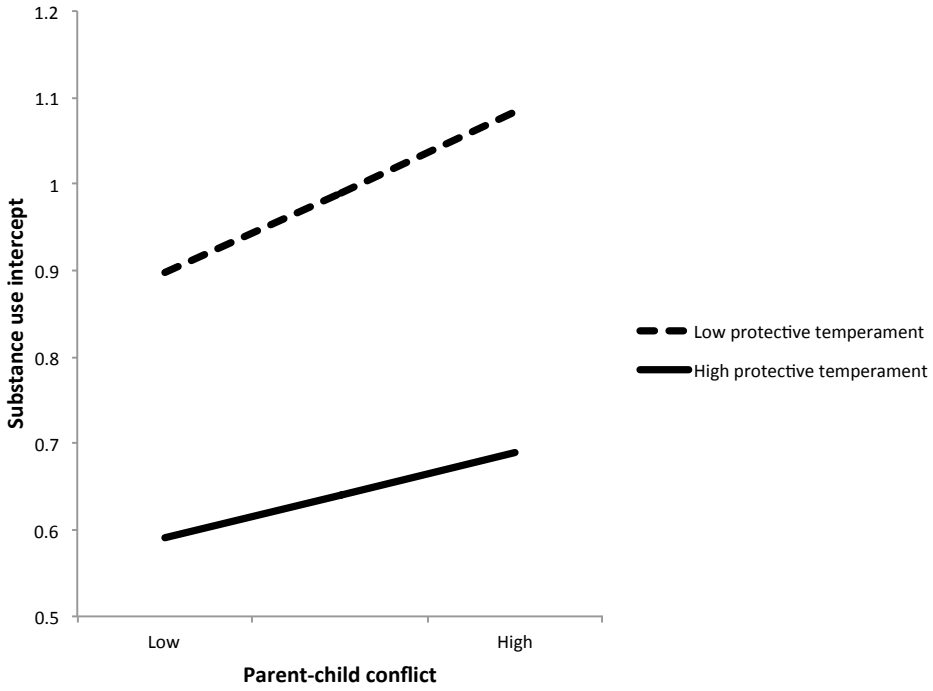
## 7. WILLS, SANDY, YAEGER & SHINAR, 2001

Note: Significance of slopes for the two temperament groups were not provided; significant interactions are based on significant group differences. Results were plotted using unstandardized coefficients for each temperament group provided in Figures 2/3 and main effects of temperament provided in Table 3 (main effects after controlling for the remaining model are not provided, so these figures should be interpreted with caution, and should only be used to give an indication of the direction of effects).

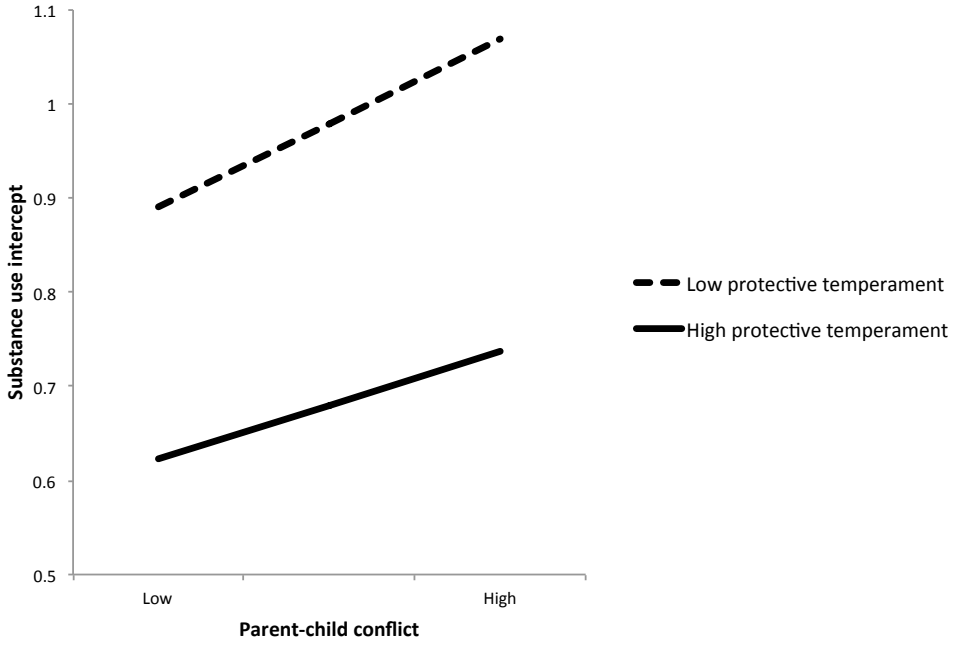
a. Teacher-reported difficult temperament*Parent-child conflict → Substance use intercept




b. Self-reported protective temperament*Parent-child conflict → Substance use intercept



c. Teacher-report protective temperament*Parent-child conflict → Substance use intercept




## 8. LEVE, KIM & PEARS, 2005

Impulsivity*Coercive parenting → Externalizing behavior intercept and slope (girls)

Fear/Shyness*Coercive parenting → Externalizing behavior intercept and slope (girls)

Plots for effects on externalizing behavior slope provided in article. Effects on the intercept are in the same direction and magnitude, suggesting the same pattern of interaction. Full information to plot the data was not available.

## 9. LOUKAS & ROALSON, 2006

Effortful control*Negative family relations → Conduct problems

Plots provided in article.

## 10. MEASELLE, STICE & SPRINGER, 2006

No significant interaction reported.

## 11. BAKKER, ORMEL, VERHULST & OLDEHINKEL, 2011

Effortful control*Family adversity → Externalizing behaviors

Plot provided in article.

## 12. SENTSE, ORMEL, VERHULST & OLDEHINKEL, 2011

Effortful control*Parent separation → Externalizing behaviors

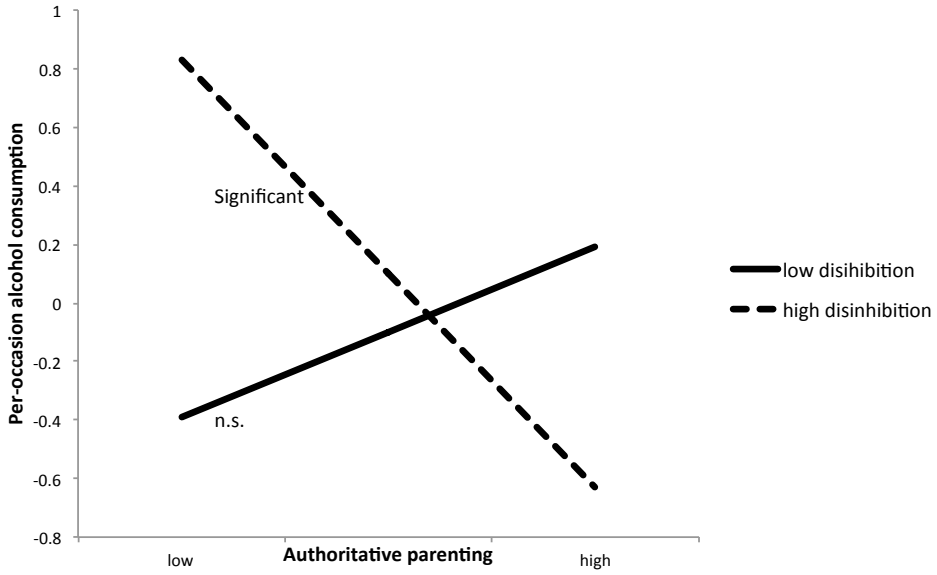
Plot provided in article.

## 13. BURK ET AL., 2011

Disinhibition*Familial stress → Alcohol use (Girls)

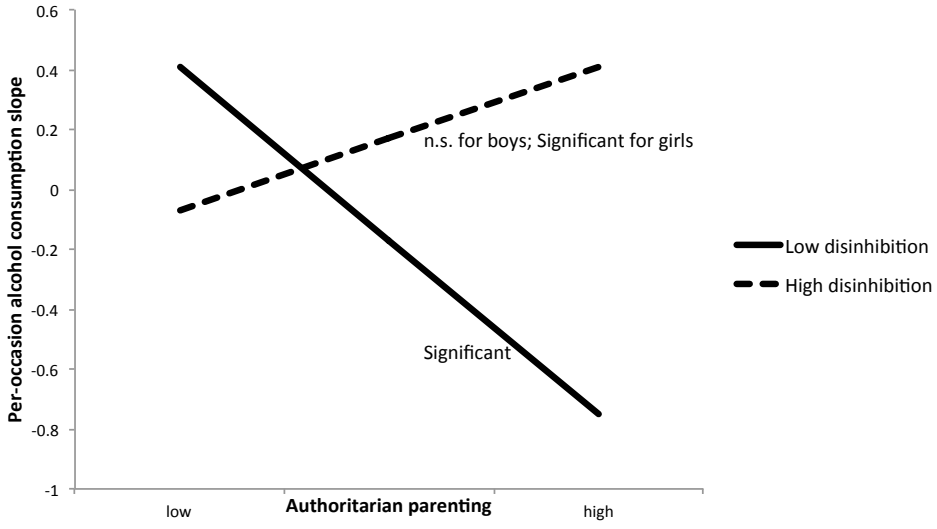
## 14. ARMSTRONG, RUTTLE, BURK, COSTANZO, STRAUMAN & ESSEX, 2013

a. Disinhibition*Authoritative parenting → Alcohol use intercept




b. Disinhibition*Authoritarian parenting → Alcohol use slope

Note: plotted slopes are based on the interaction coefficients for the whole sample



### 2.1.2. Transition entre les articles 1 et 2

La revue systématique du premier article de thèse a d'abord montré que la littérature supporte la présence d'une interaction entre certaines dimensions du tempérament et l'environnement familial dans la prédiction de la consommation de substances et des comportements extériorisés à l'adolescence. Les résultats de chaque étude ont été évalués avec les tests de pente puis visuellement en examinant les graphiques des interactions pour déterminer si les résultats correspondaient soit avec une interaction ordinale (diathèse-stress) ou disordinale (sensibilité différentielle). Cet examen fait ressortir un changement développemental; lorsque le tempérament et l'environnement familial étaient mesurés à l'enfance, les interactions appuyaient le modèle de la sensibilité différentielle, alors que lorsque le tempérament et l'environnement familial étaient mesurés à l'adolescence, les interactions appuyaient le modèle de la diathèse-stress, et ce tant pour les comportements extériorisés que pour la consommation de substances à l'adolescence. Cependant, l'examen visuel des graphiques d'interaction pour déterminer le soutien des modèles est une méthode libérale, des analyses statistiques plus poussées ayant été proposées afin de tester rigoureusement les modèles. Une seule des études revues avait comparé les modèles a priori, soit la seconde étude de cette thèse, qui examine les interactions entre le tempérament et les pratiques parentales à l'enfance dans la prédiction de la fréquence de consommation d'alcool à l'adolescence.

## 2.2. Deuxième article

# Differential susceptibility to environmental influences: Interactions between child temperament and parenting in adolescent alcohol use

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Objectifs spécifiques de cet article: Examiner l'interaction entre le tempérament à 6 ans et les pratiques parentales à 6 et 14 ans dans la prédiction de la consommation d'alcool à 15 ans.

**Statut: Publié dans *Development and Psychopathology*, 2016; *28*(1) : 265-275**

## Contribution des auteurs

**Charlie Rioux:** Conceptualisation de l'article, analyse statistique, interprétation des résultats, rédaction des différentes sections de l'article, préparation des tableaux et graphiques.

**Natalie Castellanos-Ryan:** Soutien à la conceptualisation de l'article, à l'analyse statistique et à l'interprétation des résultats, correction du manuscrit et révision de l'article.

**Sophie Parent:** Soutien à l'interprétation des résultats, révision de l'article.

**Frank Vitaro:** Révision de l'article.

**Richard E. Tremblay:** Révision de l'article.

**Jean Séguin:** Soutien à la conceptualisation de l'article et à l'interprétation des résultats, correction du manuscrit et révision de l'article.

Abstract

Temperament and parental practices are important predictors of adolescent alcohol use; however, less is known about how they combine to increase or decrease risk of alcohol use. This study examined whether age 6 temperament (i.e., impulsivity, inhibitory control) interacted with age 6 coercive parenting practices and/or age 14 parental monitoring to predict alcohol use at 15 years among 209 adolescents. Results showed that low parental monitoring was associated with more frequent alcohol use and that coercive parenting practices interacted with impulsivity to predict alcohol use. This interaction was examined as a function of two models that were not studied before in the prediction of alcohol use: (1) diathesis-stress model, i.e., impulsive children are more "vulnerable" to adverse parenting practices than those with an easy temperament; (2) differential susceptibility model, i.e., impulsive children are *also* more likely to benefit from good parenting practices. Results supported the differential susceptibility model by showing that impulsive children were at higher risk for alcohol use when combined with high coercive parenting practices, but also benefit from the absence of coercive parenting practices. This supports the suggestion that the conception of certain temperament characteristics, or in this case impulsivity, as a "vulnerability" for adolescent alcohol use may need revision since it misrepresents the malleability it may imply.

*Keywords*: temperament, impulsivity, parenting, differential susceptibility, alcohol

Differential susceptibility to environmental influences: Interactions between child temperament and parenting in adolescent alcohol use

Adolescent alcohol use is a prevalent health and social problem (Institut de la statistique du Québec, 2009; Johnston, O'Malley, Bachman, & Schulenberg, 2013) with several potential short and long-term consequences (Newbury-Birch et al., 2009). Studies have found that temperament (Wennberg & Bohman, 2002; Willem et al., 2011) and parental practices (Cablova, Pazderkova, & Miovsky, 2014; Ryan, Jorm, & Lubman, 2010) were associated with adolescent alcohol use and that they interacted to predict risk for alcohol use (Armstrong et al., 2013; Burk et al., 2011; Stice & Gonzales, 1998). While previous research considered temperament as a vulnerability factor leading to higher alcohol use in the context of adverse environments, recent theoretical work suggests temperament could also be indicative of individuals' susceptibility to environmental factors such as parenting (Belsky & Pluess, 2009, 2013): Some temperamental characteristics would be both disadvantageous in adverse environments, and advantageous in favorable environments. Thus, the purpose of this study is to examine the interaction between temperament and parenting variables in the prediction of adolescent alcohol use while considering theoretical models that could explain those interactions.

**Temperament and alcohol use**

Temperament refers to early emerging individual differences regarding reactivity, which refers to the speed and intensity of emotional arousal, attention and motor activity (e.g., impulsivity, emotionality, activity level), and self-regulation, which refers to the strategies that modify reactivity (e.g., inhibitory control, attentional control). These differences are relatively stable and have some genetic foundation (Rothbart & Bates, 2006).

Research shows that several dimensions of temperament are related to alcohol use. (Caspi, Moffitt, Newman, & Silva, 1996; Colder & Chassin, 1997; Giancola & Mezzich, 2003; Hartman, Hopfer, Corley, Hewitt, & Stallings, 2013; Tubman & Windle, 1995; Wennberg & Bohman, 2002; Willem et al., 2011; Windle, 1991). Notably, early inhibition has been associated with alcohol use (Caspi et al., 1996). Research shows that some inhibited children later develop high anxiety levels (Degnan, Almas, & Fox, 2010; Degnan & Fox, 2007) and other internalizing symptoms, which are in turn associated with alcohol use (Hussong, Jones, Stein, Baucom, & Boeding, 2011; Saban & Flisher, 2010), suggesting that those children could be using alcohol as a self-medicating strategy to reduce negative affect (Weinberger & Bartholomew, 1996). Early impulsivity has also been shown to be associated with later alcohol use (Colder & Chassin, 1997; Willem et al., 2011), notably through increased risk for antisocial behavior (L. A. Clark, 2005), an important risk factor for substance use (Conner & Lochman, 2010; Swadi, 1999).

**Parental practices and alcohol use**

Several dimensions of parental practices have been found to be associated with adolescent alcohol use and could interact with inhibition or impulsivity to predict alcohol use. Among those, parental monitoring has been repeatedly associated with alcohol use (e.g., Abar, Jackson, Colby, & Barnett, 2014; Barnes, Reifman, Farrell, & Dintcheff, 2000; H. K. Clark, Shamblen, Ringwalt, & Hanley, 2012; DiClemente et al., 2001; S. C. Duncan, Duncan, Biglan, & Ary, 1998; Kaynak et al., 2013; Steinberg, Fletcher, & Darling, 1994; Tornay et al., 2013). A possible mechanism to explain this association is that poorly monitored youths tend to associate with more deviant peers (Ary, Duncan, Duncan, & Hops, 1999; Lloyd & Anthony, 2003; Pinchevsky et al., 2012), an important correlate of adolescent substance use (Leung,

Toumbourou, & Hemphill, 2014; Marschall-Lévesque, Castellanos-Ryan, Vitaro, & Séguin, 2014).

Coercive parenting is another parenting variable that has been shown to predict adolescent alcohol use (Aquilino & Supple, 2001; Barnes & Farrell, 1992; Fergusson & Lynskey, 1997) and is also related to externalizing problems (Burnette, Oshri, Lax, Richards, & Ragbeer, 2012; Gartstein & Fagot, 2003), which co-occur highly with substance use (Castellanos-Ryan & Conrod, 2011; Krueger et al., 2002). Coercive parenting could lead to alcohol use by increasing conduct problems in childhood, which are associated with rejection from the normal peer group and academic failure, and would, in turn, increase the likelihood of adolescents joining a deviant peer group (Patterson, DeBaryshe, & Ramsey, 1990).

**Temperament, parenting and alcohol use**

Although studies have found direct effects of both temperament and parenting on adolescent alcohol use, it has been suggested that an interaction between temperament and the environment (i.e., parenting), could lead to alcohol use as a result of their joint influence on proximal adolescent factors (e.g., academic competence and peer affiliation, Wills & Dishion, 2004). Only three studies have focused on the interplay between temperament and parenting in the prediction of adolescent alcohol use, and how parental practices may exacerbate or dampen the risk conveyed by temperamental characteristics. The earliest study was cross-sectional and found that impulsivity at ages 12 and 13 years was positively associated with more frequent alcohol use and this association was greater at low levels of paternal support (Stice & Gonzales, 1998). The other two studies assessed the link between childhood predictors (temperament and parenting practices) and adolescent alcohol use in the same prospective cohort. The first one (Burk et al., 2011) found that boys scoring high on

temperamental disinhibition at age 4 years had higher levels of alcohol use in Grade 10 only when exposed to low levels of authoritative parenting in childhood, which is characterized by clear rules and monitoring that still allowed child independence. The second study (Armstrong et al., 2013) found that girls and boys high in temperamental disinhibition at ages 3.5 and 4.5 years who were exposed to low authoritative parenting in childhood had higher levels of Grade 9 alcohol use. In contrast, authoritarian parenting, characterized by control, criticism and punishment, predicted growth of alcohol use from Grade 9 to Grade 12. Boys and girls low in disinhibition at ages 3.5 and 4.5 years exposed to low authoritarian parenting showed a steeper increase in their alcohol use at the beginning of high school that then leveled off, while those exposed to high authoritarian parenting had less alcohol consumption initially but increased more rapidly by Grade 12. Whereas boys high in disinhibition all had a steep increase in alcohol use from Grade 9 to Grade 12, authoritarian parenting may have had a protective effect on girls high in temperamental disinhibition, for whom the increase in alcohol consumption leveled off by Grade 12.

**Personal characteristics by environment interactions: theoretical models**

Most of the research on interactions between personal characteristics, such as temperament, and the environment, such as parenting, is based on the diathesis-stress model (Monroe & Simons, 1991; Zuckerman, 1999), which posits that vulnerable individuals (e.g., impulsive or inhibited children) are more likely to be affected negatively by an environmental stressor. Thus, according to this theory, highly impulsive and inhibited children are "vulnerable" and would have higher levels of adolescent alcohol use than "resilient" children without those temperamental characteristics when exposed to adverse parental practices. This

vulnerability is only observed in adverse environments: "Vulnerable" and "resilient" children would develop similarly in the absence of adverse parental practices.

A more recent and complementary theory challenges this conception. The differential susceptibility model posits that, in addition to being affected adversely by negative environmental conditions, individuals with certain susceptibility factors may also benefit more from good environmental conditions or from the absence of adversity (Belsky, 2005; Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2007; Belsky & Pluess, 2009, 2013; Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2011). This theory hypothesizes that the susceptibility factor would be rooted in a nervous system that is more "plastic and malleable" (Pluess & Belsky, 2009, 2010). Thus, rather than being "vulnerable" to adverse environments, children with so-called difficult temperament characteristics could be "susceptible" to both negative as well as positive parental practices. Accordingly, "susceptible" impulsive and inhibited children would have lower levels of alcohol use than non-impulsive and non-inhibited children when exposed to positive parental practices in addition to having higher levels of alcohol use when exposed to adverse parenting. Impulsivity and inhibition would no longer be conceived exclusively as risk factors; they would also hold the promise of greater benefits from positive environments.

These two models may be distinguished empirically by careful analyses of the patterns of statistical interaction. Statistical support for the diathesis-stress model comes from a pattern where an individual characteristic is related to an outcome and an ordinal (fan-shaped) interaction is found (Belsky et al., 2007). Support for the differential susceptibility is demonstrated when (1) a disordinal (crossover) interaction is found, with (2) the slope of the association between the environmental factor and the outcome for the susceptible group being

significantly different from zero and (3) significantly steeper than the slope for the non-susceptible group. Finally, (4) the susceptibility factor should not be related to the environmental factor or to the outcome (Belsky et al., 2007; Belsky & Pluess, 2009). Once these criteria have been met, two additional steps designed to test the significance of the crossover interaction have been proposed that go beyond simple appraisal of the plots (Roisman et al., 2012; Widaman et al., 2012). Alternatively, a model fitting test has recently been proposed to more directly compare interaction patterns representing "weak" and "strong" versions of the diathesis-stress and differential-susceptibility models without requiring a significant statistical interaction, making this approach more liberal (Belsky, Pluess, & Widaman, 2013).

The majority of previous studies examining interactions between temperament and parenting as well as other family factors in the prediction of adolescent alcohol use and other outcomes were conducted within a diathesis-stress frame of reference. However, recent studies found gene-environment interactions in the prediction of substance use that support the differential susceptibility model (Daw et al., 2014; Daw et al., 2013; Laucht et al., 2012; Park, Sher, Todorov, & Heath, 2011). Furthermore, Belsky and Pluess (2009, 2013) reexamined prior published studies to determine the extent to which they supported the differential susceptibility model. Potential support for the model was found with temperament and family measures in the prediction of externalizing problems (Bradley & Corwyn, 2008; Lengua, 2008; Leve, Kim, & Pears, 2005; Pitzer, Jennen-Steinmetz, Esser, Schmidt, & Laucht, 2011; Pluess & Belsky, 2009; Poehlmann et al., 2012; Smeekens, Riksen-Walraven, & van Bakel, 2007; van Aken, Junger, Verhoeven, van Aken, & Dekovic, 2007), depression symptoms (Lengua, Wolchik, Sandler, & West, 2000), attachment security (Velderman, Bakermans-

Kranenburg, Juffer, & van Ijzendoorn, 2006) and other outcomes. It is possible that this may also be the case for adolescent alcohol use, which should be examined specifically and a priori.

**The present study**

The first objective of this study was to examine whether child temperament and parenting characteristics interact in the prediction of alcohol use at 15 years. It is hypothesized that high coercive parenting in early childhood and/or low parental monitoring in adolescence will be associated with a higher frequency of adolescent alcohol use for children high in impulsivity and/or low in inhibitory control. The second objective was to examine whether low coercive parenting and/or low parental monitoring will also be associated with a lower frequency of alcohol use for children high in impulsivity and/or low in inhibitory control, which would support the differential susceptibility model.

## Method

**Participants**

Participants for this study come from a longitudinal study aiming to better understand the social, psychological and cognitive development of children in Québec, Canada. One thousand families from all socioeconomic backgrounds were randomly selected from urban areas in the Québec birth registry in 1996-1997 (Santé Québec, 1997), with 572 francophone (90%) and anglophone (10%) families participating at the first assessment when the children were five months old. This urban sample differed slightly from a larger more representative population based sample of Québec 5-month-old children born 2 years later: Parents in the urban sample were 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 older than in the larger population at the birth of the participants (29.9 vs 28.8 years). There were no differences between the urban and population samples regarding fathers' age (32.3 vs 31.8 years) and proportion of family income under 30,000 CAN$ (26% vs 29%; Tremblay et al., 2004).

The participants were followed annually. Due to attrition, loss to follow-up, and year-to-year variations in participation rates, 209 participants (52% girls) participated at age 15 years and constitute the sample for the present study. This final subsample did not differ significantly from the remainder of the urban sample on parenting at 6 years ($p = 0.41$; $n = 363$) and temperament at 6 years ($p = 0.10$; $n = 273$) as well as sex ($p = 0.80$; $n = 572$) and family income at 5 months ($p = 0.18$; $n = 538$). The University of Montreal, the Hôpital Louis Hippolyte Lafontaine and the CHU Sainte-Justine Research Center ethics committees approved this project.

**Measures**

**Temperament.** Child temperament was assessed at 6 years using the Children's Behavior Questionnaire (Rothbart, Ahadi, Hershey, & Fisher, 2001), rated by the mother using seven-point scales with 1 referring to "extremely inaccurate" and 7 to "extremely accurate". Two scales were used: six items on impulsivity (speed of response initiation; e.g., has a habit of jumping into an activity without much prior thought; $M = 26.89$, $SD = 5.58$; skewness = -0.28; kurtosis = 0.20) and six items on inhibitory control (capacity to plan and to suppress inappropriate responses under instructions or in novel situations; e.g., when told that a place is dangerous, he/she goes there slowly and carefully; $M = 30.28$, $SD = 5.58$; skewness = -0.39; kurtosis = -0.16). The Cronbach alphas for both scales were 0.78 (Rothbart et al., 2001).

**Parental practices.** Coercive parenting was assessed at 6 years using questions based on the Parent Practices Scale (Strayhorn & Weidman, 1988) and on the first cycle of the National Longitudinal Survey of Children and Youth (Statistics Canada, 1995). Mothers reported on a seven-question scale (e.g., how often do you raise your voice, scold or yell at him/her?). Each item was rated on a five-point scale with 1 referring to "never" and 5 referring to "many times each day" or "all the time", depending on the question asked (M = 14.99, SD = 2.98; skewness = 0.58; kurtosis = 0.66). Cronbach's alpha for this scale was 0.71 (Statistics Canada, 1998).

Parental monitoring was assessed by adolescent-report when the participants were 14 years old with two items asking "Do your parents know where you are when you go out?" and "Do your parents know with whom you are when you go out?".[1] Answers for these questions were given on a five-point scale ranging from "never" to "always" (M = 3.37, SD = 0.78; skewness = -0.89; kurtosis = -0.19). These questions were sensitive in other studies (e.g., Brendgen, Vitaro, Tremblay, & Lavoie, 2001; Haapasalo & Tremblay, 1994).

**Alcohol use.** Adolescents reported on their substance use when they were 15 years old. Alcohol use frequency was assessed with a question based on the *Québec survey on tobacco, alcohol and drug use and gambling in secondary school students* (Institut de la statistique du

[1] La mesure de supervision parentale utilisée représente un aspect spécifique de la supervision, soit la connaissance parentale quant aux allées et venues de l'adolescent. Les résultats s'appliquent donc à cet aspect de la supervision parentale, leur généralisation à la supervision en général devant être confirmée par des études futures. L'article 3 inclus une définition détaillée de la supervision parentale et de l'aspect de la connaissance parentale.

Québec, 2007) and asking participants at what frequency they had consumed alcohol in the last 12 months. Answers for this question were given on a seven-point Likert scale ranging from "I have never used alcohol" to "every day" (M = 2.27, SD = 1.90; skewness = 0.08; kurtosis = -1.30).

**Data analyses**

In order to test main and interaction effects of age 6 and age 14 parental practices and age 6 temperament in the prediction of age 15 adolescent alcohol use, a series of linear regressions (path analysis) were conducted using Mplus version 7.0 (Muthén & Muthén, 1998-2012) and following guidelines provided by Cohen, Maiersperger, Gower, and Turner (2003) and Frazier, Tix, and Barron (2004). We included sex, the two predictors (age 6 coercive parenting and age 14 parental monitoring) and the two moderators (age 6 impulsivity and inhibitory control) in the first model and the interaction terms between the predictors and the moderators were included in the second model. All predictor and moderator variables were standardized before computing interaction terms and entering variables in the analysis. Full information maximum likelihood (FIML) was used to account for missing data. Three-way interactions with sex were also tested and were not significant. When significant interactions were found, the effect of the predictor was plotted as a function of the moderator and followed by simple slope tests to determine the nature of the interaction.

To determine if the differential susceptibility model was supported, significant interactions were examined according to the four criteria previously mentioned. Following the examination of those criteria, additional steps have been proposed (Roisman et al., 2012), which include the identification of the regions of significance using the Johnson-Neyman technique. While this method has been used in most recent studies examining the differential

susceptibility model, it can lack power in small samples and when the environmental variable does not cover the entire range, from very enriched to very adverse (Belsky et al., 2014; Dick, 2011; L. E. Duncan & Keller, 2011; Lei, Simons, Edmond, Simons, & Cutrona, 2014). A new procedure that addresses these power issues was used in this study and can determine statistically if the interaction is disordinal (Widaman et al., 2012). With this procedure, the crossover point and its confidence interval are estimated: An interaction is disordinal and supports the differential susceptibility model when the confidence interval of the crossover point falls within the observed range of the predictor (i.e., parenting). If the crossover point is outside the observed range of the predictor, the interaction is ordinal and supports the diathesis-stress model.

## Results

### Descriptive statistics

Table 1
*Correlations between sex, parenting scales, temperament scales and alcohol use*

| Variable | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Sex | – | | | | |
| 2. Parental monitoring | .18* | – | | | |
| 3. Coercive parenting | -.09 | -.22** | – | | |
| 4. Impulsivity | .07 | -.05 | .24** | – | |
| 5. Inhibitory control | .23** | .31** | -.35** | -.28** | – |
| 6. Alcohol use frequency | .03 | -.27** | .09 | .10 | -.08 |

*Note.* * $p < .05$. ** $p < .01$.

Table 1 presents correlations between the variables that were used in regression analyses. There was a small correlation between sex and parental monitoring at 14 years, and between sex and inhibitory control at 6 years; girls reported more monitoring from their parents and had higher levels of inhibitory control. Inhibitory control at 6 years was mildly negatively correlated with impulsivity at 6 years. Coercive parenting at 6 years and parental

monitoring at 14 years were mildly and negatively correlated with each other. Coercive parenting at 6 years was negatively associated with inhibitory control and positively correlated with impulsivity, both assessed at 6 years, while parental monitoring at 14 years was only associated positively with inhibitory control at 6 years. There was no correlations between alcohol use scores at 15 years and temperament scores at 6 years, but alcohol use frequency at 15 years was mildly negatively correlated with parental monitoring at 14 years.

As noted previously, the differential susceptibility model requires the predictor and moderator to be independent from each other. However, coercive parenting was mildly associated with both impulsivity and inhibitory control at age 6. Because this could be due to shared method variance and could complicate the interpretation of interactions, coercive parenting was regressed on impulsivity and inhibitory control, and the residual coercive parenting score was used in the analyses to control for any correlation, as often done in other studies testing the differential susceptibility model (Nederhof, Belsky, Ormel, & Oldehinkel, 2012; Ramchandani, van IJzendoorn, & Bakermans-Kranenburg, 2010). The findings did not change whether the original or residual score were used. The following results are from the analysis using the residual score.

**Main and interaction effects**

As shown in Table 2, only one significant main effect was found in the first step of the model. Low levels of parental monitoring at 14 years were associated with higher levels of alcohol use frequency at 15 years ($R^2 = 0.10$). One significant interaction effect was found in the second step of the analysis: An interaction between impulsivity and coercive parenting at 6 years positively predicted alcohol use frequency at 15 years ($\Delta R^2 = 0.04$). Simple slope analyses showed that the effect of coercive parenting at 6 years was significant when

impulsivity at 6 years was high, but not when it was low (see Figure 1). Relative to children low in impulsivity, children high in impulsivity had both higher levels of alcohol use frequency at 15 years when exposed to high coercive parenting at 6 years and lower levels of alcohol use frequency at 15 years when exposed to low coercive parenting at 6 years.

Table 2
*Main and interaction effects of temperament at 6 years, coercive parenting at 6 years and parental monitoring at 14 years on alcohol use frequency at 15 years*

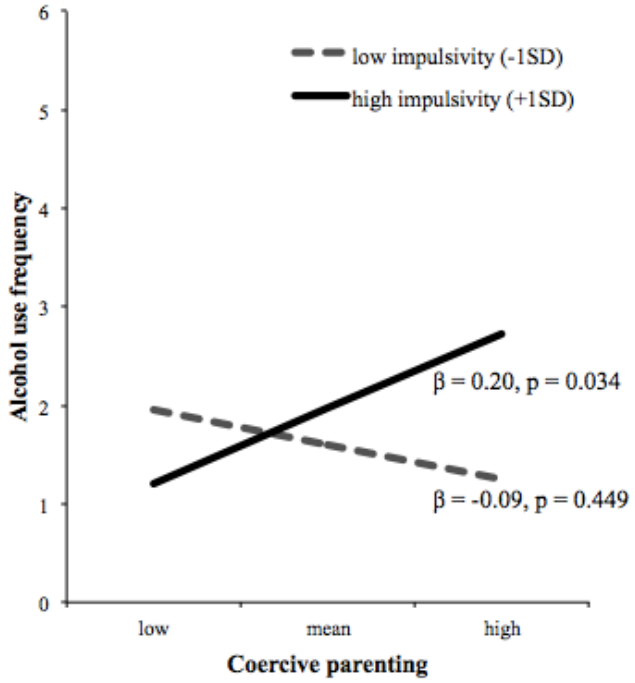
| | Alcohol use frequency | | |
|---|---|---|---|
| Main effects (model 1) | B | SE | β |
| Sex | 0.30 | 0.26 | 0.08 |
| Impulsivity | 0.15 | 0.16 | 0.08 |
| Inhibitory control | 0.05 | 0.18 | 0.03 |
| Coercive parenting | 0.15 | 0.15 | 0.08 |
| Parental monitoring | -0.55*** | 0.15 | -0.29 |
| | | | |
| Interaction effects (model 2) | | | |
| Sex | 0.26 | 0.26 | 0.07 |
| Impulsivity | 0.05 | 0.82 | 0.03 |
| Inhibitory control | -0.74 | 0.80 | -0.40 |
| Coercive parenting | 0.10 | 0.17 | 0.05 |
| Parental monitoring | -0.68** | 0.22 | -0.26 |
| Impulsivity x coercive parenting | 0.28* | 0.14 | 0.16 |
| Impulsivity x parental monitoring | 0.04 | 0.24 | 0.07 |
| Inhibitory control x coercive parenting | 0.28 | 0.19 | 0.15 |
| Inhibitory control x parental monitoring | 0.25 | 0.24 | 0.44 |

*Notes.* * $p < .05$ ** $p < .01$ *** $p < .001$.

**Support for the differential susceptibility model.** According to the plotted data and the simple slope tests, the interaction met criteria for the differential susceptibility model. (1) It was a disordinal (crossover) interaction. The estimate for the crossover point, C = -0.86 (SE = 0.14), 95% CI [-1.13, -0.59], fell just below the standardized sample mean. In addition, the confidence intervals of the crossover point fell well within the observed standardized values of coercive parenting (min = -2.22; max = 2.64). (2) The slope for the children high in impulsivity at 6 years differed significantly from zero. (3) The slope for the children high in

impulsivity at 6 years was steeper than the slope for the children low in impulsivity, which was not significantly different from zero. (4) Finally, impulsivity at 6 years was not related to alcohol use frequency at 15 years or to residuals of coercive parenting at 6 years.[2]

Figure 1
*Age 6 coercive parenting by impulsivity interaction predicting adolescent alcohol use frequency at 15 years. Sample size: low impulsivity (below -1SD) = 37, mean impulsivity (between -1SD and +1SD) = 101, high impulsivity (above +1SD) = 32.*




[2] The differential susceptibility model was also tested in SPSS using the model fitting approach proposed by Belsky, J., Pluess, M., & Widaman, K. F. (2013) and expectation-maximization single imputation for missing data. This method yielded similar results, confirming that a weak differential susceptibility model was a better fit for the interaction between impulsivity and coercive parenting, and that no other interactions were significant even when using this more liberal approach.

## Discussion

The objectives of this study were two fold. This study first aimed to determine if temperamental and parenting dimensions that predicted substance use through main effects in previous studies could interact to predict adolescent alcohol use. A second objective was to examine if such interactions could be interpreted according to a diathesis-stress or a differential susceptibility model. The main findings of this study first indicate that low parental monitoring in adolescence was associated with a higher frequency of alcohol use. Second, we found that not only did child impulsivity and coercive parenting interact to predict adolescent alcohol use, but that this interaction supports the differential susceptibility model. This suggests that, with regards to adolescent alcohol use, early impulsivity may be a key marker of plasticity, which confers risk under certain conditions and a clear advantage under other conditions.

### Joint contribution of temperament and parenting to adolescent alcohol use

After examining whether childhood temperament (i.e., impulsivity and inhibitory control) interacted with parental practices (i.e., coercive parenting in childhood and monitoring in adolescence) in the prediction of adolescent alcohol use, we found that higher levels of age 6 impulsivity were associated with more frequent alcohol use at 15 years when children were also exposed to coercive parenting at 6 years. These findings are consistent with and extend those of other studies showing that impulsive temperament traits interacted with parental practices in the prediction of substance use. Indeed, as reviewed above, interactions were found in the prediction of alcohol use with impulsivity and parental support (Stice & Gonzales, 1998) as well as with temperamental disinhibition and authoritative parenting

(Armstrong et al., 2013; Burk et al., 2011). Interactions with impulsivity and coercive parenting were also found in the prediction of externalizing problems (Leve et al., 2005).

While we found that early childhood temperament and parenting could predict adolescent alcohol use, other variables could come into play across developmental periods. Indeed, the interaction we observed between impulsivity and coercive parenting in childhood could lead to adolescent alcohol use through its contribution to other late childhood or early adolescent variables (Wills & Dishion, 2004). Thus, future studies could investigate a mediated moderation model (Muller, Judd, & Yzerbyt, 2005) where one could test whether the interaction between early impulsivity and coercive parenting is mediated by more proximal variables in adolescence that have been shown to predict adolescent alcohol use (e.g. peer affiliations (Leung et al., 2014; Marschall-Lévesque et al., 2014), conduct problems (Castellanos-Ryan, Séguin, Vitaro, Parent, & Tremblay, 2013; L. A. Clark, 2005)).

Whereas coercive parenting and impulsivity at 6 years interacted to predict alcohol use at 15 years, coercive parenting did not interact with inhibitory control at 6 years. Several factors could account for this difference across temperament dimensions. First, although these two temperamental dimensions were mildly correlated, they are quite different in that impulsivity is a measure of reactivity and inhibitory control is a measure of self-regulation. Indeed, impulsivity represents spontaneous and quick reactions to the environment whereas inhibitory control represents the conscious decision-making process involved in suppressing inappropriate dominant responses (Rothbart et al., 2001). Thus, in this sample, the tendency at 6 years to have quick spontaneous reactions seems more important in the prediction of early adolescent alcohol use than the absence of the conscious regulation of reactions when faced with exterior demands. Second, our hypothesis was based on reported links between early

"inhibition" with substance use (Caspi et al., 1996; Hussong et al., 2011). However, by using the term "inhibition", it is unclear to which of attentional, motivational, cognitive, and motor dimensions of inhibition these studies are referring to (Nigg, 2000) In this study, we measured inhibitory control, a self-regulatory measure implicating decision-making. It is possible that alcohol use is associated with other temperamental measures of "inhibition", such as measures that focus on the behavioral dimensions of inhibition. Future studies comparing different measures of inhibition could test this hypothesis.

A main effect of parental monitoring at 14 years was also found, showing that lower levels of monitoring at 14 years were associated with more frequent alcohol use at 15 years, which is consistent with the results of previous studies (e.g., Barnes et al., 2000; H. K. Clark et al., 2012; DiClemente et al., 2001; S. C. Duncan et al., 1998; Kaynak et al., 2013; Steinberg et al., 1994; Tornay et al., 2013). Although coercive parenting in childhood interacted with concurrent impulsivity in predicting adolescence alcohol use, the interactions of parental monitoring in adolescence with childhood impulsivity or inhibitory control did not predict alcohol use. This suggests that the interplay between parenting and temperament on adolescent alcohol may change across development, and that parental monitoring during adolescence may be beneficial to all adolescents in reducing risk for alcohol use. Alternatively, the fact that childhood temperament interacted with concurrent parental practices, but not with parenting in adolescence could be explained methodologically, as reports were not only obtained from different informants but also different facets of parental practices were measured. To determine whether this difference between these statistical interactions in childhood and adolescence was due to developmental or measurement differences, future studies could examine whether temperament measured in adolescence interacts with parenting in

adolescence, examine the same parenting dimension in childhood and adolescence, or use the same informant for parenting in childhood and adolescence.

**Support for the theoretical models and implications**

The significant interaction between impulsivity and coercive parenting was examined to determine whether it supported the diathesis-stress model or the differential susceptibility model, a question that had not been tested in previous studies of temperament and parenting in the prediction of alcohol use. The interaction met the four key criteria for support of the differential susceptibility model. Indeed, when exposed to low coercive parenting, children with higher levels of impulsivity at 6 years had less frequent alcohol use at 15 years than children with low levels of impulsivity. Because this sample came from a normal urban population and the coercive parenting variable was normally distributed, a mean level of coercion represented the norm. Consequently, a low level of coercive parenting represented mothers that were particularly skillful at avoiding coercive strategies to supervise and socialize their child. In other words, it was a markedly low level of coercion from the mother that may have been beneficial for 6-year-old children high in impulsivity. Whereas impulsivity is mostly seen as a risk factor, the possibility that it could be an advantage is less commonly evoked. Under the skillful guidance of meaningful adults, impulsivity may confer an advantage because of the novelty seeking aspect of this temperamental dimension, which could lead impulsive children to development opportunities. The spontaneity linked to impulsivity could bring these children to reveal themselves more readily to their non-coercive parents, leading to better parent-child communication, which was also important in the prediction of alcohol use (Ryan et al., 2010). Potential support for the differential susceptibility model was also previously found with impulsivity and coercive parenting in the

prediction of externalizing problems but had not been tested a priori; Consistent with the interactions between impulsivity and coercive parenting found in the present study, a secondary analysis of an interaction between impulsivity and coercive parenting at age 5 in the prediction of girls' externalizing problems at 17 years (Leve et al., 2005) showed that this interaction supported the differential susceptibility model (Belsky & Pluess, 2009). Since substance use is considered a subtype of externalizing problems (Castellanos-Ryan & Conrod, 2011; Krueger et al., 2002), our results provide further support for the relevance of differential susceptibility in the case of substance use and, potentially, externalizing behaviors in general.

With further studies determining which individual characteristics and environmental conditions interact following a diathesis-stress or differential susceptibility pattern, the prevalent conception of individual "vulnerability" factors would need revising in order to include susceptibility/plasticity factors in developmental models. Both the diathesis-stress and the differential susceptibility models support targeting children for prevention based on their temperament characteristics. Indeed, both models show that adverse environments negatively affect children with a "difficult" temperament, making such combinations important targets of prevention and intervention programs. However, support for the differential susceptibility model for some early markers, such as impulsivity, could change the expectations regarding the outcomes of interventions. Parents, teachers and practitioners might then develop higher, and more optimistic expectations regarding the potential of children currently described as having a "difficult" temperament. Indeed, considering impulsivity as a risk factor, and children with this temperamental disposition as "vulnerable", does not take into account the fact that their temperament could lead to aptitudes that go beyond the absence of a problem

when combined with the right environment (Belsky & Pluess, 2009; Bradley & Corwyn, 2008; Pluess & Belsky, 2009, 2010; Stright, Kelley, & Gallagher, 2008).

Applying a differential susceptibility model clinically could have an impact not only in childhood, but also later in life. Indeed, there is also evidence of differential susceptibility in early adulthood (Aron & Aron, 1997). Aron (2010) recommends personalizing clinical interventions in adulthood according to the degree of "sensitiveness" of the client, a concept closely related to the degree of susceptibility or openness to environmental influences. From a clinical perspective, Aron (2010) adds that while sensitive people may be more vulnerable, sensitivity is not only a liability but may also confer advantages. Thus, the main challenge for future studies of various temperamental characteristics is to determine which are vulnerability versus susceptibility factors and under which environmental conditions.

Experimental research is also needed. There are already various parenting interventions that can help reduce alcohol use and could be used in experimental studies. Meta-analyses have shown that while parenting programs based on social learning and cognitive-behavioral principles are effective in reducing problem behaviors in children and adolescents (Dretzke et al., 2009), those integrating components to increase positive parent-child interactions and emotional communication skills were shown to have larger effects (Kaminski, Valle, Filene, et Boyle, 2008). Randomized controlled trials testing the effects of parenting and familial interventions in the prediction of both alcohol use (Beach, Brody, Lei, & Philibert, 2010; Brody, Chen, & Beach, 2013; Brody et al., 2014; Cleveland et al., in press) and externalizing problems (Albert et al., in press; Bakermans-Kranenburg, Van IJzendoorn, Mesman, Alink, & Juffer, 2008; van den Hoofdakker et al., 2012) have shown support for genetic differential susceptibility, with clear support for dopamine-related genes (see

Bakermans-Kranenburg & van IJzendoorn, 2015 for a meta-analytic review). Intervention studies using measures of temperament to classify children have also shown support for differential susceptibility in the prediction of attachment security (Cassidy, Woodhouse, Sherman, Stupica, & Lejuez, 2011) and oppositional behavior (Scott & O'Connor, 2012). Future research could test whether the impact of interventions targeting parental practices on substance use is moderated by the impulsivity levels of children and adolescents. To test the differential susceptibility model, these studies would have to randomize the parenting intervention, but temperament can be a fixed factor (Bakermans-Kranenburg & van IJzendoorn, 2015). For example, coercive parents of children or early adolescents could be randomly assigned to a parenting intervention and control condition to then examine whether the intervention effects observed on substance use levels later in adolescence differ between the children low in impulsivity and those high in impulsivity. If the children high in impulsivity have better outcomes than those low in impulsivity, it would provide further support for the differential susceptibility model by demonstrating greater susceptibility to positive environments.

**Strengths and limitations**

Only three studies before this one had examined the interactions between temperament and parental practices in the prediction of alcohol use (Armstrong et al., 2013; Burk et al., 2011; Stice & Gonzales, 1998), with mostly Caucasian samples from the United States. Two of them were from the same laboratory and used the same sample, including measures from childhood to adolescence in a prospective design (Armstrong et al., 2013; Burk et al., 2011), a strength that the present study shares. Indeed, using a prospective design allowed the examination of the predictive relationships of temperament and parental practices from a

developmental perspective. In addition, the present study extends previous research by: 1) looking at parenting and temperamental variables that were shown to be related to alcohol use before but not studied in interaction with each other; 2) using a mostly French speaking Canadian sample, which, although mostly Caucasian, adds to the generalizability of findings across North American samples; and 3) being the first study of temperament, parenting and adolescent alcohol use outcomes that contrasts two important theoretical models of person-environment interactions. Still, some limitations should be noted. First, the rate of substance use in the sample was lower than in the general adolescent population of Quebec. Sixty six percent of the sample had used alcohol at least once by the age of 15, while the rate in the general population at this age is 80% (Institut de la statistique du Québec, 2009). It should also be noted that the sample is urban, which limits the generalization of results. The alcohol use data was also obtained through self-report, which is susceptible to bias, notably social desirability. However, self-reports are often used and considered reliable in assessing substance use (D. B. Clark & Winters, 2002). Also, parenting was assessed with mothers only, and the effect might be different with fathers. Thus, it would be important to conduct research with father-reported parenting practices to see if the results are invariant across parents, though this recommendation must take into account the high rate of children who may not be raised by the same parents over time. Although sex was included as a covariate, other predictors of adolescent alcohol use (e.g., deviant peer affiliations (Leung et al., 2014), parental alcohol use (Sher, 1991), internalizing problems (O'Neil, Conner, & Kendall, 2011), pubertal timing (Castellanos-Ryan, Parent, Vitaro, Tremblay, & Séguin, 2013; Hummel, Shelton, Heron, Moore, & van den Bree, 2013)) were not included. Thus, this study did not show whether parental monitoring, coercive parenting and impulsivity were still predictive of

adolescent alcohol use when taking into account its more proximal predictors. However, because these variables were shown to predict alcohol use and externalizing problems in other studies (e.g., Abar et al., 2014; Leve et al., 2005), we could expect the results to be robust to other predictors. Finally, the participation rate from childhood to adolescence in this sample may limit generalizability to the originally sampled population, although attrition has an impact mostly on means and not on the associations between variables (Graham, 2009; Gustavson, von Soest, Karevold, & Roysamb, 2012). Nonetheless, FIML was used to account for missing data and, as shown, the initial childhood and final adolescent samples were comparable on the main variables of interest.

**Conclusion**

Results of the present study showed that early temperament and parental practices interact in the prediction of alcohol use. Six-year-old children exposed to coercive parenting had more frequent alcohol use at 15 years when they were also impulsive at 6 years. Of greater significance, children high in impulsivity also had less frequent alcohol use than children low in impulsivity in the absence of coercive parenting, which supported the differential susceptibility model. Results also showed that low parental monitoring at 14 years was associated with a higher frequency of adolescent alcohol use at 15 years but did not interact with age 6 years temperament. With several studies on gene-environment interactions in the prediction of alcohol use now supporting the differential susceptibility model (e.g., Daw et al., 2013; Laucht et al., 2012), more studies should examine which temperamental factors are vulnerability or susceptibility factors for alcohol use and with which environmental factors they interact. Indeed, the differential susceptibility model could lead to changes in our conception of certain individual factors as “vulnerability” factors. In turn, this could change

the expectations we have concerning what children with a difficult temperament can achieve and help determine which preventive interventions work better while considering individual temperamental differences.

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### 2.2.2. Transition entre les articles 2 et 3

Le second article de thèse a comparé statistiquement les modèles de la diathèse-stress et de la sensibilité différentielle dans la prédiction de la consommation d'alcool à l'adolescence. Les résultats montrent qu'une interaction entre l'impulsivité et les pratiques maternelles coercitives à 6 ans prédit la fréquence de consommation d'alcool à 15 ans, et que cette interaction soutient le modèle de la sensibilité différentielle. Le tout offre un soutien empirique aux résultats de la revue de littérature du premier article de thèse où le modèle de la sensibilité différentielle était soutenu lorsque les variables tempéramentales et environnementales étaient mesurées à l'enfance. Cependant, aucune étude n'a testé statistiquement les modèles pour vérifier le second constat de la revue de littérature, soit que le modèle de la diathèse-stress était appuyé lorsque les variables de tempérament et d'environnement étaient mesurées à l'adolescence, ce que le troisième article de thèse examine. Plus précisément, le troisième article de thèse examine les interactions entre la personnalité et la supervision parentale à 15 ans dans la prédiction de la fréquence de consommation de substances à 15 et 17 ans.

## 2.3. Troisième article

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

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Objectifs spécifiques de cet article: Examiner l'interaction entre la personnalité (impulsivité et recherche de sensations) et la supervision parentale à 15 ans dans la prédiction de la consommation de substances à 15 et 17 ans.

**Statut: Soumis, *Child Psychiatry and Human Development***

## Contribution des auteurs

**Charlie Rioux:** Conceptualisation de l'article, analyse statistique, interprétation des résultats, rédaction des différentes sections de l'article, préparation des tableaux et graphiques.

**Natalie Castellanos-Ryan:** Soutien à l'analyse statistique et à l'interprétation des résultats, correction du manuscrit et révision de l'article.

**Sophie Parent:** Soutien à l'interprétation des résultats, révision de l'article.

**Frank Vitaro:** Révision de l'article.

**Jean Séguin:** Soutien à l'interprétation des résultats, correction du manuscrit et révision de l'article.

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, Parenting, Substance use, Diathesis-stress, Differential susceptibility

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

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 (Institut de la statistique du Québec, 2014), with similar rates in the United States (Johnston, O'Malley, Miech, Bachman, & Schulenberg, 2016). In addition to abuse, dependence and overdoses, potential 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 (Newbury-Birch et al., 2009; Odgers et al., 2008). Given these serious potential 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 have been consistently associated with lower or delayed substance use in adolescents (Ryan, Jorm, & Lubman, 2010). However, some theoretical models (Belsky & Pluess, 2009; Zuckerman, 1999) 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 (Charles, Mathias, Acheson, & Dougherty, 2017; Crawford, Pentz, Chou, Li, & Dwyer, 2003; Quinn & Harden, 2013; Stautz & Cooper, 2013). 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 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 (Belsky & Pluess, 2009, 2013). 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 (Dishion & McMahon, 1998), parental *knowledge* of their adolescent's whereabouts represents one specific dimension of parental monitoring (Stattin & Kerr, 2000). 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 (Laird, Pettit, Bates, & Dodge, 2003). 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 (Kerr & Stattin, 2000; Stattin & Kerr, 2000).

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 (Stattin & Kerr, 2000), which is also associated with delayed or low substance use (Ryan et al., 2010). Accordingly, parental knowledge has been consistently shown to be negatively associated with adolescent substance use in cross-sectional, prospective and longitudinal research (e.g., Abar, Jackson, & Wood, 2014; Delforterie et al., 2016; DiClemente et al., 2001). A meta-analysis also found that greater parental knowledge was associated with later alcohol initiation and lower levels of alcohol use (Ryan et al., 2010).

**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 (Lauriola, Panno, Levin, & Lejuez, 2014; Stautz & Cooper, 2013). This frames the problem in a person-environment perspective (Belsky & Pluess, 2009, 2013). 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 (Bevilacqua & Goldman, 2013; Dick et al., 2010), 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 (Castellanos-Ryan &

Conrod, 2012). While an earlier study showed that temperamental impulsivity at 6 years did not interact with parental knowledge in adolescence to predict alcohol use (Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016), 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 (Castellanos-Ryan et al., 2014), and found that low levels of parental knowledge were associated with higher levels of antisocial behaviors only in girls high on impulsivity (Barker, Trentacosta, & Salekin, 2011), 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 (Castellanos-Ryan & Conrod, 2012; Zuckerman, 1979). 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 (Armstrong & Costello, 2002; Castellanos-Ryan et al., 2014), which showed that low levels of parental knowledge and rule-setting were associated with higher levels of delinquency in high sensation seekers (Mann, Kretsch, Tackett, Harden, & Tucker-Drob, 2015). In contrast, a study found that between 13.4 and 16 years, parental knowledge and rule-setting were associated with higher levels of cannabis use was greater for adolescents with lower levels of sensation seeking (Epstein et al., 2017). 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 (Monroe & Simons, 1991). 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 (Belsky & Pluess, 2009, 2013). 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 (Roisman et al., 2012)

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 (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). 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. 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 (Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016). 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 (Barker et al., 2011; Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016), 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 (Santé Québec, 1997). 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%; Tremblay et al., 2004).

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 (Institut de la statistique du Québec, 2014). 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; Barker et al., 2011; Brendgen, Vitaro, Tremblay, & Lavoie, 2001; Castellanos-Ryan, Séguin, Vitaro, Parent, & Tremblay, 2013; Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016).

**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 (Castonguay-Jolin et al., 2013; Woicik, Stewart, Pihl, & Conrod, 2009), 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 (Muthén & Muthén, 1998-2012). 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 analyses 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 (Kaplan, Kim, & Kim, 2009), 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 (Kochanska, Kim, Barry, & Philibert, 2011), which 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 (Roisman et al., 2012). 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 (Roisman et al., 2012).

## 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.

Table 1

*Correlations and descriptive statistics for study variables*

| 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 at 15 | .25** | .24** | .17* | .18* | – | | |
| 6. Sensation seeking at 15 | .17** | .26** | .08 | .15* | .30** | – | |
| 7. Parental knowledge at 15 | -.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 |

*Note.* * $p < .05$. ** $p < .01$.

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 (Belsky & Pluess, 2009). 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 (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016).

**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 adolescents higher and lower on impulsivity differed on their substance use 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. The regions-of-significance test for the interaction for binge drinking indicated that adolescents higher and lower on sensation seeking differed on their binge drinking 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 adolescents higher and lower on sensation seeking differed on their drug use 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.

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

| | Binge drinking | | Drug use[1] | |
|---|---|---|---|---|
| **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[2] | 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[2] | 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 |

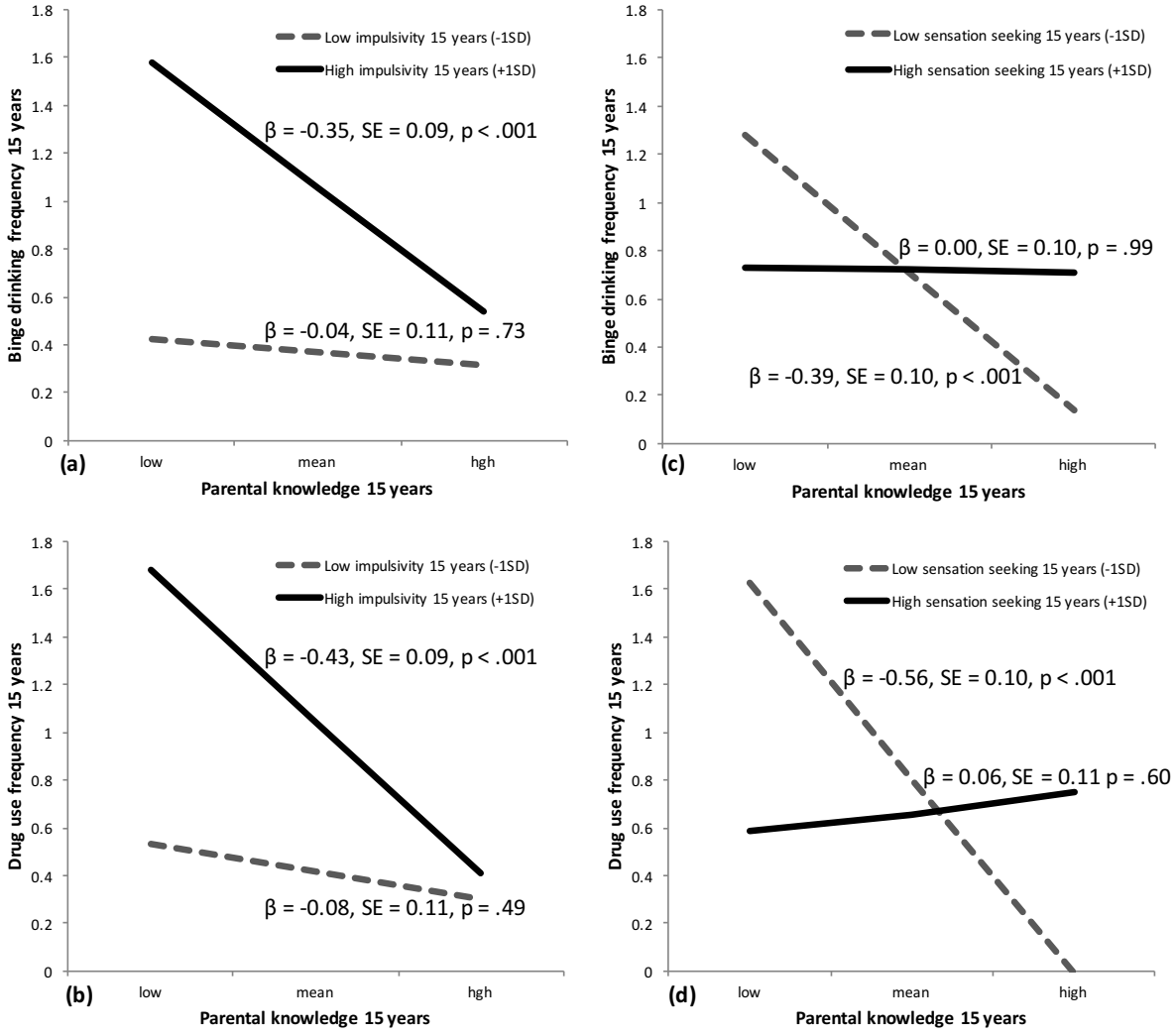
*Notes.* * $p < 0.05$; ** $p < .01$; ***$p < .001$.

[1]Results were the same for cannabis and other drugs when examined separately.

[2] 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).

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%.*



**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.

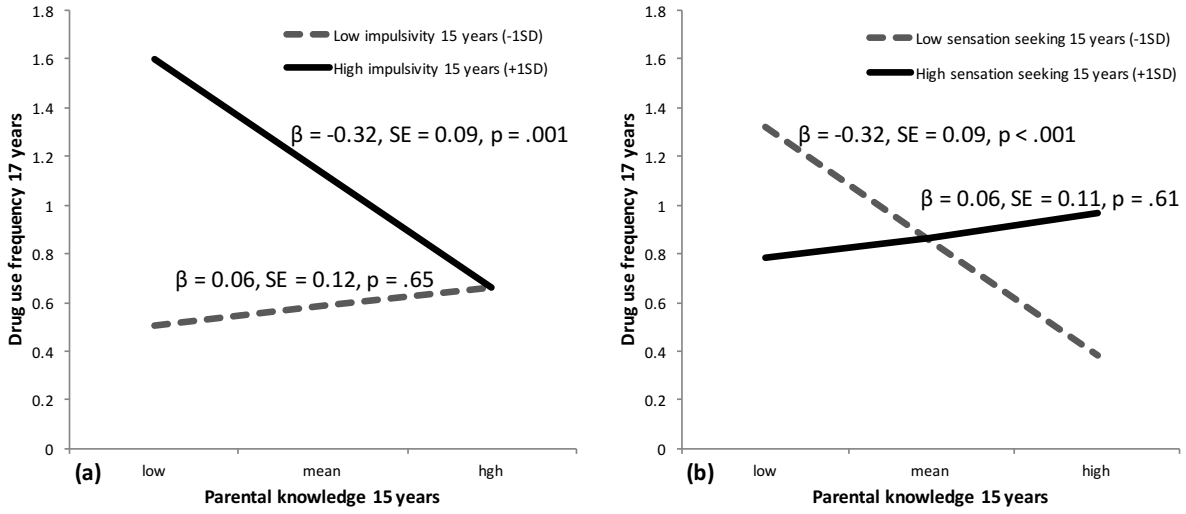
There was no interaction of parental knowledge with impulsivity or sensation seeking at 15 years in the prediction of binge drinking frequency at 17 years, but interactions were found in the prediction of drug use frequency, which were similar to those found with drug use at 15 years. Indeed, an interaction 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 adolescents higher and lower on impulsivity differed on their drug use 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 adolescents higher and lower on sensation seeking differed on their drug use 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.

Figure 2
*(a) Parental knowledge by impulsivity interaction and (b) parental knowledge by sensation seeking interaction predicting drug use frequency at 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 (Ryan et al., 2010; Stautz & Cooper, 2013). 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 (Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016).

Accordingly, this suggests a 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 (Epstein et al., 2017). 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 (Coskunpinar, Dir, & Cyders, 2013; Magid & Colder, 2007). 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 (Thompson, Roemer, & Leadbeater, 2015). Another

possible explanation could involve lower tolerance for arousal and higher stress response in low sensation-seekers (Roberti, 2003): for low sensation-seekers, an unsupportive familial environment may be associated with higher levels of anxiety (Frojd, Kaltiala-Heino, & Rimpela, 2007), and this anxiety may, in turn, explain higher levels of substance use (Lai, Cleary, Sitharthan, & Hunt, 2015). As low parental knowledge is associated with other aspects of the familial environment, including lower quality of the parent-child relationship (Malczyk & Lawson, 2017), lower parent-child communication (Ying et al., 2015) and lower parent sensitivity (Vaughn et al., 2016), 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 (Bevilacqua & Goldman, 2013; Dick et al., 2010). 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 (Castellanos-Ryan & Conrod, 2012). 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., Castellanos-Ryan & Conrod, 2011; Castellanos-Ryan, Parent, Vitaro, Tremblay, & Séguin, 2013; Collado, Felton, MacPherson, & Lejuez, 2014), and recent research found that sensation seeking did not fit within the latent structure of impulsivity measures (MacKillop et al., 2016). 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 (Van Ryzin, Fosco, & Dishion, 2012). 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 (Institut de la statistique du Québec, 2014; Johnston et al., 2016), 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 (Barker et al., 2011; Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). 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 (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). 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 (Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016). 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 replicate this finding, but 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 (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). 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 (Grabe et al., 2012; Keers & Pluess, 2017; Kumsta et al., 2010; Starr, Hammen, Conway, Raposa, & Brennan, 2014); 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 (Aron, Aron, & Jagiellowicz, 2012; Belsky & Pluess, 2009). A study of interactions between "plasticity alleles" and parenting in adolescence also supported differential susceptibility in the prediction of parental stress in adulthood (Beaver & Belsky, 2012). 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 (Graham, 2009; Gustavson, von Soest, Karevold, & Roysamb, 2012) 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 (Hagman, Cohn, Noel, & Clifford, 2010; Laforge, Borsari, & Baer, 2005), 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 (Bakermans-Kranenburg & van IJzendoorn, 2015), and looking at temperament-intervention interactions in the prediction of attachment security (Cassidy, Woodhouse, Sherman, Stupica, & Lejuez, 2011) and oppositional behaviors (Scott &

O'Connor, 2012). 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 (Slagt, Dubas, van Aken, Ellis, & Dekovic, 2017).

**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 (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). 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 (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016; Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016).

## Compliance with Ethical Standards

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**Conflict of Interest** The authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national 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.

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### 2.3.2. Transition entre les articles 3 et 4

Les trois premiers articles de thèse ont comparé les modèles de la diathèse-stress et de la sensibilité différentielle pour prédire la consommation de substances à l'adolescence, la revue de littérature du premier article ayant également examiné les comportements extériorisés en général. Comme mentionné dans l'introduction, les modèles de la diathèse-stress et de la sensibilité différentielle ont été examinés dans la prédiction d'une variété d'issues développementales. Notamment, en plus des comportements extériorisés, des études examinant les modèles ont porté sur les comportements intériorisés, le développement cognitif, la réussite scolaire, les habiletés sociales, le développement pubertaire et l'indice de masse corporelle. Cependant, le modèle de la sensibilité différentielle pourrait s'appliquer à d'autres issues développementales prédites par des interactions personne-environnement. C'est le cas notamment du trouble de la personnalité limite. En effet, le modèle de la diathèse-stress est utilisé en psychiatrie pour expliquer l'étiologie du trouble de la personnalité limite. Cependant, la possibilité que ce trouble puisse être conçu selon la perspective de la sensibilité différentielle n'a pas été examinée. En effet, plusieurs caractéristiques personnelles associées au trouble de la personnalité limite (p.ex., réactivité émotionnelle, impulsivité) pourraient refléter une sensibilité aux environnements positifs et négatifs plutôt que seulement une vulnérabilité aux environnements négatifs. Le quatrième article de thèse présente ainsi une perspective portant sur comment le modèle de la sensibilité différentielle pourrait s'appliquer au trouble de la personnalité limite.

## 2.4. Quatrième article

# Perspective: Differential Susceptibility to the Environment and Borderline Personality Disorder

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Objectifs spécifiques de cet article: Présenter comment le modèle de la sensibilité différentielle pourrait s'appliquer au trouble de la personnalité limite.

**Statut: Sous presse, *Harvard Review of Psychiatry***

## Contribution des auteurs

**Charlie Rioux:** Conceptualisation de l'article, recension des écrits, rédaction de l'article.

**Jean Séguin:** Révision de l'article.

**Joel Paris:** Conceptualisation de l'article, recension des écrits, rédaction de l'article.

Abstract

Evolutionary models of psychopathology can shed light on gene-environment interactions. Differential susceptibility to the environment means that heritable traits can have positive or negative effects depending on environmental context. Thus, traits that increase risk for mental disorders when the environment is negative can be adaptive when the environment is positive. This model can be applied to borderline personality disorder, viewing predictors such as emotional dysregulation and impulsivity, as temperamental variations leading to negative effects in an unfavorable environment, but to positive effects in a favorable environment. This model may also be useful in conceptualizing the mechanisms of effective therapy for borderline personality disorder.

*Keywords:* Borderline Personality Disorder, Human Development, Environment, Gene-Environment Interaction, Family

## Perspective: Differential Susceptibility to the Environment and Borderline Personality Disorder

### Basic Principles of Evolutionary Psychiatry

Since natural selection shapes mind and brain, evolutionary theory can make a major contribution to the understanding of the causes of psychopathology (Brune, 2015). The heritability of mental disorders, and of personality traits, has been strongly supported by the findings of behavior genetic research (Jang, 2005; Plomin, DeFries, Knopik, & Neiderhiser, 2013). Twin studies show that virtually all traits that affect behavior, emotion, and cognition have a genetic component that accounts for about half the variance in the outcome, while an environmental component accounts for the other half of the variance (Jang, 2005; Plomin et al., 2013; Turkheimer, 2000).

Traits that underlie variations in susceptibility to medical and psychiatric illnesses are also subject to natural selection (Nesse & Williams, 1993). But selection does not necessarily remove these variations from the gene pool. Moreover, not all heritable traits produce optimal outcomes, and some that are preserved in the population seem at first sight to be maladaptive. One explanation could be that these characteristics become problematic under one set of circumstances, but advantageous under another set of circumstances (Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2007). In this model, traits associated with illness are not just markers for vulnerability: what is inherited is not necessarily susceptibility to disorder, but tendencies to respond to the environment in specific ways. Thus, depending on whether the rearing environment is stressful or supportive, personality trait variations can lead to positive or negative outcomes (Belsky & Pluess, 2009b).

One example concerns one of the most common of all mental illnesses, clinical depression. While severe depression is maladaptive, milder forms may not be, but can reflect an adaptive response to defeat that is associated with greater resilience (Price, Sloman, Gardner, Gilbert, & Rohde, 1994). There may also be a link between depression and other adaptive traits; for example, several studies suggest that mood disorders can be associated with higher levels of creativity (Andreasen, 1987; Santosa et al., 2007; Simeonova, Chang, Strong, & Ketter, 2005; Strong et al., 2007).

Personality disorders provide an even better example. These conditions can be understood as pathological amplifications of normal variations in personality (Costa & Widiger, 2013). For example, compulsive traits can be associated with persistence and reliability, and narcissistic traits can be associated with ambition and optimism (Beck, Davis, & Freeman, 2015). Thus, these traits can be adaptive under some circumstances, while a personality disorder can emerge from interactions with an adverse environment (Livesley, 2003).

**Differential Susceptibility to the Environment**

The social environment can have a significant influence on development. On the one hand, *adverse environments*, which are characterized by stressors such as child maltreatment, insensitive parenting or negative life events, are associated with a higher occurrence of mental health symptoms. On the other hand, *positive environments*, characterized by supportive and enriching experiences as well as by the absence of adversity, can be beneficial and are associated with a lower occurrence of mental health symptoms.

According to Life history theory, biological traits such as growth rate, age, body size at sexual maturation, number of offspring, and length of lifespan are modeled by environmental

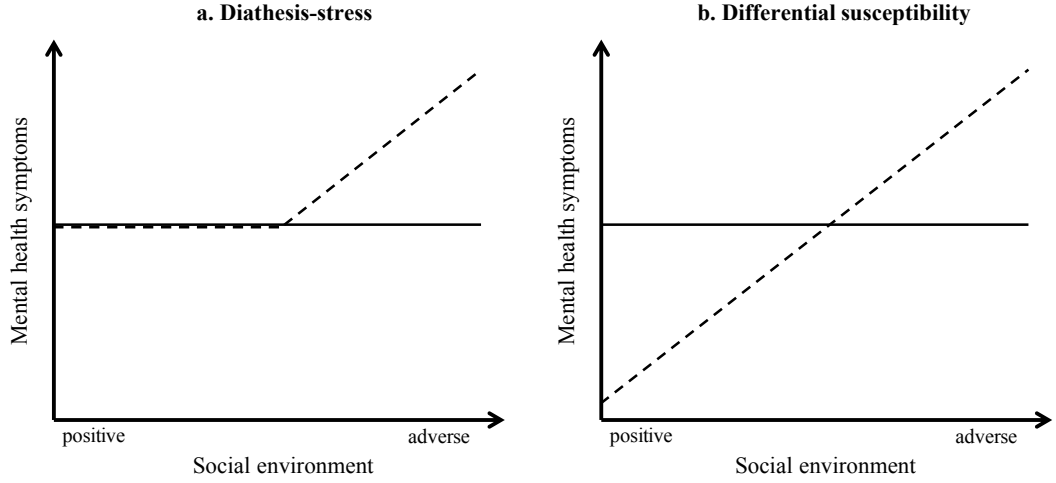
conditions. At a psychosocial level, children raised in positive environments would see the world as safe, and thus pursue *slower life history strategies*, which include maturing and reproducing later and forming stable long-term relationships. Life history theory also suggests that a less optimal development resulting from adverse environments could also be adaptive from an evolutionary standpoint. Accordingly, children raised in adverse environments would see the world as unpredictable, and thus pursue *faster life history strategies*, which include earlier maturation, sexual activity and reproduction (Belsky, Steinberg, & Draper, 1991; B. J. Ellis, 2004; Stearns, 1992). But faster life histories could also be maladaptive and associated with psychopathology (e.g., emotional dysregulation, impulsivity, lack of trustworthiness) (Brüne, 2014, 2016). In a similar manner, it has been suggested that the brain may be conditioned by an adverse environment early in life in such a way as to allow the individual to prepare and adapt to life-long stress or deprivation (Teicher et al., 2003; Teicher, Samson, Anderson, & Ohashi, 2016). However, the view that the environment alone can be considered as a single influence on the development of psychiatric disorders has shown its limits, and one must consider its interaction with individual factors. Indeed, individuals may vary in the degree to which they are influenced by the environment, and thus a person-environment interactive framework may help to fully understand and integrate the associations between the environment, life history strategies, brain development and psychiatric disorders.

*Differential susceptibility to the environment* (Belsky & Pluess, 2009a; Belsky, Pluess, & Widaman, 2013) is a construct that illuminates some of the mechanisms behind person-environment interactions in psychopathology. The theory has been proposed as an alternative to the well-known diathesis-stress framework (Monroe & Simons, 1991). Indeed, the diathesis-stress model tends to be used in both clinical and research settings to explain

interactions between environmental and individual characteristics and suggests that more "vulnerable" individuals will develop mental disorders when exposed to adverse environments, while more "resilient" individuals will remain healthy regardless of their environment (Monroe & Simons, 1991; see Figure 1). In contrast, the differential susceptibility theory, based on evolutionary biology, proposes that "susceptible" individuals will do worse than average when exposed to an adverse environment, but better than average in a positive environment (Belsky & Pluess, 2009a; see Figure 1). Thus, these individuals can be considered more malleable when exposed to both positive and adverse environmental influences, rather than only vulnerable to adverse environmental influences as the diathesis-stress model suggests. Because the same genetic potential can lead to a positive or negative outcome, this theory helps explain why alleles associated with both high and low susceptibility to pathology are retained in the gene pool. Indeed, having children with varying levels of

Figure 1

*Graphical representation of (a) the diathesis-stress model and (b) the differential susceptibility model. The continuous line represents variations in mental health across environments for resilient traits, and dashed line represents vulnerability or susceptibility traits.*



susceptibility to rearing influences within the same family would be expected to maximize reproductive fitness. On the one hand, in an adverse environment, resilient children will not reap the costs of the negative environment and thus maximize reproductive fitness within that environment. On the other hand, in a positive environment, more susceptible children will reap the most benefits from the environment, which will maximize reproductive fitness (Belsky, 2005). As Simpson and Belsky (2016; p. 109) point out: "…differential susceptibility could be adaptive… if a parent's attempt to "prepare" his or her children for the future environment is mistaken due to inherent unpredictability of future conditions". Using a similar theoretical model, Boyce and Ellis (2005) suggest that "biological sensitivity to context" is a variable trait that regulates stress reactivity.

Empirical support for one or the other theoretical model can be obtained by careful examination and statistical testing of interaction patterns (Belsky et al., 2014; Del Giudice, 2017; Roisman et al., 2012; Widaman et al., 2012) - which was not done before the differential susceptibility model was highlighted as an alternative to the diathesis-stress model. Thus, older research examining person-environment interactions operated on the assumption that statistical interactions supported a diathesis-stress model and were consequently not designed to rule out the differential susceptibility hypothesis. Indeed, a growing number of re-analyzes of previous studies on person-environment interactions initially conducted within a diathesis-stress framework now reveal the conditions under which there is support for the differential susceptibility models (Belsky & Pluess, 2009a; Rioux, Castellanos-Ryan, Parent, & Séguin, 2016).

The concept of differential susceptibility has gained momentum in recent years and has stimulated a body of research with much evidence that now supports its complementarity to

the diathesis-stress model in understanding developmental psychopathology. Dozens of studies providing support for the model have been reviewed elsewhere (Belsky & Pluess, 2009a, 2013; Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). Examples are given here to provide an idea of the wide range of the evidence supporting the model. Some studies have focused on observable characteristics as susceptibility factors, the most studied being temperament, which represents individual differences in behavior-influencing traits that appear early and are relatively stable across situations and time (Goldsmith et al., 1987; Rothbart & Bates, 2006; Shiner et al., 2012). Specific temperament dimensions are studied (e.g., impulsivity, inhibitory control, activity level, negative emotionality, harm avoidance), as well as overarching temperament profile, which are a cluster of temperamental dimensions, the most commonly used being the easy and difficult temperament profiles (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016); a child with a difficult temperament usually has irregular eating and sleeping daily routines, withdraws from people and novel stimuli, is inflexible to changes in the environment, has high intensity responses and an irritable mood (Thomas & Chess, 1977).

Studies on interactions between temperament (both specific dimensions and overarching profiles) and the familial environment have showed support for differential susceptibility in the prediction of several developmental outcomes. For example, a longitudinal study examined interactions between impulsivity and coercive parenting (i.e., use of harsh physical and/or verbal discipline) and found that highly impulsive 6-year-old children were more vulnerable to high levels of coercive parenting than less impulsive children, but also benefited more from low levels of coercive parenting when predicting alcohol use at 15 years (Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016). Regarding overarching

temperament profiles, a recent meta-analysis of research on the interaction between temperament and parenting practices within a differential susceptibility framework concluded that "children with a more difficult temperament (compared with those with a more easy temperament) were more vulnerable to negative parenting, but also profited more from positive parenting, supporting the differential susceptibility model. Differences in susceptibility were expressed in externalizing and internalizing problems and in social and cognitive competence" (Slagt, Dubas, Dekovic, & van Aken, 2016; p.216) Of note, and possibly relevant to prevention and intervention, environmental influences outside of the family were also found to interact with temperament, supporting differential susceptibility. For example, highly disinhibited 7-year-old children had high levels of mental health symptoms at 13 years when teacher-child closeness was lower, but also lower mental health symptoms than more inhibited children when teacher-child closeness was higher (Essex, Armstrong, Burk, Goldsmith, & Boyce, 2011).

The same principle has been applied to other observable characteristics than temperament, notably perceptual sensitivity. Aron and Aron (1997) found that some individuals are unusually sensitive, not only to life experiences, but also to sensory input, which they refer to as sensory-processing sensitivity or more generally as high sensitive personality. Studies have found that this trait that can be both positive or negative depending on environmental factors (Aron, Aron, & Jagiellowicz, 2012; Belsky & Pluess, 2009a), suggesting that it could be a good indicator of susceptibility.

Gene-environment interactions have also been an important focus in differential susceptibility research, with most research focusing on the serotonin transporter linked polymorphic region (5-HTTLPR) and the dopamine receptor D4 gene (DRD4). Once again,

research has found interactions with the familial environment. For example, interactions supporting the differential susceptibility model were found between 5-HTTLPR and child maltreatment in the prediction of antisocial behaviors (Cicchetti, Rogosch, & Thibodeau, 2012) and between DRD4 and maternal positivity in the prediction of prosocial behavior (Knafo, Israel, & Ebstein, 2011). Genes can also be indicators of sensitivity to environmental influences outside of the family. For example, one study found an interaction between peer behaviors and a genetic variation affecting the 5HTTLPR allele that supported the differential susceptibility model in the prediction of substance use (Daw et al., 2013). Another study found that an interaction between 5HTTLPR and racial discrimination predicted conduct problems, supporting differential susceptibility (Brody et al., 2011). Finally, a meta-analysis also found that carriers of risk genotypes benefit more from interventions changing the environment for the better than other individuals, providing experimental support for differential susceptibility (Bakermans-Kranenburg & van IJzendoorn, 2015).

A last type of susceptibility factor examined in differential susceptibility research is physiological reactivity, including cardiovascular reactivity, sympathetic nervous system reactivity and parasympathetic nervous system reactivity. With the familial environment, interactions supporting the differential susceptibility model have been found, for example, when looking at cortisol reactivity and stressful family life events in the prediction of externalizing problems (Steeger, Cook, & Connell, 2017) and when looking at respiratory sinus arrhythmia reactivity and marital conflict in the prediction of externalizing problems (Obradovic, Bush, & Boyce, 2011). With other environmental factors, a study supported differential susceptibility with an interaction between mean arterial pressure and the teacher-child relationship in the prediction of mental health symptoms (Essex et al., 2011).

**Relationship to Etiological Theories of Borderline Personality Disorder**

The etiology of borderline personality disorder has often been viewed as shaped by an adverse childhood environment. However, behavior genetic studies (Reichborn-Kjennerud et al., 2013; Torgersen et al., 2000) have shown that only half of the variance affecting an outcome of borderline personality disorder is accounted for by environmental factors, and the other half of the variance affecting this disorder is heritable. This suggests that interactions between genes and the environment may account best for the pathways to borderline personality disorder (Carpenter, Tomko, Trull, & Boomsma, 2013). This model would parallel the model developed by Caspi and Moffit (2006) for antisocial behavior, i.e., that neither genetic vulnerability nor environmental adversity alone are sufficient to produce pathology, but that a combination of both factors carries a significant risk.

The complexity of pathways to borderline personality disorder shows both multifinality and equifinality (Cicchetti & Rogosch, 2002). On the one hand, multifinality implies that different outcomes can result from a same starting point, and thus risk factors associated with borderline personality disorder can lead to many different forms of psychopathology. On the other hand, equifinality implies that a common outcome can result from different starting points and thus patients who develop borderline personality disorder can differ in the proportion of interacting genetic and environmental risk factors. One cannot therefore assume that any risk factor must be present simply because it is frequently associated with a clinical diagnosis.

The core trait underlying borderline personality disorder is emotion dysregulation (Linehan, 1993). In borderline personality disorder, emotions are highly susceptible to the social environment, leading to sharp peaks of reactivity to adverse events, with a longer time

needed to return to normal levels (Linehan, 1993). This key feature of borderline personality disorder has been shown to be heritable (Jang, 2005). Emotional dysregulation reflects unusually high levels of trait neuroticism, i.e., elevated reactivity to life events (Costa & Widiger, 2013). But borderline personality disorder patients do not necessarily react negatively to all events, and are most likely to do so when faced with trigger stimuli such as interpersonal rejection (Dixon-Gordon, Yiu, & Chapman, 2013; Sauer, Arens, Stopsack, Spitzer, & Barnow, 2014) or shame (Gratz, Rosenthal, Tull, Lejuez, & Gunderson, 2010). Since their lives are often marked by the choice of unstable attachment figures, this helps explain why borderline personality disorder patients often describe their emotional life as a "roller coaster".

The precise biological mechanisms behind the heritable vulnerability to borderline personality disorder are unknown. Some of the possibilities under investigation include: variations in the activity of oxytocin levels that modulate the attachment system (Brune, 2016; Hammen, Bower, & Cole, 2015); dopaminergic regulation of reward systems related to positive emotionality, as well as serotonergic regulation of mood and impulsivity related to emotional dysregulation (Moore & Depue, 2016). Variations in the activity of all these neurotransmitters seem to be associated with differential susceptibility to the environment (Belsky & Pluess, 2009b).

These theories, based mainly on neurotransmitter systems, may be too simple. Complex traits are not associated with single brain systems or single variations in neurochemistry, but with interactions between multiple systems (Ruocco & Carcone, 2016). This is consistent with the finding that genome-wide association studies have generally reported variations of a very large number of alleles that are associated with most mental

disorders (Ripke et al., 2014). In borderline personality disorder, while there have been many theories about its neurobiology, no biomarkers have been shown to have a consistent or specific relationship to the disorder (Paris, 2015). In any case, biological mechanisms for vulnerability can only be understood in the context of gene-environment interactions (Carpenter et al., 2013).

The literature on childhood adversity as a risk factor for borderline personality disorder can also be understood as consistent with gene-environment interactions. The most common childhood adversities reported by borderline personality disorder patients include dysfunctional families, sexual and/or physical abuse, and emotional neglect (Zanarini, 2000). However, none of these experiences, by themselves, predict the development of a mental disorder or a personality disorder. Even in the face of serious adversity, most children are resilient to adverse experiences. For example, it is rare for sibling pairs in which one has borderline personality disorder to develop the same disorder (5% of cases), even when they experience the same problematic family environment (Laporte, Paris, Guttman, & Russell, 2011; Laporte, Paris, Guttman, Russell, & Correa, 2012). Instead, non-borderline siblings have a very different temperament, as measured by personality trait profiles. Once again, the explanation lies in gene-environment interactions. A review of studies that have specifically examined gene-environment interactions in borderline personality disorder (Carpenter et al., 2013) concluded that some evidence points to significant interactions between genes and environmental influences such as divorce/break-up, violent assault, sexual assault, and job loss. They also concluded that genes influencing borderline features increase the likelihood of being exposed to these adverse life events.

**Differential Susceptibility and the Traits Underlying Borderline Personality Disorder**

As previously described, the model of differential susceptibility to the environment differs from classical models of diathesis-stress (Belsky & Pluess, 2009a; Monroe & Simons, 1991). It hypothesizes a relationship between genes and environment that is not simply additive or subtractive, but one that determines how environmental factors shape pathological outcomes depending on an individual's plasticity to the environment.

Many clinical features of borderline personality disorder, such as severe mood instability and self-harm, are maladaptive. Moreover, borderline personality disorder reduces fertility and seriously shortens the life span (Fok et al., 2012). One might therefore ask why this disorder has not been selected out of the population. But if the traits that put individuals at risk of developing borderline personality disorder actually reflect differential susceptibility to the environment, they could lead to borderline personality disorder in adverse environments, but also be adaptive in a positive environment. This differential susceptibility to environmental influences is highlighted by a metaphor differentiating between "orchid" and "dandelion" children (Boyce & Ellis, 2005; Gunnar, 2016). According to this metaphor, most children can, like dandelions, flourish in a wide range of environments. However, children with a trait that put them at risk for borderline personality disorder are, like orchids, more dependent on their environment - they will not adapt when neglected, but they can flourish and surpass their peers when they have access to sufficient levels of psychological "nutrients". This hypothesis has not yet been directly tested with borderline personality disorder as an outcome, but it could be.

Some traits associated with a higher risk of developing borderline personality disorder or higher levels of borderline personality disorder symptoms could lead to either positive or

negative outcomes. A good example concerns emotional dysregulation. This core trait has been widely researched in borderline personality disorder, using self-report scales (Gratz & Roemer, 2008; Nock, Wedig, Holmberg, & Hooley, 2008) and event-contingent recording methods providing a more immediate self-assessment of emotional response (Ebner-Priemer et al., 2007; Russell, Moskowitz, Sookman, & Paris, 2007). But less attention has been paid to the possibility that higher levels of emotional reactivity, which is likely at the root of emotional dysregulation, can sometimes be helpful and adaptive. Thus, a highly reactive person could experience not only intense negative feelings, but also more positive emotions. For example, while emotional reactivity is associated with externalizing disorders, longitudinal studies show that it does not necessarily produce psychopathology (Levenson, Aldwin, Bosse, & Spiro, 1988). Moreover, people who are emotional and extraverted tend to be attractive to others (Meier, Robinson, Carter, & Hinsz, 2010). Interestingly, emotional reactivity is already seen early in development through children's temperament, with the temperament trait of negative emotionality representing a proneness to negative emotional experiences such as frustration, fear and shyness (L. K. Ellis, 2002). Developmental studies have shown that this temperament trait interacts with the environment, supporting differential susceptibility in the prediction of externalizing problems (Kim & Kochanska, 2012) and executive function (Raver, Blair, Willoughby, & The Family Life Project Key Investigators, 2013), which could be explained by an increase in the role of sensitive parenting and parent-child mutuality for children high on negative emotionality. Indeed, it has been suggested that more skillful mothers may be more responsive to their child's emotional cues and thus provide adequate guidance to support the development of their child's regulatory skills (Crockenberg, Leerkes, & Jo, 2008). A parent-child relationship promoting self-regulatory capacity may be

particularly consequential for children high on negative emotionality, with a particularly sensitive and responsive parenting style leading to superior developmental outcomes (Kim & Kochanska, 2012). As temperamental negative emotionality has already been shown to be associated with borderline personality disorder (Carlson, Egeland, & Sroufe, 2009), it could be tested as an early susceptibility factor for later borderline personality disorder symptoms.

Impulsivity, the second core trait behind borderline personality disorder (Crowell, Beauchaine, & Linehan, 2009), manifested by self-harm, parasuicidal actions, and substance use, is the feature that brings most patients to clinical attention. It has also been shown that the environment has a key role to play in the expression of impulsivity, as borderline patients who experience multiple childhood adversities are more likely to have multiple impulsive suicide attempts (Soloff, Lynch, & Kelly, 2002). Yet variations in trait impulsivity could also be adaptive or maladaptive depending on circumstances. While it is often better to be cautious than impulsive, it is also possible to be over-cautious: a trait associated with a tendency to rapid action can be adaptive under the right circumstances. Consider, for example, the responses to danger expected from soldiers and police officers, in that effective work requires rapid action. In this case, the tendency for rapid action would be adaptive since the consequences of actions are properly considered. Still, even when the consequences of one's actions are not considered, impulsivity can be adaptive. Temperamental impulsivity has been shown to be a susceptibility factor in the prediction of externalizing behaviors, substance use and depressive symptoms (Belsky & Pluess, 2009a; Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). It has been suggested that impulsivity could act as a susceptibility factor because of the novelty-seeking tendency associated with this temperamental trait, which could lead to more developmental opportunities when there is proper guidance from meaningful

adults (Rioux, Castellanos-Ryan, Parent, Vitaro, et al., 2016). Thus, early impulsivity could be expected to have a similar interaction with the environment in the prediction of borderline personality disorder symptoms.

The third core characteristic of borderline personality disorder, disturbed relationships, has traditionally been conceptualized as determined by the environment. However, it has been argued in recent years that this characteristic could be central to the disorder and have phenotypic origins (Gunderson, 2007). Some early individual characteristics have been suggested as predictors of the disturbed relationships phenotype, and include the serotonergic and dopaminergic systems, as well as distress-prone and more irritable temperaments (Gunderson & Lyons-Ruth, 2008). These characteristics need to be researched in the context of borderline personality disorder as they could interact with the social environment in a differential susceptibility manner when predicting the disturbed relationships phenotype.

The characteristics of people at risk for borderline personality disorder have been described by evolutionary biologists as a "Hawk" temperamental phenotype, which is an overarching temperament profile characterized by a quick and impulsive approach, an expectation of reward, and tendencies toward irritability or frustration (Smith & Price, 1973). This helps us understand why borderline personality disorder patients are so often attracted to high-stimuli environments. However, the Hawk phenotype is also a marker for differential susceptibility; research shows that children with Hawk-like temperaments show both greater maladjustment with poor quality parenting environments but better psychological adjustment with high quality parenting environments. Indeed, it was found that 4.6-year-old children high in the Hawk temperament profile increased more on aggression over 3 years than children low on the Hawk temperament profile when parental intrusive control was high, but increased less

on aggression than low-Hawk temperament children when parental intrusive control was low. Similarly, high-Hawk temperament children increased more on depression than low-Hawk temperament children when sensitive parenting was low, but increased less on depression than low-Hawk temperament children when sensitive parenting was high (Hentges, 2015). Other temperamental traits that have been shown to be associated with borderline personality disorder and could be looked at as potential susceptibility factors in future research include activity level (Carlson et al., 2009) and harm avoidance (Arens, Grabe, Spitzer, & Barnow, 2011).

While temperament and personality characteristics are most definitely potential susceptibility factors for borderline personality disorder, gene-environment interactions have also been a focus in differential susceptibility research and could predict borderline personality disorder symptoms. Indeed, gene-environment interactions have been found to predict borderline personality disorder in some studies, although the differential susceptibility hypothesis was not tested. Genes interacting with the environment to predict borderline personality disorder symptoms include the serotonin transporter gene (5-HTTLPR), the brain-derived neurotrophic factor gene (BDNF) and the catechol-O-methyltransferase gene (COMPT) (Amad, Ramoz, Thomas, Jardri, & Gorwood, 2014), which have been shown to interact with the environment in a differential susceptibility manner when predicting other developmental outcomes (Belsky & Pluess, 2009a, 2013). Beyond temperament and personality traits, physiological reactivity is another interesting marker that could be studied. Notably, lower resting vagal tone has been suggested as a biological vulnerability factor for borderline personality disorder symptoms because of its association with emotional dysregulation (Koenig, Kemp, Feeling, Thayer, & Kaess, 2016; Kuo & Linehan, 2009) but

could serve as a susceptibility factor, especially considering research on anxiety (Belsky & Pluess, 2009a) and aggression (Eisenberg et al., 2012) that supported the differential susceptibility model.

As can be seen, several personal characteristics could potentially act as susceptibility factors for borderline personality disorder symptoms, making individuals at risk for borderline personality disorder in adverse environments, but also making them more likely to experience better than average outcomes in positive environments. Indeed, the literature suggests that several temperament traits, including negative emotionality, impulsivity, the Hawk phenotype, activity level and harm avoidance, as well as genes and vagal tone, could be potential susceptibility factors for borderline personality disorder. Within all the temperament traits identified, harm avoidance and negative emotionality have already been shown to interact with the environment in the prediction of borderline personality disorder (Arens et al., 2011; Haltigan & Vaillancourt, 2016), but these interactions were not fully tested within a differential susceptibility framework.

**Testing the Proposed Hypotheses**

Since all the individual characteristics identified in the previous section have not been rigorously tested as susceptibility factors in interaction with the environment to predict borderline personality disorder symptoms, research examining the differential susceptibility model with borderline personality disorder is needed. As a first step, previous studies on person-environment interactions could be re-examined to see whether they potentially supported the differential susceptibility model (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). While this is a useful first step, this method is more liberal than what can be accomplished by fully analyzing one's data, and thus studies examining the differential

susceptibility model a priori would still be needed in a second step. When conducting studies examining differential susceptibility, traditional methodologies used to assess person-environment interactions remain relevant, although ideally one should choose an environmental measure representing the full range of environmental influence, from the negative to the positive. However, statistical analyses will differ, with traditional interaction tests have to be supplemented with additional analyses.

There are now specific guidelines to test for differential susceptibility using linear regressions to test interaction effects (Frazier, Tix, & Barron, 2004). These guidelines specify criteria for distinguishing diathesis-stress from differential susceptibility. The main visual difference between interactions supporting either model concerns the presence or absence of a crossover point, which is a point in the interaction graph where the two regression lines intersect. Support for the diathesis-stress model is obtained when the individual characteristic is associated with the outcome and an ordinal interaction (i.e., without a crossover point; see Figure 1a) is found. In contrast, support for the differential susceptibility model is obtained when the individual characteristic is not associated with the outcome and a disordinal interaction (i.e., with a crossover point; see Figure 1b) is found. Furthermore, for both models, the slope of the vulnerable or susceptible group (e.g., individuals high in impulsivity or negative emotionality) has to be significantly different from zero and significantly steeper than the slope of the non-vulnerable or susceptible group (e.g., those low in impulsivity or negative emotionality).

While visual appraisal of the interaction was previously considered sufficient to determine whether the interaction is ordinal or disordinal, further statistical testing is now required to confirm the shape of the interaction. The option used in most studies is to conduct

a *region-of-significance* analysis and the quantification of the proportion of the interaction representing a "for better" effect (see Roisman et al. (2012) and Del Giudice (2017) for details on this approach). More recently, the estimation of the crossover point and its confidence interval has been suggested (Widaman et al., 2012), but it has been shown to be unreliable in small samples ($n < 500$; Lee, Lei, & Brody, 2015). Finally, an alternative to multiple regression is a model-fitting approach, where the differential susceptibility and diathesis-stress models are directly compared without first testing for significant interactions (see Belsky et al., 2013 for details).

**Clinical Implications for Borderline Personality Disorder Treatment**

Finding support for differential susceptibility in borderline personality disorder would have implications for its clinical conceptualization. Indeed, differential susceptibility is normally used to predict continuous outcomes, i.e., levels of developmental problems or psychopathology. While borderline personality disorder is currently clinically defined as the presence or absence of a set number of symptoms, the interaction between susceptibility factors and the environment would most likely predict the severity of borderline personality disorder symptoms, ranging from absent to severe, and not the presence or absence of a borderline personality disorder diagnosis. Indeed, it would make the most sense for levels of environmental adversity to be associated with varying levels of borderline symptom severity. Research on differential susceptibility and borderline personality disorder would thus contribute to the definition of the etiology of borderline personality disorder and to clarify the categorical-dimensional controversy (Paris, 2014).

Clarifying how individual characteristics interact with the environment to predict borderline personality disorder symptomatology would allow the development of early

prevention programs. As far as we know, pre-pubertal programs to prevent borderline personality disorder have never been developed, in part because of a lack of research on the developmental risk and protective factors associated with borderline personality disorder (Chanen & McCutcheon, 2013; Chanen, McCutcheon, Jovev, Jackson, & McGorry, 2007). Research on differential susceptibility would contribute to the identification of these early risk and protective factors. If with such research child temperament or early physiological reactivity is found to be associated with borderline personality disorder *when in an adverse familial environment*, parenting or familial interventions could prove effective in reducing the negative effects of this environment, including borderline personality disorder symptoms. Interventions in child care facilities or schools could also be beneficial since these environments have been shown to interact with temperament in predicting developmental outcomes (Belsky & Pluess, 2012; Essex et al., 2011; Mortensen & Barnett, 2015; Pluess & Belsky, 2009, 2010), but their relative importance for such outcomes would need to be compared with the familial environment. Furthermore, identifying children more susceptible to their environment and at risk for borderline personality disorder would allow targeted interventions, which could be useful as universal prevention programs are not considered practical due to the low prevalence of borderline personality disorder (Chanen & McCutcheon, 2013).

In a clinical setting, keeping the principle of differential susceptibility to the environment in mind can be helpful to clinicians who aim to understand the life histories of these challenging patients. There has been an unfortunate tendency in psychiatry to blame families when borderline personality disorder develops and to assume that borderline patients must have a history of childhood trauma. The idea that childhood trauma is the main cause of

borderline personality disorder has been influential in clinical settings because it is rather dramatic (Gunderson, 2010). Yet research shows that only a minority of borderline patients have experienced severe childhood trauma (Gunderson, 2010; Paris, Zweigfrank, & Guzder, 1994; Zanarini, 2000), and that the effect size of child abuse in relation to developing the disorder is small (Fossati, Madeddu, & Maffei, 1999). Borderline patients do generally experience deficits in parenting, but they can be subtle, sometimes involving a well-meaning parenting style that fails to understand a child's emotional needs, leading to a failure to validate emotions (Linehan, 1993; Marcoux, Bernier, Séguin, Boike Armerding, & Lyons-Ruth, 2017). Furthermore, as we have seen, children raised in the same family are generally not concordant for borderline personality disorder, even when exposed to similarly adverse parenting (Laporte et al., 2011; Laporte et al., 2012). Even if abuse or emotional neglect can be shown to be main effects in a trajectory leading to borderline personality disorder, this may mask interactions with temperamental factors that govern emotional reactions to the environment in individuals.

An evolutionary model of borderline personality disorder may also be helpful in understanding the mechanisms behind effective therapy. Currently, many treatment methods are based on techniques that modify environmental sensitivity by teaching patients to regulate their emotions (Linehan, 1993). This approach, based on a differential susceptibility perspective (Bakermans-Kranenburg & van IJzendoorn, 2015), can encourage agency and counteract the tendency to attribute psychological problems exclusively to adverse circumstances. The key therapeutic task for borderline patients is to thicken their skin and modulate their reactions to current interpersonal events. While working on borderline patients' susceptibility can be effective, adding an environmental component could also prove useful.

Indeed, if a person-environment interaction predicts the severity of borderline personality disorder symptoms even after the disorder has been diagnosed, one could expect an improvement in the social environment to be associated with an improvement of borderline personality disorder symptoms. Thus, the differential susceptibility hypothesis could potentially be an explanatory mechanism for the effectiveness of therapy. Indeed, therapy can influence the environment for the better in several ways. A trusting relation with a therapist can provide a safe environment, allowing the patient to work on improving the social environment, and in making better choices of partners and friends. The differential susceptibility theory could also influence therapists to think interactively about etiological or therapeutic factors instead of thinking in terms of univariate models.

**Important considerations for the differential susceptibility theory and concluding remarks**

Although person-environment interaction frameworks suggest that differences in developmental plasticity of behavior are related to genotype, plasticity itself is also influenced by the environment. Indeed, plasticity is partly influenced by genes and each individual would have a pre-natally programmed plasticity, with more susceptible individuals presenting more plasticity. However, the degree to which an individual presents plasticity at a specific time in development will be a function of the interaction between this pre-natally programmed plasticity and previous environmental influences (Pluess, Stevens, & Belsky, 2013). Thus, there might not only be individual variations in plasticity, but also developmental windows when certain individuals may show greater plasticity (Belsky & Pluess, 2013; B. J. Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2011).

If plasticity can change across development, an important aspect to take into consideration is whether the person-environment interaction proposed here would remain or change across development. Our work showing that temperament likely acts as a susceptibility factor for externalizing behaviors in childhood also suggests that it may be a vulnerability factor supporting diathesis-stress in adolescence (Rioux, Castellanos-Ryan, Parent, & Séguin, 2016). Thus, examining the differential susceptibility hypothesis to explain the emergence of borderline personality disorder would also require taking into consideration the developmental period studied. Therefore, and although evidence for differential susceptibility is accumulating, not all person-environment interactions are expected to follow this model. The goal of future research should thus not be proving differential susceptibility over diathesis-stress, but to identify in which circumstances each model applies. Thus, research will have to determine whether diathesis-stress or differential susceptibility best represent interactions between specific personal characteristics and social environments, in the prediction of specific developmental outcomes, and during specific developmental periods.

Finally, as reviewed in this article, person-environment interactions can account for at least part of the development of borderline personality disorder symptoms, and these interactions may follow a differential susceptibility pattern. However, this remains speculative given the lack of research on the subject. Future psychiatric research addressing the diathesis-stress vs. differential susceptibility perspectives will increase our understanding of the etiology of borderline personality disorder by determining whether early individual risk factors for borderline personality disorder support the differential susceptibility model in a "for better and for worse" manner. In turn, this will help inform early prevention programs for borderline personality disorder.

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# 3. Discussion générale

L'objectif principal de la présente thèse visait à examiner les modèles de la diathèse-stress et de la sensibilité différentielle dans le contexte d'interactions entre le tempérament/la personnalité (caractéristiques individuelles) et l'environnement familial dans la prédiction de la consommation de substances à l'adolescence. Le premier article de thèse a examiné ces interactions au moyen d'une revue systématique des écrits antérieurs, alors que les deuxième et troisième articles de thèse, de nature empirique, ont examiné ces interactions dans une cohorte longitudinale d'enfants québécois. Enfin, le quatrième article de thèse ne constituait ni une revue de littérature, ni une analyse empirique, mais étant de nature théorique proposait l'application de ces modèles développementaux au trouble de la personnalité limite.

## 3.1. De la sensibilité différentielle à la diathèse-stress : résultats principaux de la thèse

Le premier article de thèse consistait en une revue de littérature systématique d'études ayant examiné les interactions entre le tempérament et l'environnement familial dans la prédiction de la consommation de substances et des comportements extériorisés en général. Puisque la consommation de substances est considérée comme un type de problème extériorisé (Castellanos-Ryan et al., 2016; Castellanos-Ryan et al., 2014; Eaton, Rodriguez-Seijas, Carragher et Krueger, 2015; Krueger, 1999; Lahey et al., 2012), l'inclusion de comportements extériorisés en général permettait de maximiser le nombre d'études revues. Les résultats ont montré que les interactions observées entre le tempérament et l'environnement familial mesurés *à l'enfance* dans la prédiction de la consommation de substances et des

comportements extériorisés à l'adolescence soutenaient le modèle de la sensibilité différentielle. Cependant, les interactions observées entre le tempérament et l'environnement familial mesurés *à l'adolescence* soutenaient le modèle de la diathèse-stress. Pour arriver à ces conclusions, les graphiques des interactions rapportées dans la littérature furent l'objet d'un examen visuel afin de déterminer s'ils semblaient soutenir le modèle de la diathèse-stress ou de la sensibilité différentielle. Toutefois, cet examen visuel des graphiques ne suffit pas lors de la comparaison de ces modèles. En effet, le test des modèles requiert des analyses plus poussées avec des données complètes qui ne peuvent être réalisées avec des données secondaires de résultats publiés.

Les deux articles suivants de la thèse soutiennent empiriquement les deux conclusions principales de la revue de littérature du premier article. Ainsi, dans le deuxième article de thèse, une interaction entre l'impulsivité et les pratiques maternelles coercitives *à l'enfance* (6 ans) prédisait la fréquence de consommation d'alcool à 15 ans, soutenant le modèle de la sensibilité différentielle. Puis, dans le troisième article de thèse, une interaction entre l'impulsivité et la supervision parentale *à l'adolescence* (15 ans) prédisait la fréquence de beuveries à 15 ans ainsi que la fréquence de consommation de drogues à 15 et 17 ans, soutenant le modèle de la diathèse-stress.

### 3.1.1. Intégration à la littérature récente

Depuis la publication des deux premiers articles de thèse, deux nouvelles études ont examiné les interactions entre les pratiques parentales et le tempérament à l'enfance dans la prédiction de la consommation de substances et des comportements extériorisés à l'adolescence en fonction des modèles de la diathèse-stress et de la sensibilité différentielle. Les résultats de ces études ne vont pas dans le même sens que les conclusions des deux

premiers articles montrant que ces interactions soutiennent le modèle de la sensibilité différentielle lorsque le tempérament et les pratiques parentales sont mesurés à l'enfance. Cependant, des limites méthodologiques peuvent expliquer ces incohérences.

La première étude a examiné l'interaction entre la qualité des pratiques parentales (présence soutenante, respect de l'autonomie, structure et limites, qualité des instructions, hostilité) observées en laboratoire à 5 ans et l'affectivité négative de l'enfant rapportée par la mère à 7 ans dans la prédiction des comportements extériorisés rapportés par l'enseignant à 12 ans (Stoltz, Beijers, Smeekens et Dekovic, 2017). Les résultats ont montré que la qualité des pratiques parentales à 5 ans était associée avec les comportements extériorisés à 12 ans lorsque l'affectivité négative était élevée à 7 ans, mais pas lorsque l'affectivité négative était faible. Les analyses de région de signification indiquaient une différence au niveau des comportements extériorisés en fonction de l'affectivité négative seulement lorsque la qualité des pratiques parentales était faible, soutenant le modèle de la diathèse-stress. Cependant, les indices supplémentaires proposés pour déterminer lequel des modèles était soutenu n'allaient pas dans le même sens, le premier (proportion de l'interaction) étant ambigu quant au modèle soutenu et le second (proportion affectée) soutenant le modèle de la sensibilité différentielle. Le manque de clarté de cette étude quant au modèle soutenu pourrait être dû à un manque de puissance. En effet, l'échantillon de 129 participants est beaucoup plus faible que la taille d'échantillon recommandée pour détecter les effets de sensibilité différentielle (voir section 3.3).

La seconde étude a examiné l'interaction entre la qualité des pratiques parentales (critique, hostilité, pratiques punitives, approbation, acceptation, affection) obtenues par observations à 2 ans et l'impulsivité rapportée par la mère à 2 ans dans la prédiction de

l'agressivité et de la consommation de substances autorapportées par l'adolescent à 12 et 15 ans (Hentges, Shaw et Wang, 2017). Les résultats ont montré qu'il y avait une interaction entre la qualité des pratiques parentales et l'impulsivité dans la prédiction de l'agressivité seulement à 12 ans et de l'agressivité et la consommation de substances à 15 ans. La qualité des pratiques parentales à 2 ans était associée avec l'agressivité à 12 et 15 ans ainsi que la consommation de substances à 15 ans lorsque l'impulsivité à 2 ans était élevée, mais pas lorsqu'elle était faible. Les analyses de région de signification indiquaient une différence au niveau de l'agressivité et de la consommation de substances en fonction de l'impulsivité seulement lorsque la qualité des pratiques parentales était faible, soutenant le modèle de la diathèse-stress. Cependant, aucun des autres indices statistiques recommandés pour comparer les modèles de la diathèse-stress et de la sensibilité différentielle n'a été calculé. De plus, malgré un échantillon plus grand que pour l'étude de Stoltz et al. (2017), l'échantillon de 305 participants signifie que la puissance des analyses de région de signification était relativement faible (voir section 3.3). Ainsi, alors que ces deux études récentes ne vont pas dans le même sens que les résultats des deux premiers articles de la thèse montrant que les interactions entre les pratiques parentales et le tempérament à l'enfance dans la prédiction de la consommation de substances et des comportements extériorisés à l'adolescence soutiennent le modèle de la sensibilité différentielle, ces incohérences pourraient être dues à des limites statistiques et méthodologiques.

### 3.1.2. Mécanismes explicatifs

Plus d'études seront nécessaires pour confirmer les conclusions développementales de la présente thèse, surtout considérant les résultats des études récentes rapportés dans la section précédente. Si les effets développementaux trouvés dans les études de la présente thèse sont

confirmés par d'autres études, les mécanismes expliquant ces changements devront aussi être examinés, soit ce qui expliquerait que l'interaction entre les pratiques parentales et le tempérament à l'enfance dans la prédiction de la consommation de substances et des comportements extériorisés à l'adolescence soutiendrait le modèle de la sensibilité différentielle alors que l'interaction entre ces facteurs à l'adolescence soutiendrait le modèle de la diathèse-stress.

Le changement de la nature de l'interaction en cours de développement pourrait en partie être expliqué par une plasticité face aux influences environnementales à l'adolescence qui serait modifié par les interactions personne-environnement plus tôt dans le développement. Le tout pourrait être reflété par le fait que le tempérament serait le reflet d'influences génétiques au début de la vie et refléterait de plus en plus l'influence de l'environnement avec le temps. En effet, les théories de la personnalité suggèrent que le tempérament serait une caractéristique principalement génétique à la naissance (une influence de l'environnement intra-utérin devant tout de même être considérée), et forme la base de la personnalité en combinaison avec les influences environnementales (De Pauw et Mervielde, 2010; Rothbart, 2011). Tant les mesures de tempérament que de personnalité pourraient ainsi refléter l'influence croissante de l'environnement au cours du développement. Une méta-analyse appuie d'ailleurs l'hypothèse selon laquelle les influences génétiques sur la personnalité diminuent avec l'âge alors que les influences environnementales augmentent (Briley et Tucker-Drob, 2014). En ce qui concerne les modèles de la diathèse-stress et de la sensibilité différentielle, on pourrait penser que les mesures de tempérament et de personnalité à l'adolescence et l'âge adulte refléteraient l'interaction entre le tempérament et l'environnement en bas âge. Des études montrent que des changements dans le tempérament et

la personnalité au cours de la vie peuvent être expliqués par des événements environnementaux (Laceulle, Nederhof, Karreman, Ormel et Van Aken, 2012; Lee, Zhou, Eisenberg et Wang, 2013; Shiner, Allen et Masten, 2017) et des études de jumeaux montrent que les changements dans le tempérament et la personnalité à l'adolescence et l'âge adulte sont expliqués par des facteurs génétiques et environnementaux (Ganiban, Saudino, Ulbricht, Neiderhiser et Reiss, 2008; Kandler, Riemann et Angleitner, 2013). Cependant, peu d'études ont examiné spécifiquement les interactions entre le tempérament et l'environnement tôt dans la vie pour prédire le tempérament ou la personnalité à l'adolescence ou à l'âge adulte; une étude sur l'interaction entre la qualité des pratiques parentales et l'impulsivité à 2 ans dans la prédiction de l'impulsivité à 12 et 15 ans n'a pas trouvé d'interactions significatives (Hentges et al., 2017). D'autres études examinant les interactions entre divers traits de tempérament et facteurs environnementaux seraient nécessaires pour mieux comprendre les interactions impliquées dans le développement du tempérament et de la personnalité à l'adolescence et à l'âge adulte.

D'autres études soutiennent l'idée que les niveaux de plasticité face aux influences environnementales seraient modifiés par les interactions personne-environnement tôt dans le développement en examinant des interactions triples entre les gènes, l'environnement à l'enfance *et* l'environnement à l'adolescence ou à l'âge adulte dans la prédiction de problèmes intériorisés. Une première étude a examiné l'interaction entre le génotype (gène du transporteur de la sérotonine : 5-HTTLPR) et les événements de vie stressants entre 11 et 15 ans dans la prédiction du changement dans les problèmes émotionnels entre 11 et 15 ans chez deux groupes d'enfants, soit un groupe d'enfants nés et adoptés au Royaume-Uni et un groupe d'enfants adoptés au Royaume-Uni, mais provenant d'orphelinats de Roumanie où ils avaient

vécu des conditions de privation extrême (Kumsta et al., 2010). Une seconde étude a également examiné le génotype (5-HTTLPR), mais en interaction triple avec l'abus à l'enfance et les événements traumatiques à l'âge adulte (mesures rétrospectives) dans la prédiction des symptômes dépressifs auprès d'un échantillon d'adultes de 30 à 90 ans (Grabe et al., 2012). Une troisième étude a examiné l'interaction triple entre deux gènes (5-HTTLPR et gène du récepteur de type 1 de la corticolibérine (CRHR1)), l'adversité familiale dans les 5 premières années de vie et le stress chronique à 20 ans dans la prédiction des symptômes dépressifs à 20 ans (Starr, Hammen, Conway, Raposa et Brennan, 2014). Finalement, une quatrième étude a examiné l'interaction triple entre le génotype (score polygénique incluant 13 gènes associés à la plasticité à l'environnement), l'environnement matériel (classe sociale, statut d'emploi, difficultés financières et statut du mode d'occupation) de la famille entre 7 et 16 ans et l'environnement matériel du participant entre 23 et 50 ans dans la prédiction de la détresse psychologique associée avec des troubles émotionnels entre 23 et 50 ans (Keers et Pluess, 2017). Les résultats de ces études étaient cohérents, montrant que l'environnement à l'enfance influençait la plasticité à l'âge adulte chez les individus considérés comme étant plus sensibles génétiquement. Ainsi, lorsqu'ils avaient été exposés à un environnement adverse à l'enfance, les individus plus à risque génétiquement étaient plus vulnérables face à l'adversité environnementale à l'adolescence et à l'âge adulte. Cependant, en absence d'adversité à l'enfance, l'adversité environnementale à l'adolescence et à l'âge adulte n'avait pas d'influence sur les problèmes intériorisés des individus plus à risque génétiquement, qui avaient alors un niveau de problèmes intériorisés semblable ou plus faible que les individus qui n'étaient pas à risque génétiquement. Plus d'études seront nécessaires afin de déterminer si

ces effets s'appliquent aussi aux problèmes extériorisés et à la consommation de substances, ainsi qu'aux interactions avec le tempérament.

Ainsi, ces deux propositions non mutuellement exclusives pourraient expliquer que les patrons d'interactions entre certaines caractéristiques personnelles et environnementales changeraient au cours du développement. Alors que la première proposition met l'accent sur le changement de la caractéristique individuelle et la seconde présume la stabilité de la caractéristique individuelle, ces deux propositions mettent en évidence le fait que l'environnement tôt dans la vie prédirait à quel point les individus sont influencés par leur environnement plus tard dans le développement.

Une plus grande plasticité observée à l'enfance et l'importance de l'environnement à l'enfance pour déterminer la résilience face aux influences environnementales adverses à l'adolescence et l'âge adulte impliquent que les programmes de prévention pourraient avoir une plus grande efficacité en étant implantés tôt au cours de la vie. Ainsi, des programmes de prévention ciblant l'environnement des enfants les plus sensibles aux influences environnementales pourraient s'avérer particulièrement efficaces. Malgré tout, les interventions à l'adolescence et l'âge adulte peuvent être efficaces auprès de certains individus, certaines caractéristiques personnelles pouvant être de meilleurs marqueurs de plasticité à l'âge adulte.

### 3.1.3. Sensibilité différentielle à l'adolescence et à l'âge adulte

Moins d'études ont comparé les modèles de la diathèse-stress et de la sensibilité différentielle avec des prédicteurs à l'adolescence et à l'âge adulte qu'avec des prédicteurs à l'enfance. Ce manque d'études sur le sujet s'explique potentiellement par la tendance qu'ont les chercheurs en développement à supposer que la plasticité serait la plus grande au début de

la vie, à la petite enfance et à l'enfance (Belsky et Pluess, 2013a). Pourtant, de nombreux changements neurobiologiques se produisent à l'adolescence (Fuhrmann, Knoll et Blakemore, 2015; Spear, 2000, 2013; Steinberg, 2008) et se poursuivent à l'âge adulte (Taber-Thomas et Perez-Edgar, 2015; Wang et Young, 2014), soutenant l'importance d'étudier la sensibilité face aux influences environnementales tout au cours du cycle de vie. Alors que les résultats de la présente thèse montrent que les interactions de l'environnement familial avec le tempérament et l'impulsivité à l'adolescence soutiennent le modèle de la diathèse-stress, d'autres caractéristiques personnelles et environnementales pourraient constituer des marqueurs plus sensibles de plasticité à l'adolescence, reflétant ainsi la sensibilité différentielle. Les résultats du troisième article de thèse suggèrent qu'un faible niveau de recherche de sensations pourrait être un marqueur de sensibilité à l'adolescence. En effet, les résultats de cette étude montrent que lorsque la recherche de sensations était faible, une plus faible supervision parentale était associée avec une fréquence de beuveries plus élevée à 15 ans et une fréquence de consommation de drogues plus élevée à 15 et 17 ans que lorsque la recherche de sensations était élevée. De plus, une supervision plus élevée était associée avec une fréquence de beuveries et de consommation de drogues plus faible lorsque la recherche de sensations était faible que lorsqu'elle était élevée, soutenant le modèle de la sensibilité différentielle.

D'autres traits individuels semblent aussi être associés à une plus grande sensibilité aux environnements positifs et négatifs à l'adolescence et l'âge adulte, dont le trait de l'hypersensibilité sensorielle. L'hypersensibilité sensorielle comprend un système nerveux sensible avec une tendance à être facilement surstimulé par l'environnement. Les individus élevés sur ce trait ont tendance à traiter leurs expériences plus en profondeur, vivre des réactions émotionnelles fortes et présenter une plus grande sensibilité aux stimuli subtils

(Aron, 2006, 2010; Aron et Aron, 1997). La théorie suppose que l'hypersensibilité sensorielle serait associée avec une plus grande réactivité aux environnements tant positifs que négatifs. Les quelques études conduites sur l'interaction entre ce trait et l'environnement suggèrent que le modèle de la sensibilité différentielle pourrait être soutenu lorsque l'hypersensibilité sensorielle est examinée chez des adultes (Aron, Aron et Jagiellowicz, 2012; Belsky et Pluess, 2009; Boyce, 2016; Carr et Nielsen, 2017).

En utilisant la typologie de personnalité développée par Block (1971) et Robins, John, Caspi, Moffitt et Stouthamer-Loeber (1996), la personnalité sous-contrôlée pourrait aussi constituer un marqueur de sensibilité à l'environnement lorsque comparée aux personnalités résiliente et surcontrôlée. La personnalité résiliente se caractérise par la confiance en soi, l'autonomie, la stabilité émotionnelle et l'énergie, la personnalité surcontrôlée se caractérise par la fragilité émotionnelle, la sensibilité, l'introversion et la fiabilité, tandis que la personnalité sous-contrôlée se caractérise par l'entêtement, la désobéissance, l'impulsivité et une activité physique élevée (Bohane, Maguire et Richardson, 2017; Donnellan et Robins, 2010; Robins et al., 1996). Sur les dimensions du *Big Five*, la personnalité résiliente se caractérise par un profil de caractère extraverti, consciencieux et peu névrotique, la personnalité surcontrôlée se caractérise par un profil de caractère névrotique et peu extraverti, tandis que la personnalité sous-contrôlée se caractérise par un profil de caractère agréable et peu consciencieux (Asendorpf, Borkenau, Ostendorf et Van Aken, 2001; Donnellan et Robins, 2010; Robins et al., 1996). Une étude a examiné l'interaction entre ces types de personnalité mesurés avec les dimensions du *Big Five* à l'adolescence et la qualité des relations romantiques au début de l'âge adulte dans la prédiction de la délinquance. Les résultats montrent que l'association entre la qualité des relations romantiques et la délinquance est

significative pour les individus sous-contrôlés, mais pas pour les individus résilients et surcontrôlés (Yu, Branje, Keijsers et Meeus, 2015). L'interaction semble soutenir le modèle de la sensibilité différentielle lorsque le graphique est examiné visuellement, mais les tests statistiques supplémentaires requis pour tester les modèles n'ont pas été conduits. Considérant le peu d'étude s'y étant attardé, l'examen des modèles de la diathèse-stress et de la sensibilité différentielle requiert plus de recherche avec des prédicteurs à l'adolescence et à l'âge adulte, ce qui permettra de déterminer les instances dans lesquelles un ou l'autre des modèles s'appliquent. Le tout permettra également d'identifier les individus pouvant bénéficier le plus des programmes de prévention administrés à l'adolescence et l'âge adulte.

## 3.2. Limites des études de la thèse et implications pour les études futures

Au-delà des limites de chaque étude individuelle de la thèse, qui sont discutées dans les articles, certaines limites globales doivent être prises en compte afin d'y remédier dans des études futures. D'abord, malgré certaines analyses prospectives ou longitudinales, tant les études empiriques de la thèse (articles 2 et 3) que les études incluses dans la revue de littérature systématique (article 1) sont de nature corrélationnelle, ce qui empêche de conclure quant à la causalité des liens examinés. Des études expérimentales permettraient de clarifier ces liens. Notamment, les études randomisées examinant les effets d'interventions familiales peuvent tester la sensibilité aux environnements positifs dans la prédiction de la consommation de substances et des comportements extériorisés. Des études ont examiné comment l'effet d'interventions familiales est modéré par les gènes des jeunes dans la prédiction des comportements extériorisés, une méta-analyse concluant que les effets des interventions sont plus grands chez les jeunes avec des allèles de risque (Bakermans-

Kranenburg et van IJzendoorn, 2015). Moins d'études se sont intéressées à la modération des effets d'intervention par le tempérament et la personnalité. Une étude a montré qu'une intervention pour améliorer les pratiques parentales menait à une plus grande diminution des problèmes de comportements chez les enfants émotionnels-dérégulés comparativement aux autres enfants (Scott et O'Connor, 2012). Au-delà de l'environnement familial, une étude a également trouvé que l'effet d'une intervention pour les comportements extériorisés en milieu scolaire était plus efficace pour les enfants consciencieux et peu extravertis (Stoltz et al., 2013), deux traits qui sont associés à l'hypersensibilité sensorielle (Ahadi et Basharpoor, 2010; Grimen et Diseth, 2016; Pluess et al., 2018). La modération des effets d'interventions familiales et d'autres types d'interventions par le tempérament et la personnalité demeure peu étudiée et gagnerait à être examinée dans des études futures. Notamment, la modération d'interventions familiales par l'impulsivité n'a pas été examinée, tout comme l'effet de cette modération sur la consommation de substances à l'adolescence. Il peut être plus difficile de tester de manière expérimentale la sensibilité aux environnements positifs *et négatifs* étant donné les contraintes éthiques. Ainsi, la majorité des environnements adverses ne peuvent être induits dans une expérimentation. Cependant, il demeure possible de tester de manière expérimentale certaines conditions négatives, mais sans conséquences à long terme. Par exemple, lors de jeux de rôle avec des marionnettes, une étude a examiné si l'effet d'une rétroaction positive ou négative sur les changements d'affect positif et négatif était modéré par l'émotivité négative d'enfants de 4 à 6 ans (Slagt, Dubas, van Aken, Ellis et Dekovic, 2017). Alors que l'effet de la rétroaction sur les changements d'affect n'était pas modéré par l'émotivité négative, il a été trouvé que 10.31% des enfants étaient vulnérables face aux effets de la rétroaction négative.

Une seconde limite de la thèse concerne les mesures utilisées pour les différentes périodes développementales. En effet, malgré les résultats de la thèse suggérant que les interactions entre le tempérament et l'environnement familial dans la prédiction des comportements extériorisés et de la consommation de substances à l'adolescence soutiennent le modèle de la sensibilité différentielle lorsque les prédicteurs sont mesurés à l'enfance et le modèle de la diathèse-stress lorsque les prédicteurs sont mesurés à l'adolescence, il serait possible que le changement de mesures au cours du développement explique ces résultats. En effet, les mesures de tempérament et d'environnement familial incluses dans les articles 2 et 3 n'étaient pas les mêmes à l'enfance et à l'adolescence. En ce qui concerne l'environnement familial, l'interaction à l'enfance incluait les pratiques parentales coercitives tandis que l'interaction à l'adolescence incluait la supervision parentale. Afin de pallier cette limite, des études pourraient examiner si des changements dans les patrons d'interaction sont observés lorsque le même type de pratiques parentales ou la même variable familiale sont examinés à l'enfance et à l'adolescence. Quant aux caractéristiques individuelles, le changement de patron d'interaction a été observé avec l'impulsivité à 6 et 15 ans. Cependant, malgré qu'il s'agisse du même construit à l'enfance et l'adolescence, l'instrument de mesure à l'enfance était le *Children's Behavior Questionnaire* (Rothbart, Ahadi, Hershey et Fisher, 2001) et l'instrument à l'adolescence était le *Substance Use Risk Profile Scale* (Castonguay-Jolin et al., 2013; Woicik, Stewart, Pihl et Conrod, 2009). Bien qu'il soit difficile d'utiliser des mesures identiques à l'enfance et à l'adolescence puisque les manifestations du tempérament et de la personnalité changent au cours du développement, des mesures validées sur le plan conceptuel et de la continuité développementale pourraient être utilisées. Par exemple, des instruments sont disponibles pour mesurer les traits de tempérament selon la conceptualisation de Mary K.

Rothbart à tous les âges. Notamment, alors que le *Children's Behavior Questionnaire* permet de mesurer des traits de tempérament entre 3 et 7 ans, le *Early-Adolescent Temperament Questionnaire* (9 à 15 ans; Capaldi et Rothbart, 1992; Ellis, 2002) et le *Adult Temperament Questionnaire* (Evans et Rothbart, 2007) permettent de mesurer ces traits à l'adolescence et l'âge adulte, mais avec une mesure appropriée pour l'âge du participant. En utilisant des mesures de caractéristiques individuelles et de l'environnement sensibles à la continuité développementale, des études pourraient permettre d'atténuer l'effet possible du changement de mesure comme explication alternative des changements développementaux observés dans la thèse.

### 3.2.1. Application des modèles de la diathèse-stress et de la sensibilité différentielle au-delà de la consommation de substances et des comportements extériorisés

Alors que dans la présente thèse les modèles de la diathèse-stress et de la sensibilité différentielle ont été comparés dans la prédiction de la consommation de substances et des comportements extériorisés dans les trois premiers articles de la thèse, ces modèles peuvent également s'appliquer à plusieurs autres résultats développementaux. Comme mentionné dans l'introduction, des études ont examiné les modèles de la diathèse-stress et de la sensibilité différentielle dans la prédiction des problèmes intériorisés (Brock, Kochanska et Boldt, 2017; Davis et al., 2017; Essex, Armstrong, Burk, Goldsmith et Boyce, 2011; Liu et al., 2017; Morgan, Shaw et Olino, 2012; Sulik et al., 2015), du développement cognitif (Kegel, Bus et van Ijzendoorn, 2011; Raver, Blair, Willoughby et The Family Life Project Key Investigators, 2013), de la réussite scolaire (Belsky et al., 2014; Jaekel, Pluess, Belsky et Wolke, 2015; Kochanska, Kim, Barry et Philibert, 2011; Obradovic, Bush, Stamperdahl, Adler et Boyce, 2010), des habiletés sociales (Belsky et al., 2014; Belsky et Pluess, 2013b; Kochanska et al.,

2011; Pluess et Belsky, 2009), du développement pubertaire (Ellis, Shirtcliff, Boyce, Deardorff et Essex, 2011) et de l'indice de masse corporelle (Anzman et Birch, 2009; Anzman-Frasca, Stifter, Paul et Birch, 2014; Wu, Dixon, Dalton, Tudiver et Liu, 2011). Cependant, on ne sait pas dans quelle mesure les changements développementaux observés dans la présente thèse quant au soutien des modèles de la diathèse-stress et de la sensibilité différentielle s'appliquent à ces issues développementales, ce qui pourrait être examiné dans des études futures.

De plus, certains résultats développementaux auxquels les modèles de la diathèse-stress et de la sensibilité différentielle pourraient s'appliquer n'ont pas fait l'objet d'études comparant les modèles. C'est notamment le cas de plusieurs psychopathologies, pour lesquelles le modèle de la diathèse-stress est utilisé afin d'expliquer leur développement et manifestation (p. ex., Haltigan et Vaillancourt, 2016; Hewitt, Caelian, Chen et Flett, 2014; Howes et McCutcheon, 2017; Seeds et Dozois, 2010), mais sans avoir été comparé au modèle de la sensibilité différentielle (Assary, Vincent, Keers et Pluess, in press). Pourtant, dans tous les cas où des interactions personne-environnement permettent d'expliquer certains résultats développementaux, la comparaison des modèles de la diathèses-stress et de la sensibilité différentielle pourrait être considérée afin de mieux interpréter les résultats. À cet égard, et comme présenté dans le quatrième article de thèse, le modèle de la sensibilité différentielle pourrait s'appliquer à l'étiologie du trouble de la personnalité limite. En effet, plusieurs traits étant associés au risque de développer le trouble de la personnalité limite, tels que la réactivité émotionnelle et l'impulsivité (Cailhol, Gicquel et Raynaud, 2015; Paris, 2015), ont été montrés comme étant associés à une sensibilité aux environnements négatifs et positifs, supportant le modèle de la sensibilité différentielle dans la prédiction d'autres issues

développementales que le trouble de la personnalité limite (Belsky et Pluess, 2009, 2013a). Le tout est pertinent non seulement afin d'améliorer la compréhension du développement du trouble de la personnalité limite, ce qui pourrait potentiellement mener à des programmes de prévention efficaces, mais également pour améliorer les soins thérapeutiques. En effet, comme présenté dans le quatrième article, l'intégration du modèle de la sensibilité différentielle à l'étiologie du trouble de la personnalité limite pourrait permettre aux cliniciens d'avoir une meilleure compréhension de leurs patients et des mécanismes sous-tendant une thérapie efficace.

### 3.2.2. Réceptivité aux environnements positifs

Malgré que la présente thèse ait porté spécifiquement sur les modèles de la diathèse-stress et de la sensibilité différentielle, il ne s'agit pas des seuls modèles d'interactions personne-environnement. Alors que le modèle de la diathèse-stress souligne la vulnérabilité aux influences environnementales négatives seulement et que le modèle de la sensibilité différentielle souligne la sensibilité aux influences environnementales positives et négatives, il est également possible d'observer une réceptivité aux influences environnementales positives seulement, ce qui est reflété dans le modèle la *réceptivité avantageuse* (Pluess et Belsky, 2013). Ainsi, selon ce modèle, certains individus plus réceptifs bénéficient plus des effets d'un environnement enrichi sans être pénalisé par un environnement adverse. Tel que présenté à la section 3.2., l'efficacité d'interventions scolaires et familiales peut être modérée par les gènes ou le tempérament des jeunes. La réceptivité avantageuse est notamment le mécanisme qui sous-tendrait ces différences individuelles quant à l'efficacité d'interventions (de Villiers, Lionetti et Pluess, 2018).

Les trois modèles (diathèse-stress, réceptivité avantageuse et sensibilité différentielle) peuvent être intégrés théoriquement pour expliquer les interactions personne-environnement (Pluess, 2015). Ainsi, le modèle de la diathèse-stress décrit les différences individuelles quant aux réponses aux influences environnementales négatives exclusivement et le modèle de la réceptivité avantageuse décrit les différences individuelles quant aux réponses aux influences environnementales positives seulement. De son côté, le modèle de la sensibilité différentielle représente la combinaison des modèles de la diathèse-stress et de la réceptivité avantageuse *en fonction des mêmes facteurs individuel et environnemental*.

## 3.3. Considérations méthodologiques: le futur des études sur la sensibilité différentielle

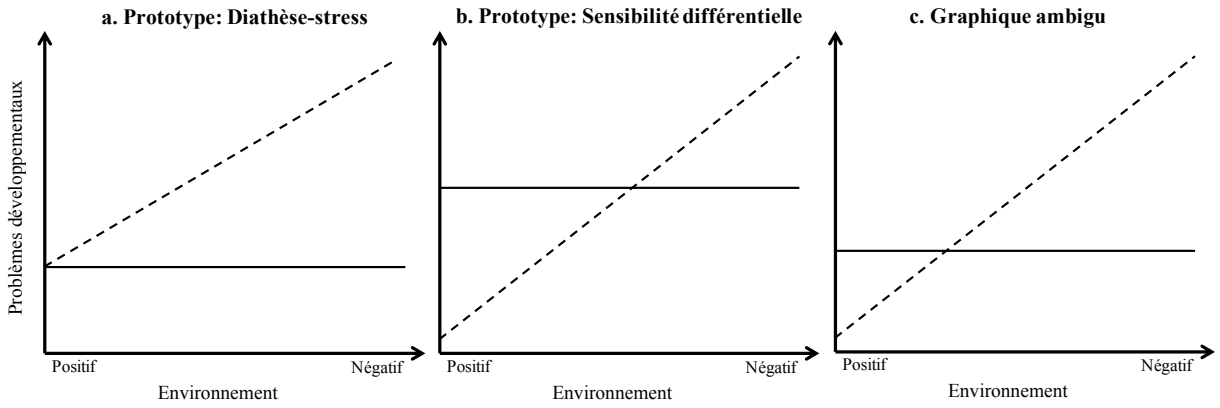
L'étude du modèle de la sensibilité différentielle en comparaison au modèle de la diathèse-stress étant relativement récente, les méthodes statistiques pour distinguer les modèles sont en constante évolution. Ainsi, les développements récents quant aux analyses visant à comparer les modèles devraient être pris en compte dans les études futures sur le sujet.

Plusieurs critères devraient être examinés dans la comparaison des modèles (Belsky, Bakermans-Kranenburg et van Ijzendoorn, 2007). D'abord, la variable environnementale et la variable individuelle ne devraient idéalement pas être associées (Kraemer, Stice, Kazdin, Offord et Kupfer, 2001; Kraemer, 2012). Cependant, une faible corrélation peut être corrigée en utilisant des résiduels. Ensuite, pour les deux modèles, la pente pour le groupe présumé vulnérable ou sensible à l'environnement doit être significativement différente de zéro et plus grande que pour le groupe présumé résilient ou non sensible. Alors que pour le modèle de la

diathèse-stress, la variable individuelle doit être associée avec la variable dépendante, ce n'est pas le cas pour le modèle de la sensibilité différentielle. Finalement, le graphique d'interaction diffère selon le modèle soutenu; il s'agit d'une interaction ordinale pour le modèle de la diathèse-stress (les droites ne se croisent pas; voir Figure 1a) alors qu'il s'agit d'une interaction disordinale pour le modèle de la sensibilité différentielle (les droites se croisent; voir Figure 1b).

Auparavant, l'examen visuel des graphiques était effectué afin de déterminer si l'interaction était ordinale ou disordinale. Cependant, cet examen visuel peut être subjectif, les deux problèmes principaux étant la possibilité pour les chercheurs de choisir l'étendue des valeurs de la variable environnementale représentée graphiquement et les points de croisement plus près des extrémités du graphique qui sont plus difficiles à interpréter (voir Figure 1c). Cette méthode demeure intéressante pour tenter de déterminer lequel des modèles semble le plus soutenu pour des études ne les ayant pas comparés a priori, ce qui a été effectué dans le cadre de la revue de littérature du premier article. Cependant, l'examen visuel ne suffit pas pour les nouvelles études empiriques portant sur la comparaison des modèles.

Figure 1
*Représentation graphique des modèles de la diathèse-stress et de la sensibilité différentielle.*



L'identification des régions de signification avec la technique Johnson-Neyman (Dearing et Hamilton, 2006) a été proposée afin de qualifier statistiquement la forme de l'interaction lorsque les modèles de la diathèse-stress et de la sensibilité différentielle sont étudiés (Kochanska et al., 2011). La méthode Johnson-Neyman est habituellement une alternative aux tests de pentes effectués à des valeurs spécifiques d'un modérateur continu, permettant ainsi de déterminer à partir de quelles valeurs sur le modérateur le prédicteur est associé à la variable dépendante. Cependant, dans l'examen des modèles de la diathèse-stress et de la sensibilité différentielle, la technique Johnson-Neyman est inversée afin de déterminer les niveaux du prédicteur auquel le modérateur est significativement associé à la variable dépendante. Ce test permet ainsi de déterminer à quelles valeurs de la variable environnementale on retrouve des différences significatives en fonction de la caractéristique individuelle. Selon ce test, une interaction soutient le modèle de la sensibilité différentielle lorsque la région de signification est présente aux deux extrémités de la distribution de la variable environnementale, et ce à l'intérieur de deux écarts types au-dessus et en dessous de sa moyenne. Cependant, puisque ce test n'est pas invariant à la taille d'échantillon, des tests supplémentaires ont été proposés (Roisman et al., 2012). La première option est le test de proportion de l'interaction (PdI), qui mesure la proportion de l'aire de l'interaction attribuable à l'effet de sensibilité différentielle. Par exemple, dans les Figures 1b et 1c, la PdI représenterait la proportion de l'aire d'interaction (espace entre les deux droites) qui est au-dessous du point de croisement. L'interaction prototypique de la diathèse-stress aurait une PdI = .00 alors que l'interaction prototypique de la sensibilité différentielle aurait une PdI = .50. Les critères proposés par Roisman et al. (2012) sont qu'une PdI = .40-.60 soutiendrait le modèle de la sensibilité différentielle. Cependant, ce critère est associé à une

occurrence élevée de faux négatifs même avec de très grands échantillons, et il a donc été proposé d'assouplir ces critères pour une PdI = .20-.80 (Del Giudice, 2017b). Une deuxième option comme test supplémentaire aux régions de signification est le test de la proportion affectée (PA), qui mesure la proportion de l'échantillon influencée par un environnement positif. Ainsi, dans les Figures 1b et 1c, le point de croisement serait calculé et la PA représenterait la proportion de cas au-dessous du point de croisement sur la variable environnementale. Comme pour la PdI, l'interaction prototypique de la diathèse-stress aurait une PA = .00 alors que l'interaction prototypique de la sensibilité différentielle aurait une PA = .50. En assumant la normalité de la variable environnementale, Roisman et al. (2012) ont proposé qu'une PA > .16 serait cohérente avec le modèle de la sensibilité différentielle.

Deux aspects importants doivent être pris en compte lors de l'utilisation de ces tests supplémentaires. D'abord, le calcul de ces deux tests supplémentaires a été proposé pour une variable environnementale pour laquelle un score élevé représente un environnement plus positif, les régions d'intérêt pour le calcul de la proportion de l'interaction et de la proportion affectée étant alors au-dessus du point de croisement (c.-à-d., à droite du point de croisement). Ceci constitue un point important puisque plusieurs valeurs de proportion de l'interaction rapportées dans la littérature sont incorrectes étant donné que les auteurs n'ont pas inversé le calcul lorsque nécessaire (c.-à-d., lorsqu'un score élevé pour la variable environnementale représente un environnement plus adverse) (Del Giudice, 2017a). Ensuite, malgré que ces tests aient été proposés afin de pallier la sensibilité à la taille d'échantillon des analyses de régions de signification, la puissance des analyses doit être considérée. En effet, les analyses de région de signification combinées aux tests de PdI ou PA requièrent plus de participants afin de détecter les effets de sensibilité différentielle que ce qui est généralement recommandé dans

des analyses de puissance pour la modération. Ainsi, pour atteindre un taux de détection de 80%, il serait nécessaire d'ajouter environ 50% de participants au nombre obtenu avec les analyses de puissance typiques. Avec une petite taille d'effet ($\Delta R^2 = .01$), environ 900 participants seraient nécessaires afin d'atteindre un taux de détection de 80% pour des analyses de régions de signification (Del Giudice, 2017b). Ainsi, une attention particulière doit être portée aux problèmes de puissance lorsque le modèle de la diathèse-stress est soutenu avec ces analyses dans un petit échantillon.

Une autre analyse permettant de tester statistiquement si une interaction est ordinale ou disordinale est l'estimation du point de croisement et de son intervalle de confiance (Widaman et al., 2012). Si l'intervalle de confiance du point de croisement se trouve à l'intérieur des valeurs observées sur la variable environnementale, l'interaction est disordinale, ce qui offre du soutien pour le modèle de la sensibilité différentielle. Si l'intervalle de confiance du point de croisement est à l'extérieur des valeurs observées sur la variable environnementale, l'interaction est ordinale, ce qui offre du soutien pour le modèle de la diathèse-stress. Cependant, la taille d'échantillon doit encore une fois être prise en considération. En effet, l'intervalle de confiance du point de croisement dans des échantillons de moins de 200 participants est trop large et ne permet donc pas de distinguer les interactions ordinales et disordinales. Un échantillon d'au moins 500 participants maximiserait les chances d'obtenir un intervalle de confiance assez restreint pour bien départager les interactions ordinales et disordinales (Lee, Lei et Brody, 2015).

L'estimation du point de croisement et de son intervalle de confiance est à la base d'analyses confirmatoires (Belsky, Pluess et Widaman, 2013), qui seraient une alternative aux tests d'interaction en régression multiple qui sont habituellement effectués pour comparer les

modèles. Dans cette approche, les équations de régression sont reparamétrisées pour comparer quatre modèles, soit des versions « fortes » et « faibles » des modèles de la diathèse-stress et de la sensibilité différentielle, qui sont comparées avec les indices d'ajustement. Pour le modèle de la sensibilité différentielle « fort », le point de croisement est à l'intérieur des valeurs observées sur la variable environnementale et la pente du groupe non sensible est fixée à 0. Pour le modèle de la sensibilité différentielle « faible », la pente du groupe non sensible n'est pas fixée à 0. De façon similaire, pour le modèle de la diathèse-stress « fort », le point de croisement est fixé à l'extrémité des valeurs observées sur la variable environnementale et la pente du groupe résilient est fixée à 0, alors que pour le modèle de la diathèse-stress « faible », la pente du groupe résilient n'est pas fixée à 0. Lorsque des interactions ont déjà été étudiées dans la littérature, mais sans tester les modèles, cette approche peut être particulièrement intéressante. De plus, cette approche est plus valide que les approches basées sur les régions de signification lorsqu'on a affaire à des petits échantillons (Jolicoeur-Martineau et al., 2017). Certains auteurs procèdent à des tests d'interaction en régression multiple avant de tester les modèles avec les analyses confirmatoires. Dans ces cas, il a récemment été recommandé d'utiliser le ratio F plutôt que le test de signification afin de justifier de passer au test des modèles avec les analyses confirmatoires. Ainsi, selon ces recommandations, indépendamment de la signification du résultat de l'interaction, une valeur F près de ou plus grande que 1.0 constituerait le critère pour effectuer les analyses confirmatoires (Belsky & Widaman, 2018).

# 4. Conclusion: implications pour la clinique et la recherche

Les résultats de la présente thèse montrent que les individus, notamment les enfants, considérés comme vulnérables (c.-à-d., à risque de problèmes développementaux lorsqu'exposés à des environnements adverses) pourraient sous certaines conditions présenter une sensibilité aux environnements négatifs *et* positifs. Le tout implique qu'il pourrait être important de réviser la notion de « vulnérabilité », qui ne représenterait pas adéquatement une sensibilité pouvant mener à un développement supérieur à la moyenne lorsque l'environnement le permet, ainsi que la notion de « résilience » qui représenterait plutôt une faible plasticité face aux influences environnementales, qu'elles soient négatives ou positives. De plus, malgré que plus d'études soient nécessaires, ces résultats s'avèrent importants pour guider les programmes de prévention et d'intervention. En effet, les ressources peuvent être maximisées si les interventions familiales et environnementales ciblent les jeunes sensibles à ces influences. Les études expérimentales randomisées examinant l'effet d'interventions en fonction des caractéristiques individuelles des participants s'avèreront essentielles pour l'application clinique des résultats des études observationnelles portant sur les modèles de la diathèse-stress et de la sensibilité différentielle.

Pour ce qui est de la recherche, une implication clé de la présente thèse concerne l'importance d'aller au-delà des différences de pentes dans l'interprétation des effets d'interaction. En effet, tel que le proposent les modèles théoriques étudiés et tel que le montrent les résultats de la thèse, restreindre l'interprétation des interactions aux différences quant à l'ampleur des pentes selon les niveaux du modérateur donne un portrait incomplet des résultats. En ce qui concerne les modèles de la diathèse-stress et de la sensibilité différentielle, il ne s'agira pas de montrer qu'un des modèles est supérieur à l'autre, mais plutôt de

déterminer dans quelles circonstances chacun des modèles s'applique - soit pour quelles caractéristiques individuelles, en interaction avec quelles influences environnementales, et pour quelles périodes développementales. C'est cette distinction qui permettra de mieux guider l'intervention et la prévention.

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# Annexe 1: Échelle de pratiques maternelles coercitives

Au cours des 12 derniers mois…

À quelle fréquence vous mettez-vous en colère lorsque vous punissez l'enfant ?

Jamais Rarement Parfois Souvent Tout le temps

Lorsque votre enfant désobéissait ou faisait des choses qui lui étaient défendues, à quelle fréquence vous est-t-il arrivé d'élever la voix, de le gronder ou de lui crier après?

Jamais Rarement Parfois Souvent Tout le temps

À quelle fréquence vous arrive-t-il : De lui infliger des punitions corporelles ?

Jamais | Environ une fois par semaine ou moins | Quelques fois par semaine | Une ou deux fois par jour | Plusieurs fois par jour

À quelle fréquence vous est-il arrivé de taper(frapper) l'enfant lorsqu'il s'était montré difficile ?

Jamais | Moins de la moitié du temps | Environ la moitié du temps | Plus de la moitié du temps | Tout le temps

À quelle fréquence vous est-il arrivé de vous fâcher après l'enfant à la suite d'une parole ou d'un geste qu'il n'était pas sensé dire ou faire ?

Jamais | Moins de la moitié du temps | Environ la moitié du temps | Plus de la moitié du temps | Tout le temps

À quelle fréquence vous est-il arrivé d'empoigner fermement ou de secouer votre enfant lorsqu'il/elle s'était montré/e difficile ?

Jamais | Moins de la moitié du temps | Environ la moitié du temps | Plus de la moitié du temps | Tout le temps

# Annexe 2: Échelles d'impulsivité et de contrôle inhibiteur du *Children's Behavior Questionnaire*

*Note:* *Impulsivité **Contrôle inhibiteur

## Instructions

***(Demander à la mère de prendre un papier/crayon pour écrire les choix de réponses)***

Dans la section suivante, je vais vous lire un ensemble d'énoncés qui décrivent les réactions des enfants dans diverses situations. Nous aimerions que vous nous indiquiez quelle réaction est susceptible d'avoir **votre** enfant dans ces situations. Il n'y a bien sûr aucune façon « correcte » de réagir; les enfants varient grandement dans leurs réactions, et ce sont ces différences que nous essayons de mieux connaître. Veuillez décider pour chaque énoncé s'il s'agit d'une description « **exacte** » ou « **inexacte** » de la réaction de votre enfant **au cours des six derniers mois**. Utilisez l'échelle suivante pour indiquer à quel point un énoncé décrit bien cet enfant :

**Encerclez le # si l'énoncé est :**

**1 extrêmement inexact par rapport à cet enfant**
**2 plutôt inexact par rapport à cet enfant**
**3 légèrement inexact par rapport à cet enfant**
**4 ni vrai ni faux par rapport à cet enfant**
**5 légèrement exact par rapport à cet enfant**
**6 plutôt exact par rapport à cet enfant**
7 **extrêmement exact par rapport à cet enfant**

Si vous ne pouvez répondre à l'un des items parce que vous n'avez jamais vu votre enfant dans cette situation ( ar exemple, si l'énoncé concerne la réaction de l'enfant lorsque vous chantez et que vous n'avez jamais chanté à votre enfant), encerclez **NA** (ne s'applique pas).
**Veuillez vous assurer d'encerclez un nombre ou NA pour chacun des items.**

| **Mon enfant :** | **Extrême-ment inexact** | **Plutôt inexact** | **Légère-ment inexact** | **Ni vrai ni faux** | **Légère-ment exact** | **Plutôt exact** | **Extrême-ment exact** | **NA** |
|---|---|---|---|---|---|---|---|---|
| 29. A l'habitude de se précipiter dans une activité sans trop y réfléchir.* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 33. Se précipite souvent dans les situations nouvelles.* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 34. Prend beaucoup de temps avant d'aborder des situations nouvelles.* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 35. Peut attendre avant de s'engager dans de nouvelles activités si on le lui demande.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 36. Est lent/lente et peu pressé/pressée de décider quoi faire à la suite d'une activité.* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 37. Éprouve des difficultés à attendre en ligne pour quelque chose.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 39. Tend à dire la première chose qui lui vient à l'esprit et maintient cette opinion.* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 40. Éprouve des difficultés à s'asseoir tranquille quand c'est nécessaire (par exemple: au cinéma, à l'église, etc...).** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 42. Est bon/bonne pour suivre des instructions.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 44. Lorsqu'on lui a dit qu'un endroit est dangereux, il/elle s'en approche lentement et prudemment.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 45. Peut facilement arrêter une activité lorsqu'on lui dit «non!»** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |
| 46. Est parmi les derniers enfants à essayer une nouvelle activité.* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NA |

# Annexe 3: Échelles d'impulsivité et de recherche de sensations du *Substance Use Risk Profile Scale*

*Note:* *Impulsivité **Recherche de sensations

| | **Fortement en désaccord** | **En désaccord** | **En accord** | **Fortement en accord** |
|---|---|---|---|---|
| SUR_Q2 Je ne réfléchis pas toujours avant de parler.* | 1 | 2 | 3 | 4 |
| SUR_Q3 J'aimerais faire du parachute.** | 1 | 2 | 3 | 4 |
| SUR_Q5 Je fais souvent des choses que je regrette ensuite d'avoir faites.* | 1 | 2 | 3 | 4 |
| SUR_Q6 J'aime les expériences nouvelles et excitantes même quand elles ne sont pas classiques.** | 1 | 2 | 3 | 4 |
| SUR_Q9 J'aime faire des choses qui me font un peu peur.** | 1 | 2 | 3 | 4 |
| SUR_Q11 D'habitude, je ne réfléchis pas avant de faire quelque chose.* | 1 | 2 | 3 | 4 |
| SUR_Q12 J'aimerais apprendre à conduire une moto.* | 1 | 2 | 3 | 4 |
| SUR_Q15 En général, je suis une personne impulsive.* | 1 | 2 | 3 | 4 |
| SUR_Q16 Je suis intéressé(e) par certaines expériences, même si elles sont illégales.** | 1 | 2 | 3 | 4 |
| SUR_Q19 J'aimerais faire de grandes randonnées dans des endroits sauvages et inhabités.** | 1 | 2 | 3 | 4 |
| SUR_Q22 Je sens qu'il faut que je sois un peu manipulateur pour obtenir ce que je veux.* | 1 | 2 | 3 | 4 |