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Childhood poverty and behavior problems in early adolescence: Examining the links over time and potential mechanisms

par

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Résumé

Problématique : La pauvreté est un facteur de risque bien établi chez les enfants et les adolescents pour le développement des problèmes de comportements. Cependant, des recherches sont nécessaires afin de préciser si cette association varie au cours du développement, et afin de spécifier les mécanismes par lesquels une telle association peut se produire. Le présent travail a pour but d'étudier les liens spécifiques entre la pauvreté et les problèmes de comportement, en utilisant des approches statistiques et épidémiologiques appliquées aux données longitudinales, pour déterminer les voies prédictives et les mécanismes sous-jacents de cette association.

Objectifs: L'objectif général est d'évaluer le risque de problèmes de comportement et les mécanismes sous-jacents à l'exposition à la pauvreté à différents stades du développement, soit de la naissance jusqu'au début de l'adolescence. Trois objectifs de recherche, chacun correspondant à un article de recherche formant le corps principal de cette dissertation, sont: (1) Déterminer les médiateurs reliés aux caractéristiques familiales dans l'association entre la pauvreté chronique et les problèmes de comportement au cours de la petite enfance; (2) Étudier les modèles de changement dans l'association entre la pauvreté et les problèmes de comportement au cours de l'enfance; 3) Examiner le rôle de la pauvreté chez les enfants, selon la période développementale et la durée d'exposition, sur la prédiction des problèmes de comportements au début de l'adolescence.

Méthodes: Les données proviennent des vagues 1998-2011 de l'Étude Longitudinale du Développement de l'Enfant au Québec (ÉLDEQ) des enfants suivie prospectivement de 0.5 à 13 ans (N = 2120). La pauvreté a été évaluée selon les seuils de faible revenu définis par Statistique Canada. Les variables dépendantes étaient des problèmes de comportement, soient l'hyperactivité, l'opposition et l'agressivité physique, évalués par la mère et l'enseignant. Des modèles d'analyse de régressions multiples et d'effets linéaires mixtes ont été utilisés afin d'estimer les associations longitudinales entre la pauvreté et les problèmes de comportement.

Implications: Cette thèse vise à souligner l'importance de réduire la pauvreté chez les familles avec de jeunes enfants par l'intermédiaire de politiques publiques. Les futures

initiatives visant à réduire les problèmes de santé mentale chez les jeunes devront prendre en considération l'importance de la période développementale et de la durée de l'exposition à la pauvreté des enfants.

Mots-clés: Pauvreté, Hyperactivité, Agressivité physique, Opposition, Parcours de vie

Summary

Background: Poverty is a well-established risk factor for behavior problems among children and adolescents. Yet, research is needed to clarify whether the association varies over the course of development, as well as the mechanisms through which such associations may occur. The purpose of the current work is to investigate specific links between poverty and the behavior problems, using statistical and epidemiological approaches applied to longitudinal data to ascertain predictive pathways.

Objectives: The overall aim of the present work is to assess the risk of behavior problems and underlying mechanisms related to poverty exposure at various stages of development. Three research objectives, each corresponding to a research paper forming the main body of this dissertation, are : (1) To investigate the potential for mediators relating to family characteristics in the association between chronic poverty and behavior problems during early childhood; (2) To investigate the patterns of change in the association between poverty and behavior problems over the course of childhood; and (3) To examine the timing and duration of childhood poverty in the prediction of behavior problems in early adolescence.

Methods: The data originated from the 1998–2011 waves of the Quebec Longitudinal Study of Child Development (QLSCD), a population-based longitudinal study of children followed prospectively from 0.5 to 13 years (N=2120). Poverty was defined based on low-income lines defined by Statistics Canada. Outcomes variables were behavior problems reported by mothers and teachers, including hyperactivity, opposition and physical aggression. Multiple regression analysis and linear mixed-effects models were applied to estimate the longitudinal associations between poverty and behavior problems.

Implications: The overall scope of this thesis resides in informing the timing and targets for prevention programs aimed at reducing the detrimental impact of poverty on behavior problems. Future initiatives may consider time and duration of exposure to poverty when prioritizing resources aimed at reducing poverty in families with young children.

Keywords: Poverty, Hyperactivity, Physical aggression, Opposition, Life course

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UNICEF - United Nations Children's Fund

QLSCD - Quebec Longitudinal Study of Childhood Development

CDC - Centre of Disease Control

DSM - Diagnostic and Statistical Manual of Mental Disorders

ICD - International Classification of Diseases

ADHD - Attention Deficit/Hyperactivity Disorder

ODD - Oppositional Defiant Disorder

CD - Conduct Disorder

DALYs - Disability-Adjusted Life Years

YLLs - Years of Life Lost

YLD - Years Lived with Disability

OECD - Organisation for Economic Co-operation and Development

LICOs - Low Income Cut-Offs

MBM -Market Basket Measure

LIM - Low Income Measure

UNCRC- United Nations Convention on the Rights of the Child

GDP - Gross Domestic Product

HPA - Hypothalamic-Pituitary Adrenocortical

BEH - Behavior Scale Questionnaire

DAG - Directed Acyclic Graph

LMMs - Linear Mixed Models

MAR - Missing At Random

MNAR –Missing Not At Random

FCS - Fully Conditional Specification

MICE - Multiple Imputations by Chained Equations

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In loving memory of my mother *Maria Aparecida*, whose long last impression was about courage and happiness.

For my husband who is my daily inspiration,

Eduardo Mazza

CHAPTER 1

An introduction

1.1 Statement of problem

1.1.1 Behavior problems: A pervasive problem

Poverty and mental health problems are two contemporary public health concerns. While each is important in its own right, there is evidence that they may be etiologically related. Poverty represents a major risk factor for poor mental health and disability among children and adolescents (Reiss, 2013; Boat & Wu, 2015), and its possible role in the development of psychopathology has been increasingly investigated. Estimates of the prevalence of mental health problems in the past decade suggest that at least 20% of children will have a mental health problem in any given year (Costello, 2003; Costello, Egger, & Angold, 2005; Merikangas et al., 2010). Prevalence rates of having at least one disorder by 16 years are as high as 37% (Costello, 2003; Costello et al., 2005).

Behavior problems, namely hyperactivity, aggression, and defiant behavior, affect a significant number of children and adolescents. They are the second most common condition, following anxiety disorders, with prevalence estimates as high as 19.6% for at least one disorder between 13-18 years (Merikangas et al., 2010). This is a major cause of concern, due in part to the fact that they may track into adulthood (Fergusson, Boden, & Horwood, 2010) in the form of conduct and self-regulation problems which may contribute to criminality, violence, substance abuse problems and internalizing problems (Monahan, Steinberg, Cauffman, & Mulvey, 2009; Odgers et al., 2007; Pingault et al., 2013).

Behavior problems are considered the most socially destructive form of mental health problems, as they increase the risk for adult criminality and social adjustment problems (Fontaine et al., 2008; Kuja-Halkola et al., 2014; Satterfield et al., 2007). In turn, the social and economic costs of behavior disorders are disproportionately large because symptoms are severe, persistent, and usually begin early in life or in early adolescence resulting in a lasting impact on the individual's economic opportunities and contribution (Colman et al., 2009; Galéra et al., 2012). Early prevention efforts targeting behavior problems before they become severe would largely reduce the burden of mental health by redirecting children to a more positive developmental trajectory (Deković et al., 2011; Kieling et al., 2011).

1.1.2 The role of poverty in the development of behavior problems

Poverty has been associated with behavior problems during childhood and adolescence in many regions of the developed world, including North America and Europe (Amone-P'Olak et al., 2009; Ramanathan, Balasubramanian, & Krishnadas, 2013; Russell, Ford, Rosenberg, & Kelly, 2014; Shaw, Lacourse, & Nagin, 2005). Children living in poverty are not only more likely to develop behavior problems than their counterparts but also behavior problems are more likely to be severe. This is concerning given the current times of economic hardship. Specifically, the present economic context reflecting the 2008 crisis and the global recession have harmed children's physical and mental health, and disproportionately affected the most disadvantaged groups (Rajmil et al., 2014). A recent report concluded that child poverty has increased since 2008 in high income countries (UNICEF Office of Research, 2014). However, Canada has seen a small decrease in child poverty from 23% to 21% from 2008 to 2012. Despite this decline child poverty remains high among Canadians under 18 years. Furthermore, child poverty rates are expected to reach 24% and 23% respectively by 2020 and 2021 (UNICEF Innocenti Research Centre, 2012).

Several mechanisms have been evoked to explain the association between poverty and behavior problems across development. Poverty leads to an increased risk of behavior problems in children through intermediary determinants. These include material factors such as housing and overall living conditions as well as psychosocial factors, including stress, parental psychopathology, epigenetic regulation and physiological alterations (Conger, Conger, & Martin, 2010; Evans & Cassells, 2014; Hatch, 2005; Shelleby et al., 2014).

The dominant mechanistic hypotheses about how poverty shapes children's behavioral development focuses on the direct effect of the lack of material resources which, in turn, indirectly affects behavioral development via psychosocial stressors (e.g. social support, family and marital conflict, parental psychopathology and coping styles) and health-related behavior (e.g. parenting, parental tobacco and alcohol consumption, decreased health care visits) (Elder & Caspi, 1988). With family events (e.g. change in family composition, unemployment) being so highly related to poverty, research has primarily focused on the family stress model (Conger & Donnellan, 2007). Specifically, in this model, economic hardship increases parental emotional distress indirectly affecting children's adjustment through parental mental health, quality of parenting, marital and family conflict.

While there is growing awareness of the importance of child poverty and underlying mechanisms in understanding the development of behavior problems, less attention has been paid to how the timing of exposure to poverty and the length of time spent in poverty relates to behavior problems, and rarely have patterns of change been studied over time alongside with the overall associations with age. This raises the question of whether the development of behavior problems is more likely because of exposure to poverty during certain periods of life, or whether it is a matter of prolonged exposure over time. For instance, studies have shown that poverty is most strongly associated with child outcomes with prolonged exposure over the years (Nikiéma, Gauvin, Zunzunegui, & Séguin, 2012; Roy & Raver, 2014). Furthermore, it remains unclear how underlying mechanisms of the poverty-behavior problems link operate over time, that is, how their effects vary according to timing and duration of exposure. Research is needed to inform more on the targets and timing for the development of effective primary prevention approaches targeting behavior problems among economic disadvantaged children and youth.

1.2 General objectives of the current thesis

The objectives of this research are (1) to investigate specific family–related mediators of the association between poverty and behavior problems during early childhood (i.e., the first 5 years of life), a period characterized by children's high levels of dependence on caregivers and vulnerability to adverse and stressful environmental conditions; and (2) to examine the differential effects of the timing of poverty between birth and late childhood on behavior problems in early adolescence. This dissertation is grounded in the life course framework (Kuh, Ben-Shlomo, Lynch, Hallqvist, & Power, 2003; Lynch & Smith, 2005) which are etiologic models describing how exposure to adversity throughout the lifecycle relates to later-life health, and in particular, experiences related to poverty and the associated social disadvantages. This research will inform on the time and targets across human development for interventions aimed at reducing behavior problems risk in youth.

The present research extends the current literature by examining the association between poverty and behavior problems on a developmental span over 13 years from birth to early adolescence. One of our aims was to conduct time-specific models to assess whether exposure to poverty occurring at earlier versus later points in human development differentially influences the occurrence of behavior problems. Specifically, a longitudinal study spanning from birth to early adolescence allows an examination of whether the association between poverty and behavior problems is stronger or weaker depending on the timing of poverty across different developmental periods such as early and middle childhood. For the purpose of the present dissertation, we defined developmental periods by age corresponding to three groups: (a) early childhood between ages 0-5 years, (b) childhood between ages 6-12 years; and (c) early adolescence at age 13. Age ranges approximates conceptualizations of developmental periods as proposed by the Centre of Disease Control (CDC, childhood between ages 4-11) and the Diagnostic and Statistical Manual of Mental Disorders (DSM, American Psychological Association; childhood between ages 7-12). Age ranges were also based on the acquisition of cognitive structures (Piaget, 1964) as well as transition periods in school settings (e.g. from child care to school entry at age 6, or from elementary to high school at age 13). These topics are further discussed in the Chapter 3.

1.3 The organization of the thesis

Chapter 1 presents behavior problems as a pervasive health problem warranting prevention strategies. It also frames the purpose of the current thesis by outlining poverty and behavior problems as prevalent and costly social problems that are etiologically related.

Chapter 2 informs on the need to take into account the patterns of growth and changes of these conditions across different developmental periods as well as continuity-discontinuity as a central issues to the field of developmental psychopathology. In this chapter, we referred to several studies indicating the importance of distinguishing subtypes of behavior problems. Specifically, it focused separately on three subtypes of behavior problems corresponding to hyperactivity, opposition and physical aggression domains as they do not fully overlap. Next, it presents an overview of poverty within which to understand more about health and social risks associated with child poverty. Chapter 2 also introduces a life course framework within which to understand how timing of exposure to poverty relates to behavior problems from birth to early adolescence. This section begins with a strong focus on poverty as a well-established risk factor for the development of behavior problems, and then a review of the mechanisms underpinning this association is given. Describing mechanisms by which poverty is linked to behavior problems is relevant for a several reasons such as (a) to explain which factors may underlie the epidemiological associations, (b) to inform the time and targets for interventions to limit the detrimental impact of poverty on behavior problems, and (c) to provide policy recommendations to further reduce poverty in families with young children. Further, limitations of the current literature on behavior problems-poverty link are listed. Finally, we present the added value of the present thesis residing in the examination the role of timing and duration as well as identification of possible mechanism linking exposure to poverty to the development of behavior problems.

Chapter 3 provides the objectives of the present dissertation, each containing a specific objective and hypothesis for the three research papers contained in the present dissertation. The study design and its application to the in the current work are made explicit. A detailed description of the Quebec Longitudinal Study of Childhood Development or QLSCD is given. Then, some key methodological issues pertaining the study design and its application to the in the current work as well as behavior problems and poverty measurements are made explicit. Statistical methodologies addressing the longitudinal data are also presented.

Chapter 4 contains all three research papers derived from present dissertation in chronological order. All three manuscripts have been published in peer-reviewed journals. Research paper 1 entitled “Poverty and behavior problems during early childhood: The mediating role of maternal depression symptoms and parenting” extends our understanding of family mediators through which poverty shapes behavior problems during early childhood. Research paper 2 entitled “Poverty and behavior problems trajectories from 1.5 to 8 years of age: Is the gap widening between poor and non-poor children?” examines whether poverty predicts changes in behavior problems overtime. Finally, research paper 3 entitled “Early adolescence behavior problems and timing of exposure to childhood poverty: Comparing lifecourse models” focuses on the differential effects of the timing of poverty between birth and late childhood on behavior problems in early adolescence

Chapter 5 reviews the main results of all research papers and discusses the findings in relation to the scientific contributions, strengths and limitations, before addressing current work’s public health implications, emerging issues and future research. Finally, Chapter 6 presents the conclusion.

CHAPTER 2

Literature Review

Our literature review is organized in three parts. The first reviews our current understanding of a range of behavior problems across the lifespan. The second part focuses on the definition and measurement of poverty. The third section describes the association between poverty and behavior problems across the lifespan, and points to poverty and the mechanisms underpinning the poverty-behavior problems association as possible targets for intervention.

2.1. Behavior problems: An Overview

2.1.1 What are behavior problems?

Behavior problems is an umbrella term summarizing a wide range of behavior that includes hyperactivity, aggression, emotion dysregulation, defiance, rule breaking, and destructive behavior (Achenbach & Edelbrock, 1991; Achenbach, 1992; Dodge, Coie, & Lynam, 2007). They are also referred as "externalizing", "conduct problems", "disruptive" or "antisocial" behavior interchangeably in several studies. The common denominator of this mix of behavior seems to be that they are challenging and generally felt to be disruptive in a social context (Tremblay 2000). Behavior problems are common complaints of caregivers of children and adolescents as well as defining features of psychiatric disorders such as Attention Deficit/Hyperactivity Disorder (ADHD), Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD).

Some disruptive behaviors are considered to be normative during early childhood and to represent transient developmental disturbances that tend to decrease over the course of human development as more adaptive social skills emerge (Barker, Oliver, & Maughan, 2010; Côté, Vaillancourt, LeBlanc, Nagin, & Tremblay, 2006). Possibly, difficult behaviors among young children such as defiance to parental requests (e.g. repeatedly saying 'no!'), physical aggression toward siblings or peers, and difficulty controlling anger (e.g. tantrums) are attempts to establish autonomy and master environmental constraints (Campbell, 2006). Typically, with age, children tend to "out-grow" these difficult behaviors following the development of more age-appropriate social and communication skills such as negotiating, sharing, and playing cooperatively.

However, behavior problems are considered to be harmful and to increase the risk for psychiatric disorders if they persist over time, leading to severe disability and interfering with developmental and social functioning (Campbell, Shaw, & Gilliom, 2000; Campbell, 1995). In many instances, manifestations of behavior problems in the form of high levels of activity, frequent tantrums, peer relational problems, noncompliance, and aggression towards others are of concern and are likely to necessitate clinical attention. Behavior problems may persist into adulthood in the form of conduct and self-regulation problems, i.e. tobacco, alcohol, or drug dependence (Melchior et al., 2007; Poulton et al., 2002; Tsal, Shalev, & Mevorach, 2005). They are considered the most socially destructive form of mental health problems, as they increase the risk for adult criminality and social adjustment problems (Fontaine et al., 2008; Kuja-Halkola et al., 2014; Satterfield et al., 2007).

Behavior problems can be classified into several diagnostic categories. They include Attention Deficit/Hyperactivity Disorder (ADHD) and disruptive behavior disorders, namely Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD), which can be diagnosed as early as 7 years. Behaviors encompassed in ADHD, ODD and CD are varied and include: a) ADHD: inattention, distraction, disorganization, hyperactivity, restlessness and impulsiveness; b) ODD: disobedience, defiance, poor response to discipline, arguing with people, blaming others, being touchy and annoyed, and being angry or resentful; and c) CD: delinquent acts, aggression towards people and animals, dissocial behavior such as deceitfulness and truancy. Importantly, most medical classification systems define behavior problems as symptoms of a disorder based on their severity, frequency, persistence, and functional impairment relative to what is considered to be normative for an individual's age, gender, and culture.

Two systems for classifying types of behavior problems - the DSM (American Psychiatric Association) and the International Classification of Diseases (ICD-10, World Health Organization) - are largely adopted to guide research and clinical practice. Specifically, in the DSM-5 (American Psychiatric Association, 2013), ODD and CD refer to problems in emotional and/or behavioral regulation that are manifested uniquely in the form of behaviors that violate the rights of others (e.g., aggression, destruction of property) and/or that bring the individual into significant conflict with societal norms or authority figures. In turn, ADHD refers to a neurodevelopmental disorder defined by impairing levels of inattention, disorganization, and/or hyperactivity-impulsivity. Neurodevelopmental disorders represent a wide range of conditions with onset in a certain developmental period, typically manifested early in development (i.e. before grade school).

2.1.2 Prevalence studies of behavior problems in childhood and adolescence

Overall, estimates of the prevalence of mental disorders in the past decade suggest that at least 20% of children will have a mental health problem in any given year (Costello, 2003; Costello et al., 2005; Merikangas et al., 2010). Prevalence estimates of having at least one disorder by age 16 years are as high as 37% (Costello, 2003; Costello et al., 2005). Given the high prevalence from early childhood to adolescence, mental health problems are seen as one of the leading health problems among Canadian children (Waddell et al., 2005).

Behavior problems are the second most common condition in adolescence with point estimates as high as 19.6% for at least one disorder from age 13-18 years (Merikangas et al., 2010). In particular, prevalence rates were around 13% of the sample (6.5% for severe cases) for ODD and nearly 7% met criteria for CD (2.2% for severe cases). For ADHD, rates were nearly 9% (4.2% for severe cases). Further, this study showed the rates of ADHD and ODD remained relatively stable by age group, whereas rates of CD increased to a peak of 9.6% among the oldest adolescents. Findings from a recent meta-analysis of international community surveys in youth reported lower estimates for mental disorders and behavior problems between ages 6-18 years than what has been reported by Merikangas et al. (2010) (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015). Worldwide prevalence estimates were as follow: 13.4% for any mental disorders, 3.4% for ADHD, and 5.7% for any disruptive disorder (3.6% for ODD and CD was 2.1%). Moreover, ADHD and CD were found to be more prevalent in boys than girls, with a 3 to 4 times increased estimates for boys. However, sex differences in the prevalence of ODD are less clear (Costello et al., 2005; Merikangas, Nakamura, & Kessler, 2009). With regards to Canadian samples, the prevalence of behavior problems between ages 6-14 years were as follows (Breton et al., 1999): a) ADHD ranged from 3.8-9.8%; b) ODD ranged from 0.7-5.8% (0.5-9.1% for boys and 0-2.8% for girls); and c) CD ranged from 0.2-2.3%. Another study based on an older sample (14-17 years of age) reported that prevalence rates ranged from 5.2-8.8% for CD/ODD and from 1.0-3.9% for ADHD (Romano, Tremblay, Vitaro, Zoccolillo, & Pagani, 2001). Variability in prevalence estimates could be explained by sample size and composition, differences in assessment methods as well as the diagnostic criteria and age of individuals.

Regarding trends in the prevalence of behavior problems over time, one study using survey data reported that most behavior problems between 10-15 years of age, including CD and aggression, remained relatively stable from 1994/95 to 2008/09, with the exception of hyperactivity that showed escalating rates over time (McMartin, Kingsbury, Dykxhoorn, & Colman, 2014). Similarly, another study showed an upward trend in the prevalence of prescribed ADHD medications and ADHD diagnosis for school-age children only, but not for preschoolers in Canada from 1994 to 2007 (Brault & Lacourse, 2012).Taken together, findings suggest that behavior problems in the form of ADHD, ODD and CD affect a significant number of children and adolescents in Canada and worldwide.

2.1.3 Developmental patterns of behavior problems

Research has focused on developing models of behavior problems based on the timing of symptoms manifestation. The central focus is the developmental taxonomy of early-onset or childhood-onset versus late-onset or adolescence-onset behavior problems. The overriding idea is that the age of onset plays an important role in the etiology, course, and prognosis of behavior problems later in life (Moffitt, 1993; Odgers et al., 2008). Childhood-onset behavior problems are characterized by difficult behavior of high-risk children that originated early in life and are exacerbated by environmental risk (e.g. family and school context), leading to persisting behavior problems across development. In turn, adolescent-onset behavior problems emerge when young people enter adolescence as an adaptation response to biological and contextual factors that are specific to the transitions into early and late adolescence (Moffitt & Caspi, 2001; Moffitt, 2003). The adolescence-onset subtype seems to operate through associations with delinquent peers, and/or seeking social status through delinquent behaviors (Vitaro, Brendgen, & Tremblay, 2000).

A comprehensive review on the childhood- and adolescent-onset behavior problems distinction suggests that childhood subtype tend to increase in rate and severity throughout childhood and into adolescence whereas the adolescent subtype is specific to a single developmental stage (i.e., adolescence) and results from a failure to adequately adjust to the developmental demands (e.g., separation and individuation from parents) of that stage (Frick & Viding, 2009). In this study, not only subtypes were presented as following different developmental trajectories over time but they also differed in terms of individual and contextual risk factors. Specifically, the childhood-onset subtype was associated with: a) individual-level risk factors that included cognitive deficits and ineffective socialization as well as temperamental and personality risk factors (e.g. impulsivity); and b) contextual-level risk factors corresponding to homes with greater family instability (e.g., more family conflict, poor parental supervision) and poor quality schools. Furthermore, this subtype was reported as being likely to persist into late adolescence and adulthood. On the other hand, the adolescence-onset subtype was associated with fewer risk factors corresponding to higher levels of rebelliousness and being more rejecting of conventional values as opposed to individual-level vulnerability. This subtype was conceptualized as an exaggeration of the normative process of adolescent rebellion that was less likely to persist beyond adolescence (Moffitt, 2003, 2006). Nevertheless, some studies have reported that both the childhood- and adolescence-onset subtypes contribute to negatives outcomes in adulthood including undetected crimes, school dropout, violence, substance abuse problems and internalizing problems (Monahan et al., 2009; Odgers CL et al., 2007; Pingault et al., 2013).

Several diagnostic categories of the DSM encompass this dual taxonomy of childhood versus adolescent-onset with a cut-off age for childhood between 10-12 years of age

(American Psychiatric Association, 2000, 2013). Specifically, childhood-onset CD is defined based on the presence of symptoms emerging prior to age 10 years. In contrast, ADHD is referred as a childhood disorder emerging before age 12 years. Furthermore, there is a broad consensus from longitudinal studies that behavior problems generally identified in school-age children are also prevalent in preschool children (Carbonneau, Boivin, Brendgen, Nagin, & Tremblay, 2015; Egger & Angold, 2006; Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014; Shaw et al., 2005). Other intervention studies have found that interventions targeting children identified as aggressive in kindergarten reduced the risk of CD and ODD in adolescence and criminal behavior in young adulthood (Hektner, August, Bloomquist, Lee, & Klimes-Dougan, 2014; Vitaro, Barker, Brendgen, & Tremblay, 2012). Collectively, these studies provide evidence that behavior problems are not limited to childhood or adolescence.

In addition to the age of onset of behavior problems, it is important to better understand that course of behavior problems over time in terms of severity and persistency. Many prospective studies using group-based trajectory analyses (Nagin & Tremblay, 1999) have provided information on the continuity and change in behavior problem patterns over the course of development. There are marked individual differences in behavior problems across development. Evidence suggests heterogeneity in the course of behavior problems in terms of severity as well as persistency; that is, individuals following chronic, moderate-desisting, moderate, high-desisting and low behavior problems trajectories from as early as age 2 years (Côté et al., 2006; Fanti & Henrich, 2010a; Shaw et al., 2005).

An examination of behavior problems across multiple sites, including Canada, the United States and New Zealand, suggests that patterns of physical aggression gradually increase or decrease over time but have consistent rank stability across sites and sex (Broidy et al., 2003). There is no evidence for the late-onset physical aggression the studies cited above. Furthermore, results suggest that high levels of physical aggression and hyperactivity during childhood (6-12 years) predict violence and nonviolent delinquency during adolescence (13-17 years). Similarly, another study showed that behavior problems declined in frequency with age (6-15 years) and that high levels predict juvenile delinquency (17 years) (Nagin & Tremblay, 1999). Specifically, a chronic oppositional trajectory, with physical aggression and hyperactivity trajectories held constant (i.e. no overlap with other chronic trajectory groups), was associated with covert delinquency only, such as theft. By contrast, chronic physical aggression trajectory, with the oppositional and hyperactivity trajectories being held constant, was associated with overt delinquency (e.g. physical violence) and other serious delinquent acts. A late-onset group of behavior problems was not identified. Instead, this study suggested continuity in behavior problems patterns between middle childhood and adolescence, as oppositional and physically aggressive adolescents were oppositional and physically aggressive children.

Another study focusing exclusively on physical aggression (6-17 years) suggests continuity across the two lifecourse stages - childhood and adolescence (Brame, Nagin, & Tremblay, 2001). Results showed that higher childhood physical aggression trajectories were more likely to transition- to a higher-level adolescent aggression trajectory than boys from lower childhood physical aggression trajectories. Additionally, enduring patterns of aggression during childhood (5-7 years) were found to be associated with the severity and acquisition of more behavior problems in late adolescence (17-19 years), such as CD and reactive anger (Okado & Bierman, 2014). This pattern of findings was also confirmed for severe hyperactivity in clinically-referred individuals. One study demonstrated that the clinical diagnosis of combined-type ADHD (5-19 years) strongly persists into late adolescence and young adulthood (van Lieshout et al., 2016). Another study examining a sample of children with and without *DSM-5* ADHD from early childhood to young adulthood (5-18 years) found that ADHD persistence was associated with more severe ADHD symptoms in childhood (Agnew-Blais et al., 2016). However, they also found that the majority of individuals with *DSM-5* adult ADHD did not have ADHD diagnosed in childhood, indicating late-onset ADHD group with no childhood diagnosis, and a smaller group with persistent ADHD.

With regards to behavior problems during early childhood (i.e. before 5 years), evidence shows that physical aggression and hyperactivity during this period of development tend to decrease over time as a result of preschool and school-aged socialization (Campbell, Spieker, Burchinal, Poe, & The NICHD Early Child Care Research Network, 2006; Côté et al., 2006; Galéra et al., 2011; Larsson, Dilshad, Lichtenstein, & Barker, 2011; Romano, Tremblay, Farhat, & Côté, 2006; Tremblay et al., 2004). Numerous studies have shown evidence for the stability of these behavior problems from early to middle childhood based on group-based trajectory analysis (Nagin, 1999) as well as ODD, CD and ADHD diagnosis in preschool children. One study showed that the majority of children displayed low levels of behavior problems from 2-12 years, and that those displaying moderate or high levels exhibited decreases in behavior problems with age (Fanti & Henrich, 2010b). Results also suggested that children exhibiting high and continuous behavior problems across this 10-year period were more likely to engage in risky behaviors, to be associated with deviant peers and to present peer relational problems in early adolescence. The second study on behavior problem diagnosis in referred preschool children (3.5-5.5 years) demonstrated that ODD, CD and ADHD are likely to persist into the school-age period and that diagnostic reassessments play an important role in identifying new cases and changes in symptoms manifestations (Bunte, Schoemaker, Hessen, van der Heijden, & Matthys, 2014).

Using non-clinical and clinical classifications, the evidence provided above highlights the importance of examining behavior problems during early childhood and beyond the dual taxonomy of childhood- and adolescent-onset subtypes. Behavior problems may appear as early as age 1.5 years with a general tendency to decline over time due to maturation and learning experiences. Both non-clinical and clinical perspectives suggest a continuum between normative behavior problems and clinically significant symptoms across childhood development based on frequency, duration, and impairment. In addition, there is an evolving consensus that only a small proportion of children exhibiting high levels of behavior problems during early childhood that tend to persist and increase in severity later in life (Connor, Steeber, & McBurnett, 2010; Egger & Angold, 2006; Shaw, 2013a; Tremblay, 2010).

Given that behavior problems exist along a continuum, there is a large body of evidence supporting the notion of *homotypic prediction* within subtypes of behavior problems, referring to the fact that prior disorder status is typically the strongest predictor of having the same disorder later in life (Costello, Copeland, & Angold, 2011; Reef, Diamantopoulou, Meurs, Verhulst, & Ende, 2010). Thus, behavior problems during early childhood would be the strongest predictor of behavior problems in subsequent developmental periods.

2.1.4 Behavior problems and patterns of change over time

Understanding how behavior problems change in *level and growth* across developmental periods and whether patterns of change are specific to a certain subtype of behavior problems can be helpful for treatment and prevention strategies. A review of studies of school-age children and adolescents on physical aggression and oppositional behavior provided compelling evidence on the importance of distinguishing subtypes of behavior problems as they have different developmental trajectories and require specific corrective interventions (Tremblay, 2010). This review suggests very strongly that subtypes of behavior problems should not be aggregated into composite measures. In fact, the aggregation of behavior problems fails to capture variability in the frequency of different forms of symptoms, thus making it impossible to compare subtypes of behavior problems. The author illustrated this issue by emphasising that CD severity is measured in terms of variety rather than the frequency of behavior problems. Further, this aggregating tendency was seen to mask essential aspects of behavior problems that might be age-dependent.

A more recent study found that, whereas the overall behavior problem score increased during the first few years of elementary school and remained flat thereafter, several subtypes of behavior problems showed different patterns of growth between 5 and 13 years of ages (Olson et al., 2013). While these studies challenge the notion of combining subtypes of behavior problems, the evidence is largely based on scores and developmental taxonomies encompassing several different kinds of behavior rather than considering constructs separately.

There is increasing recognition for the need to distinguish between subtypes of behavior problems when examining patterns of change between early childhood, middle childhood and adolescence, as well as how they related to different outcomes in adulthood. In fact, a 10-year longitudinal follow-up study on clinically-treated boys with ADHD showed that, whereas inattentive symptoms were more common than hyperactive symptoms in adolescence, by adulthood both types were equally rare (Biederman, Petty, Evans, Small, & Faraone, 2010).

In addition, research points to different developmental patterns in childhood and adolescence for ADHD symptoms (Bonafina et al., 2000; Galéra et al., 2011). Inattention can be detected as early as 2 years of age with estimates increasing later in life (Polderman et al., 2010; Preston et al., 2009; Spira & Fischel, 2005), whereas hyperactivity follows the opposite pattern as it is common in early years with estimates decreasing thereafter (Fontaine, et al., 2008; Pingault et al., 2011; Romano et al., 2006). Additionally, previous research has suggested that CD, ODD and ADHD in adolescence have distinctive patterns of association with longer term consequences in adulthood. Specifically, ADHD alone was linked to poor educational and related outcomes, whereas ODD and CD increased risks of later crime and internalizing problems (Fergusson et al., 2010). Similarly, behavior problems from early childhood to adolescence such as aggression, opposition, and property and status violations were associated with different adult outcomes. Status violations (e.g. running away, truancy) increased the risk for substance use, anxiety and mood disorders in adulthood, whereas opposition mainly predicted anxiety disorder in adulthood over a period of 24 years (Reef et al., 2010).

2.1.5 Behavior problems and sex-differences

Another important issue is accounting for sex-differences within certain subtypes of behavior problems. Over the previous two decades several studies focused exclusively on male samples, documenting a general tendency for behavior problems to decrease with age among boys as well as a small proportion of boys who persistently display high levels of behavior problems over time (Haapasalo & Tremblay, 1994; Kokko, Tremblay, Lacourse, Nagin, & Vitaro, 2006; Nagin & Tremblay, 1999; 2001; Vitaro et al., 2000). One possible explanation for a broader focus of behavior problems research on males rather than females is that girls are less likely manifest severe behavior problems such as physical aggression (Archer & Côté, 2005). Another explanation is that behavior problems in females are less likely to predict subsequent psychiatric diagnoses (such as CD) later in life and, hence appear to be less of an economic burden to society (Foster & Jones, 2005). Empirical evidence, nevertheless, has identified different developmental trajectories of behavior problems in females that, in turn, are predictive of CD diagnosis and are similar to the ones identified in males (Côté, Zoccolillo, Tremblay, Nagin, & Vitaro, 2001; Fontaine, Carbonneau, Vitaro, Barker, & Tremblay, 2009). Developmental trajectories found in females include early-onset/life-course-persistent, childhood-limited, adolescence-limited, adolescence-delayed-onset, adulthood-onset. Importantly, the review study cited above suggested that the adolescence-delayed-onset trajectory could be specific to girls and could be linked to childhood risk factors and later behavior problems in adulthood. However, findings refer to a global measure of behavior problems that include physical aggression, indirect aggression, opposition, and delinquent and criminal behaviors from early childhood to adulthood (up to 39 years of age).

In studies with samples including both males and female participants, sex-differences in point estimates of specific subtypes of behavior problems are well documented. Compared to males, females are less likely to be on the high trajectory of physical violence, and their trajectories of other behavior problems (e.g.. vandalism, theft) are less strongly associated with high levels of physical violence from 10 to 15 years (Lier, Vitaro, Barker, Koot, & Tremblay, 2008). A review on the development of aggression from childhood to adolescence suggested that more boys than girls display high levels of physical aggression, and more girls than boys display the lowest levels of physical aggression (Côté, 2007). Another important finding was that indirect (relational) aggression appeared later in development and was particularly elevated among adolescent girls. It seems that sex-differences are a function of the type of aggression considered as well as the developmental period studied. Subsequently, one study suggested that a small percentage of highly aggressive boys displayed a clinical profile similar to Moffitt's life-course-persistent antisocial pattern from as early as 3 years. No such group was identified for girls (Lussier, Corrado, & Tzoumakis, 2012).

An examination across multiple sites, including Canada, the United States and New Zealand found that patterns of physical aggression appear to be relatively stable from 5 to 10 years for boys and girls (Broidy et al., 2003). Yet, an association between physical aggression and later delinquency was found among boys but not among girls. For oppositional behavior, there is evidence that the age of onset can be as early as 2 years (Egger & Angold, 2006; Petitclerc et al., 2009), and that boys have an earlier age of onset than girls (2.5 years vs. 5.5 years) (Rowe et al., 2002). However the evidence was mixed in other studies of sex-differences in behavior problems.

Furthermore, evidence drawn from a clinical sample reported that the prevalence of CD did not differ significantly by sex from 8 to 17 years of age (Vera, Ezpeleta, Granero, & Osa, 2010). Instead, results indicated a higher frequency for 13–17 year olds, and a greater number of symptoms in boys. Hence, sex and age differentially affected the expression of some CD symptoms in terms of impairment and severity. Using a sample followed up over 40 years, one study found few significant differences between men and women for the association between CD in adolescence and outcomes in adulthood (Colman et al., 2009). Specifically, men with severe CD were more likely to be in a manual labour social class and to be unemployed in adulthood; this relationship was not apparent for women. But, more importantly, they found no sex-difference between severe CD and adversity in adulthood, suggesting that men and women with severe CD during adolescence are affected equally in adulthood.

Discrepancies in the literature cited here could be due to methodological problems such as small sample sizes, homogeneity in sample composition, maternal report bias, and differences in assessment methods over time. Despite these limitations, there is sufficient empirical evidence supporting the importance of sex and age on the development of behavior problems across the life span.

2.1.6 Childhood and adolescent risk factors for behavior problems

Overall, behavior problems result from complex associations between an extensive list of biological, psychosocial and environmental risk factors, acting across different stages of development. Findings on risk factors for behavior problems from early childhood to adolescence point to the importance of prenatal and postnatal family risk factors (Huijbregts et al., 2008). These family risk factors include material and psychosocial factors such as low income and poverty (Brooks-Gunn & Duncan, 1997; Huijbregtsh et al., 2008; Linver, Brooks-Gunn, & Kohen, 2002; Tremblay et al., 2004), food-insecurity and nutritional deficiency (Huang, Oshima, & Kim, 2010; Kleinman et al., 2002; Melchior et al., 2009), parenting practices (Boivin et al., 2005a; Geoffroy et al., 2010; Leve, Kim, & Pears, 2005; Shaw, Bell, & Gilliom, 2000), toxic exposure such as to heavy metals (Dietrich, Douglas, Succop, Berger, & Bornschein, 2001; Nigg et al., 2008) and parental mental health problems (Côté et al., 2009; Dearing, McCartney, & Taylor, 2006; Rafferty & Griffin, 2010).

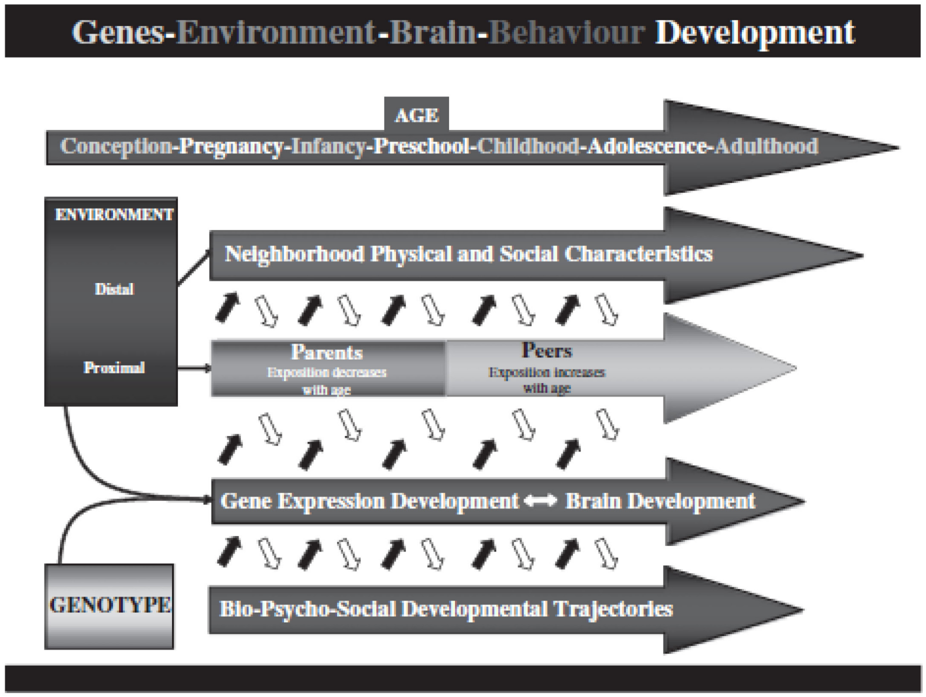
Other important psychosocial risk factors are non-reliance on child care services for children of mothers with low levels of education (Côté et al., 2007), the influence of deviant peers (Vitaro et al., 2000) and school social climate (LeBlanc et al., 2008). Further, findings from a Canadian study using survey data of adolescents between 12-15 years also points to contextual risk factors such as school and family settings (Zhang, 2011). Risk factors were three-fold: (1) school quality measured by "in-class cooperation through group activities" was linked to better academic performance and less crime for boys and girls, while conventional school quality measures, such as class size or teacher's education level, did not have a significant impact on behavior problems, (2) having deviant peers was associated with more criminal behavior, and (3) family background was associated with criminal behavior.

In addition to these factors, there is also evidence that genetic factors may be strongly implicated in the development of behavior problems such as hyperactivity (Faraone, Doyle, Mick, & Biederman, 2001; Gizer, Ficks, & Waldman, 2009) and physical aggression

(Brendgen et al., 2005). It is possible biological susceptibilities to physical aggression could be present from birth, and that these susceptibilities may develop as a function of environmental adversities. Research suggests that individual differences in the development of physical aggression are due to genetic vulnerability moderated by prenatal and post-natal environmental risk (Boivin et al., 2013; Lacourse et al., 2014).

A global summary of risk factors bio-psycho-social as discussed above is presented in Figure 1, *Gene-Environment-Brain-Behavior Development* (Tremblay, 2010). This summary presents putative or well-established associations between bio-psycho-social risk factors that may explain the development of behavior problems from early childhood to adulthood in a series of connections and temporal sequences. Here, behavior problems are presented as a function of genetic and environmental endowment. Moreover, the author presents early environmental risk factors as being easily identifiable and related most strongly to the mother and family context. This is arguably coherent with previous interventional research aimed at reducing behavior problems risk and preventing futures consequences by improving the early environment and increasing early detection (Shaw, 2013).

Figure 1 *Gene-environment-brain-behavior development*



2.1.7 The health and economic burden of behavior problems

There is accumulating evidence that behavior problems from childhood into adolescence and from adolescence into adulthood are associated with a wide range of negative outcomes. They vary from impaired family and peer relationships, academic failure, fewer qualifications, substance abuse, criminality to anxiety and depressive disorders (Biederman et al., 2012; Fergusson, Horwood, & Ridder, 2005; Klein, Mannuzza, Olazagasti, & et al, 2012; Lier et al., 2008; Pagani, Boulerice, Vitaro, & Tremblay, 1999; Pingault et al., 2013; Pingault et al., 2011; Washbrook, Propper, & Sayal, 2013). Importantly, behavior problems during childhood and adolescence have been linked to working disability in which individuals struggle to maintain employment, are more likely to have low socioeconomic status and low economic productivity in adulthood (Colman et al., 2009; Galéra et al., 2012; Mordre et al., 2012).

Furthermore, evidence shows that childhood ADHD was associated with reduced quality of life quality of life as well as functional impairment (Hampel & Desman C, 2005), and that overall impact on quality of life was at least as great as seen for many mental health and physical disorders (Danckaerts et al., 2009). Another study examining specific aspects of quality of life reported that the most affected domains for both ADHD and CD (6-18 years) were school functioning and social functioning (Bastiaansen, Koot, Ferdinand, & Verhulst, 2004). So it is not surprising that these individuals, having a host of negative outcomes not only in terms of criminality but also in areas of education, health, and welfare, create a significant individual and societal burden.

Moreover, a report summarising the total burden of mental disorders worldwide showed that childhood behavioral disorders, including ADHD and CD, accounted for 3.4% of disability-adjusted life years (DALYs) (Whiteford et al., 2013). The latter is a composite measure that combines premature mortality as years of life lost (YLLs, with deaths in people with mental disorders coded as the physical cause of death and suicide coded as injuries under self-harm) and in years lived with disability (YLDs). Another burden quantification study examined separately CD and ADHD and reported differences between the two disorders, in particular high rankings of CD in terms of years lived with disability as well as disability-adjusted life years (Erskine et al., 2014). In this study, CD and ADHD accounted for 0.80% of total global years lived with disability and 0.25% of total global disability-adjusted life years from 5-19 years of age. Hence, taken together both disorders were particularly prominent in terms of nonfatal burden. Specifically, CD was the 72nd leading contributor and among the 15 leading causes in terms of global disability-adjusted life years despite a complete lack of premature mortality as years of life lost. Conversely, ADHD ranked 98th in terms of years lived with disability and did not reach the top 100 leading causes of global disability-adjusted life years.

In sum, the global burden of CD and ADHD was shown to be significant, particularly in male children. Based on these considerations, behavior problems are not only prevalent but disabling disorders with lower mortality in childhood and adolescence. Analysing burden estimates in this aggregated level is useful to inform policy makers and address population health. It allows assessing the societal burden of behavior problems with a greater emphasis on clinically significant distress and impairment in youth.

Regarding the economic impact of behavior problems, research has reported on the cost-estimates and patterns of expenditures with a broader focus on ADHD and CD. First, it is possible that the economic costs are higher for children and adolescents (5-15 years) with behavior problems compared to those with emotional disorders (Snell et al., 2013). Second, differences in costs across disorder types have been evoked. One study suggested that childhood (6-7 years) CD had the greater impact than hyperactivity on public sector costs in early adulthood (18 years of age), with more than half the average cost due to contacts with the criminal justice system (D'Amico et al., 2014). An expenditure gap was also found between CD and ODD over a 7-year period (7-13 years) (Foster & Jones, 2005). Cost-estimates were higher for individuals with CD than for those with ODD, in which expenditures accounted mostly for school costs, followed by juvenile justice costs and estimated to be about 20%. Overall, cost-estimates cited here refer to the costs of crime as well as educational, health, and social services expenditures. Despite differences in the economic-impact across disorders types, public expenditures on youth behavior problems are high and plead for intervention strategies aimed at preventing behavior problems which could, in turn, decrease the costs.

Different patterns of expenditures in North America and Europe have also been highlighted in relation to behavior problems. In a recent review, cost-estimates in Europe for children and adolescents with CD was lower than for those with ADHD although the reverse was true for United States (Beecham, 2014). For ADHD, cost-estimates for health care varied from US$ 660 to $3,140 whereas education-cost were on average about US$ 5,000 per annum. For CD, cost–estimates were around a mean of £5,960 per annum in which £1,277 fell mainly to the health care and education services. A systematic-review on ADHD-related incremental costs for children/adolescents and adults in the United States reported that most of these costs were incurred by adults ($105B-$194B) compared with children/adolescents ($38B-$72B) (Doshi et al., 2012). This review also highlighted that the largest cost category was productivity and income losses ($87B-$138B) for adults whereas the largest cost categories were health care ($21B-$44B) and education ($15B-$25B) for children.

There is also evidence of substantial economic burden of behavior problems during early childhood. One study showed that young children with hyperactivity (3 years) had 17.6 times higher average costs per annum across domains than their counterparts (i.e. £562 for each hyperactive individual versus £30 for those with no behavior problems). In Canada, the economic cost of youth behavior problems has received relatively little attention. There is a lack of information describing health expenditures or education costs linked to ADHD, CD and ODD. However, the high cost of health expenditures due to mental health has been documented. Specifically, mental health expenditures and services account for over $14 billion annually in direct and indirect costs or 7% of total government health expenditures (Mental Health Commission of Canada, 2012). This failure to provide economic analyses on the behavior problems-related cost makes it particularly difficult for policymakers to make informed decisions.

2.1.8 Behavior problems and the potential for primary prevention

Given the significant individual and societal burden of behavior problems, preventing these disorders before they become chronic could considerably reduce their burden. There is a need to reconsider reallocating expenditures towards primary prevention approaches early in life to contain the progression of disorders as a cost-effective response. Importantly, one study suggested that public expenditures may be reduced if resources are moved from coping with problem behaviors to preventing them (E. M. Foster & Jones, 2005). For the authors, the key policy question is not whether to spend money on these children but rather *how to spend it*. A related point bears mention. Evidence suggested that behavior problems that reach the level of a diagnosable disorder - including ADHD , ODD and CD – are treatment-resistant and generate small to medium effects of interventions in terms of effectiveness (Kazdin, 1987; McCart, Priester, Davies, & Azen, 2006). This pleads for a greater focus on the prevention aimed at earlier manifestations of behavior problems before they progress to diagnosable disorders ("Initial Impact of the Fast Track Prevention Trial for Conduct Problems," 1999; Shaw, 2013). This is coherent with numerous studies suggesting the long-term benefits of early intervention and service provision to promote and support child development (Hamad & Rehkopf, 2015; Richter et al., 2016; Shonkoff, 2010).

Another important issue is defining the optimal time across human development to invest on programs and services directed at behavior problems among children and youth. Research suggests that the economic return from early interventions is high, and the return from later interventions is low with remedial programs in the adolescent and young adulthood being much more costly in producing the same level of skill attainment later in life (Heckman, 2006). A review on the economic case for early childhood interventions in The United States and in Europe suggest "*antenatal investment hypothesis*" (Doyle, Harmon, Heckman, & Tremblay, 2009). The later refer to impact of intervening at early years of the child's and mother's life would be more effective than interventions starting later in life for a host of developmental outcomes, including behavior problems. Also, this hypothesis indicates that the return on the antenatal investment may be higher than the postnatal investment, both initially and in the long-term, and may increase the rate of return on investment at every subsequent period. It is possible that early interventions might be best to forestall the further acceleration of problems behavior later in life and reducing their burden, but investments are also needed during adolescence to target adolescent-onset risk.

Importantly, studies reviewing the effects of prevention programs conducted during early and middle childhood on adult mental health suggest that early intervention and prevention efforts may reduce later adult mental health problems and improve personal well-being and productivity (Deković et al., 2011; Kieling et al., 2011). Specifically, in Kieling et al (2011) efforts took place as early as age 2 years. In these studies, outcomes measures were overall mental health problems, criminality and behavior problems including hyperactivity, aggressive behavior and delinquency. Further research is needed to better understand the risk factors for behavior problems and predictors of the continuity of these problems later in life as potential targets prevention programs. In addition, clear evidence and a monitoring system are also warranted to inform on the effectiveness of interventions.

Despite the fact that behavior problems in youth are prevalent and typically preceded diagnosable disorders in adulthood (Kessler et al., 2005), the provision of mental-health services is weakest during adolescence and youth (Patel, Flisher, Hetrick, & McGorry, 2007). Specifically in Canada, youths with mental health difficulties face delayed detection; long waiting lists with shorter wait times for higher priority individuals; inaccessible, unengaging services; abrupt transitions between services; and, especially in remoter regions, even a complete lack of services (Iyer et al., 2015; Kowalewski, McLennan, & McGrath, 2011). Furthermore, there is far too little of Canadian prevention programs specifically aimed at children's mental health (Waddell, Hua, Garland, Peters, & McEwan, 2007; Waddell et al., 2005). Next, there is an absence of a broader youth-focused mental health strategy in Canada integrating existing youth mental-health interventions and youth health promotion programmes.

A population-based, youth focused strategy, explicitly integrating mental health with other youth health and welfare services is required to address behavior problems in youth and should be among Canadian public health priorities. This said, there is growing recognition for the need for a national framework to guide changes prioritizing youth mental health care. Recently, Canada's first national child and youth mental health framework, entitled Evergreen, was created to inform and assist the development of child and youth mental health care (Kutcher & McLuckie, 2013; Mulvale et al., 2015). In both publications, Evergreen is presented as a research-informed mental health framework development designed to guide stakeholders in the development, implementation, and review of child and youth mental health policies, plans, and services nation-wide. This is relevant considering the seriousness of behavior problems among other mental health disorders affecting many young Canadians.

2.2. Child poverty: Understanding economic disadvantage among children and youth

2.2.1 Child poverty: Definition and measurement

Poverty is an economic indicator typically determined by the lack of financial resources such as income, consumption, wealth and assets. It is also referred as “income poverty”, “monetary poverty” or “economic poverty” interchangeably in poverty research. The definition of poverty encompasses individuals living below the conditions of the average citizen and deemed as socially unacceptable suggesting that they are society’s most vulnerable members (Oakes & Kaufman, 2006).

A broader definition of poverty invokes the notion of economic hardship that is wedded to social exclusion and barriers to positive well-being as well as livelihood. Individuals, families and groups in the population are considered to be living in poverty when they lack the economic resources preventing their full participation in the society in which they live (Townsend, 1979). From this perspective, poor individuals are prevented to participate in the activities and to have the living conditions, or are they unable to acquire the goods and services which are expected in the societies to which they belong. The real concern appears to be that, at some level of poverty, individual’s health problems reflect the feeling of being marginalized and socially isolated as well as lack of access minimum physical necessities such as food consumption and health care.

When measuring poverty, the amount of income or the standard to meet needs required before one can be categorized as being poor needs definition. A cut-off identification strategy setting thresholds or poverty lines on income and/or expenditures patterns is useful in creating poverty statistics as distributional indicators. There is a long-lasting debate on identifying whether an individual is considered to be poor based on the degree of dimensionality used to capture the definition and measurement of poverty. Here we discuss briefly two main approaches referring to the dimensions of poverty.

One approach to define poverty is to decompose the different elements that contribute to poverty corresponding to a multidimensional measurement. Yet, another approach has been to measure poverty as a unidimensional concept. Multidimensional poverty goes beyond an income-based conception of being poor, and rather emphasises several other economic forms of disadvantage such as occupational capabilities and education achievement. In a recent report in the United States, five different components were proposed to define multidimensional poverty (Reeves, Rodrigues, & Kneebone, 2016):1) low household income, 2) limited education (i.e. less than a high school degree), 3) lack of health insurance, 4) low income area, and 5) household unemployment. The authors reported that different dimensions of disadvantage overlap, or cluster together for particular group of individuals and families. Specifically, they found that almost half the population suffered from at least one of our five disadvantages. Almost a quarter had two or more disadvantages and almost a tenth had three or more. Only a few (about 2%) suffered from four or more disadvantages. Additionally, the proportion of the population classified as being poor was broadly similar on each of the dimensions, with the exception of household unemployment. Regarding unidimensional poverty, there is a stronger emphasis on a single aspect of the individual's life such as household income or one other dimension as opposed to other dimensions. In this thesis we do not focus on the dimensionality debate. Rather, we adopt a unidimensional description of poverty based on household income to identify the most disadvantaged individuals. Other poverty dimensions, such as education, are taken into account in our analytical strategies.

Furthermore, poverty lines may be described in terms of absolute or relative measures. The use of a relative measure of poverty refers to differences in contemporary living standards such as one's relative position in the distribution of income, whereas an absolute measure represents one's level of economic well-being and ability to acquire basic necessities (Sarlo, 2013). Hence, to a certain extent both approaches are driven by the distribution of economic resources and the commodities available in society to measure the condition of poverty. In this sense, the notion of relativity in society's economic resources is central in defining and measuring poverty. Given this, poverty among children or child poverty can be reported using absolute or relative measures. In each case, we capture information of individuals – essentially children – living in poor families or households. Based on household incomes, child poverty can be defined as disadvantage children at the bottom of the income distribution, but also to what extent poor children differ in the levels of material deprivation compared to wealthier counterparts.

Moreover, relative and absolute poverty lines are often contrasted engaging an important debate over which view best describes child poverty rates. Relative child poverty is the most commonly used measure in poverty research. Using absolute measures is of concern because they are often fixed, that is, not accounting for differences between richer and poorer countries nor changes in patterns of expenditures over time (Caminada, Goudswaard, & Koster, 2012). In the case of Organisation for Economic Co-operation and Development (OECD) countries, the deprivation index used for the United States is also applied for countries such as Bulgaria or Romania, which in turn could lead to high poverty rates among poorer countries given their lower rates of consumption (UNICEF Innocenti Research Centre, 2012). Ideally, absolute measures should reflect patterns of expenditures and living standards in each country. Conversely, relative poverty lines reflect levels of economic deprivation of the population in a specific country. It informs on income level of poor individuals against general rises in incomes in the population which changes from nation to nation, that is, the extent to which nations become more or less unequal over time.

However, relative measures are not without faults. The report cited above argues that relative measures may be insufficient to detect household income fluctuation such as bonuses and working fewer hours; and they are highly dependent on family's security and spending power which are based not only on income but also on savings and debts. To this end, relative measures can mislead the real levels of economic resources available. Nonetheless, indexing child poverty as children living in households whose income are below the average and usually set between 40% to 60% below the national median income (UNICEF Innocenti Research Centre, 2012), may be a reasonable guide to identify disadvantaged children at the bottom of the income distribution. Reassuringly, a recent study using data from several high-income countries showed that using relative measures, which has close associations to overall inequality, has an stronger impact on child mortality than absolute measures and should be a major concern within countries (Fritzell, Rehnberg, Hertzman, & Blomgren, 2015).

Most research on poverty in high-countries relies solely on household income or expenditures to capture living standards and, in turn, distinguish the poor as individuals living below these same standards. In countries members – mainly from the European Union- of the Organisation for Economic Co-operation and Development, child poverty is defined as follows (UNICEF Innocenti Research Centre, 2012): a) relative child poverty as the proportion of children growing up in a household where disposable income, when adjusted for family size and composition, is less than 50% of the median disposable household income for the country concerned; and b) absolute child poverty as the proportion of children growing up in a household materially deprived. Several items are currently used measure material deprivation based on material possession, services and opportunities : 1) three meals a day, 2) at least one meal a day with meat or protein, 3) fresh fruit and vegetables every day, 4) books suitable for the child's age and knowledge level (not including schoolbooks), 5) outdoor leisure equipment (e.g. bicycle, roller-skates), 6) regular leisure activities (e.g. swimming, playing an instrument, participating in youth organizations), 7) at least one indoor games per child (e.g. educational baby toys, building blocks, board games, computer games), 8) money to participate in school trips and events, 9) a quiet place with enough room and light to do homework, 10) an internet connection, 11) some new clothes (i.e. not all second-hand), 12) two pairs of properly fitting shoes, 13) the opportunity to invite friends home to play and eat, 14) the opportunity to celebrate special occasions (e.g. birthdays, name days, religious events). A child is considered to be living in absolute poverty if living in a household which cannot afford at least three out of all items, thus gauging the proportion of individuals whose living conditions are affected by a lack of economic resources.

In Canada, there is no official income poverty threshold. Instead, existing studies on the topic are based on low-income measures produced yearly by the federal statistics agency - Statistics Canada. A total of three measures are proposed to define low-income population in Canada, in which two are relative measures corresponding to Low Income Cut-Offs (LICOs) and the Low Income Measure (LIM), and one absolute measure referring to the Market Basket Measure (MBM). For each low-income measure, calculation procedures are as follow (Statistics Canada, 2013). First, LICOS are income thresholds below which a family will likely devote a larger share of its income on basic necessities such as food, shelter and clothing than the average family. Here, low-income threshold are estimated when families are expected to spend ≥20% than the average Canadian family on food, shelter and clothing. Second, LIM is calculated at a fixed percentage (50%) of median adjusted household income and are usually used for international comparisons. Finally, MBM is based on the cost of a specific basket of goods and services representing a modest, basic standard of living. This the costs of food, clothing, footwear, transportation, shelter and other expenses for a reference family of two adults aged 25-49 and two children. Given this, child poverty in Canada is to be interpreted as children who are residing in low income families or households according to the LICOs, LIM or MBM.

In this thesis, we use the relative approach to measure child poverty following international standards and based on LICOs. Specifically, our poverty measurement represents a combination of lack of money for food, clothing, and housing while considering the number of people living in the household and the area of urbanization. This measurement does not solely refer to the lack of money but to a broader measure of material deprivation, capturing access to food, housing and possibly overcrowding. This topic is further discussed in the Chapter 3.

2.2.2 How big of a problem is child poverty?

Children relay solely on their direct environment for the provision of basic needs making them more vulnerable, so that they are disproportionately likely to be poor than other groups of individuals (Sarlo, 2013). Particularly, one study examining data from a diverse group of high-income countries showed that younger children under age 6 are more likely to be poor than all children under age 18 (2-24% more likely); and, in general, their relative disadvantage is larger (Gornick & Jäntti, 2012). The authors also suggested several factors that might place younger children at a greater risk for poverty. First, parents of the younger children - particularly mothers - are less likely to work because younger children need more care at home. Second, parents are likely to be young and, in turn, they are more likely to be unemployment and to hold low-paid jobs. And finally, young parents are less likely than their older counterparts to receive some categories of social income, such as unemployment, disability, and retirement pensions. Furthermore, child poverty is a selfreinforcing cycle that can be transmitted from one generation to the next. In this sense, poverty is reproduced by first becoming adult poverty and then being passed on to the next generation of children as child poverty and so on. Particularly worrying is the likely increase in the proportion of children who are poor to remain poor when they reach adulthood. Studies of intergenerational poverty in the European countries suggest that family poverty is an important predictor of income earned in adult age by the offspring (Franzini & Raitano, 2009),with that individuals who are poor during childhood are nearly twice as likely to be poor as adults (Gibbons & Blanden, 2006). In this sense, it is feedback loop that contributes to the perpetuation of poverty.

There is growing recognition that child poverty has increased since the 2008 crisis in high-income countries (Rajmil et al., 2014) and that rates vary markedly between countries depending on their social spending and policy. Among the 35 economically advanced countries (and mostly country members of the Organisation for Economic Co-operation and Development), child poverty ranged from 5% in Iceland to 25% in Romania (UNICEF Innocenti Research Centre, 2012). Nordic countries (i.e. Denmark, Finland, Norway, and Sweden), Cyprus and the Netherlands had the lowest rates of child poverty, with less than 8% of children living in poor households. The United States had one the highest poverty rates among industrialized countries, with about 24% of children living in poor households. Canada ranked higher than the average of 12% and places the 24th position with rates decreasing from 23% in 2008 to 21% in 2012. Accordingly, a more recent report targeting only the Canadian context identified a deepening of this trend since 2000 (Campaign 2000, 2015). It noted that there was a decline in poverty rates between the results of the 2000 and the 2013 reports from 22.2 % to 19.0% for all children under age 18 years, with a greater decreased for children under age 6 years of 25.0% in 2000 to 20.3% in 2013. In all reports, point estimates were calculated using LIM. Despite this decline child poverty in Canada remains high and 1 in 5 Canadian children live in poverty.

It is widely accepted that wealth redistribution is critical in reducing child poverty and its health effects (Chzhen & Bradshaw, 2012; Engster & Stensöta, 2011; Milligan & Stabile, 2011). Studies have looked at differences of the impact of income transfer policies on child poverty across several country members of the Organisation for Economic Co-operation and Development. For instance, after accounting for taxes and transfers, Finland had the lowest observed child poverty rate of 2.8% among European and other high-income countries (Heuveline & Weinshenker, 2008). In turn, without accounting these same financial benefits, child poverty rate would be estimated to increase up to 18.6%. In another study, a comparison of the pre- and post-tax child poverty rates between the United Kingdom and the Unites States showed a dramatic difference in rates through taxes and transfers (Gornick & Jäntti, 2012). In the United Kingdom, pre-tax child poverty was 34% whereas post-tax child poverty was 19%. In turn, in the Unites States pre-tax child poverty was 25% (i.e. much lower than in the United Kingdom) and about 22% post-tax (i.e. higher than in the United Kingdom). Taken together, these findings suggest that child poverty in high-income countries is especially compelling because it is strongly shaped by the design of countries' resources of redistribution such child benefits policies and income transfer programs

2.2.3 Why poverty matters to child development and well-being?

Overall, child poverty has received increasing attention in the health and social arenas. The central issue regarding child poverty is the degree to which economic hardship and disadvantage impact development and well-being of children and youth. In addition, child poverty and material deprivation can be seen as a breach of children's rights as established in the United Nations Convention on the Rights of the Child (UNCRC,1989).

The link between poverty and children's health and well-being is well understood. Considerable evidence shows that child poverty is a risk factor for a wide range of later life outcomes, including lower school achievement, reduced productivity and earnings, higher rates of unemployment and increased dependence on welfare, higher likelihood of involvement in crime and substance abuse, and increased health care costs to a higher incidence of mental illness (Duncan et al., 2009; Fryers, Melzer, & Jenkins, 2003; Nuru-Jeter et al., 2010; Pickett & Wilkinson, 2007; Reiss, 2013). These associations are robust across high-income countries with different health care and social policy contexts (Kiernan & Mensah, 2009; Spencer, 2003).

Regarding the economic impact of child poverty, research has reported on the cost-estimates and patterns of expenditures across middle- and high income countries. A recent study suggested that child poverty is likely to forgo about 25% of average adult income per year, and the cost of inaction to Gross Domestic Product (GDP) can be double what some countries currently spend on health (Richter et al., 2016). Results are in accordance with previous studies indicating a total cost of child poverty of about $500 billion per year, or the equivalent of nearly 4% of GDP (Holzer, Schanzenbach, Duncan, & Ludwig, 2008). Specifically, this study suggested that child poverty each year: (1) reduced productivity and economic output by about 1.3% of GDP, (2) raised the costs of crime by 1.3% of GDP, and (3) raised health expenditures which reduced the value of health by 1.2% of GDP. Therefore, there is an economic case for addressing child poverty. If we can lift children out of poverty thought social spending and policies, they are likely to join the work force and give society a better economic return.

As mentioned earlier, poor children are more likely to achieve less, exhibit more behavior problems, and are less healthy than children raised in more affluent families. There are two leading mechanistic hypotheses about how poverty shapes children's health and development. One hypothesis is through a direct effect on material deprivation necessary for biological survival (e.g. poor diets, inadequate heating and housing conditions, and air pollution), and a second hypothesis is through an effect on social participation and opportunity to control life circumstances (e.g. increased exposure to stress and risk behavior including smoking and adolescence pregnancy) (Marmot, 2002; Wilkinson, 1997). Evidence using data from the low-income parents in the United Kingdom showed that higher incomes were associated with lower psychological distress across the income spectrum, demonstrating the importance of material factors. Conversely, income status (i.e. their income position in relation to others') was associated with psychological distress only at higher incomes, suggesting that psychosocial factors are more relevant to distress in more advantaged, higher income parents (Garratt, Chandola, Purdam, & Wood, 2016). It is possible that lack of income may not be the only predictor of children's health and later attainment. Research shows that low education may have detrimental psychological effects by engendering social comparisons of one's status in society that generate negative feelings and low self-esteem (Bannink, Pearce, & Hope, 2016; Pickett & Wilkinson, 2007). Children and adolescents might be aware of increased status differentiation relative to parental education in society and make invidious social comparisons themselves. Overall, the evidence cited above suggests that both material and psychosocial factors contribute directly or indirectly to children's health and well-being.

Finally, reducing child poverty and promoting child well-being are therefore critical to reducing the social and economic burden of impaired development and poor social adjustment across the lifespan. Furthermore, child poverty in high-income countries was included in the post-2015 agenda of the Millennium Developmental Goals aiming to promote political commitment for better services and benefits to children living in poverty (UNICEF Office of Research, 2014). Research is needed to inform more about health and social risks associated with child poverty across different periods of human development in high-income countries with different health care systems and social policies. In the present thesis, we pay particular attention to the harmful effects of poverty on behavior problems from birth to early adolescence and to the underlying mechanisms using data from Canadian children.

2.3 What do we know about the association between behavior problems and poverty?

We describe five lines of research progress mostly stemming from population-based observational studies that are relevant to this research: (1) Poverty and behavior problems: Findings from quasi-experimental, experimental and longitudinal studies; (2) Pathways linking poverty to behavior problems; (3) A life course approach of childhood poverty predicting behavior problems later in life; (5) Limitations of extant studies.

2.3.1 Poverty and behavior problems: Findings from quasi-experimental, experimental and longitudinal studies

Evidence shows that poverty is more likely to be associated with externalizing behavior (such as aggression and opposition) than internalizing behavior (such as depression and anxiety) in children (Amone-P'Olak et al., 2009; Dearing et al., 2006; Kaminski et al., 2013; NICHD Early Child Care Research Network, 2005). Some of the strongest evidence on the association between poverty and behavior problems (including DSM *IV* diagnoses of CD and ODD) come from quasi-experimental research on income-transfer policies. These studies support that increasing family income for families living in poverty is associated with lower levels of behavior problems as well as a lower incidence of criminal behavior for minor offenses (Akee, Copeland, Keeler, Angold, & Costello, 2010; Costello, Compton, Keeler, & Angold, 2003; Costello, Erkanli, Copeland, & Angold, 2010; D'Onofrio et al., 2009; Gennetian & Miller, 2002). Most of these studies focus on children aged 4-12 years.

Only three studies have examined the associations between poverty and behavior problems in children younger than 5 years of age. First, a Swedish study showed an association between low family income and ADHD prior to age 5 (Larsson, Sariaslan, Långström, D'Onofrio, & Lichtenstein, 2014). Second, a study on the largest poverty alieving program in The United States suggested that extending financial benefits to poor families with children prior to age 2 are associated with meaningful improvements in child development, including reduced levels of behavior problems (Hamad & Rehkopf, 2016). The third study used data from a Canadian survey and showed positive impacts of housing subsidies on behavior problems, including hyperactivity and CD on children aged 3-11 years (Gagné & Ferrer, 2006).

Further, most studies were based on global measures of behavior problems capturing specific aggressive and delinquent behaviors. For instance, a meta-analyses of behavior problems and SES suggested a stronger association in studies focussing on mixed behavior problems (i.e. composite score) than on aggressive or non-aggressive behaviors (e.g.

irritability, oppositionality) examined separately (Piotrowska, Stride, Croft, & Rowe, 2015). The authors raised the question of whether this mixed group included a specific subtype of behavior problems that could have driven the strong relationship. Taking together, the weight of the evidence suggests that increases in income for poor families are related to improvements in behavior problems from early childhood to adolescence. However, evidence from experimental and quasi-experimental studies should be interpreted with caution. Experimental studies are limited in terms of external validity and therefore in their capacity for generalization. Thus, it is important to examine whether other observational studies corroborate results from experimental designs.

Longitudinal studies yield similar results as quasi-experimental and experimental research on income-transfer policies. A large body of research conducted in the United States have uncovered significant links between poverty and behavior problems and have suggested that income effects are nonlinear. So that, changes in family income predicts changes in behavior problems for children aged 0-7 years and 4-9 years, particularly for poor and low income families (Dearing et al., 2001; Dearing et al., 2006; Dearing & Taylor, 2007; Duncan & Brooks-Gunn, 2000; McLeod & Shanahan, 1996; Strohschein, 2005). This literature have documented that the development of behavior problems among children in families at the bottom of the income distribution tends to be more strongly associated with income changes than among children in higher income families. In other words, poor children are more likely display higher levels of behavior problems over time, thus falling behind their economically advantaged counterparts.

For instance, one study showed that differences in behavior problems (4-14 years) between high and low income families increased over time (Strohschein, 2005). Another study showed that the number of years living in poverty was associated with higher trajectories of behavior problems during those years between ages 5-9 years (McLeod & Shanahan, 1996). Accordingly, a more recent study also suggested that changes in family socioeconomic status - measured as a composite of educational level, household income, occupation, and being on welfare - were related to changes in delinquency between ages 7-18. In this paper, youths were more likely to offend during years in which parent's socioeconomic status was lower than during years in which it was higher (Rekker et al., 2015). Similar associations have been found in studies from the United Kingdom with associations between low income and behavior problems occurring prior to age 5 (Flouri, Tzavidis, & Kallis, 2010; Hope, Pearce, Whitehead, & Law, 2014; Kiernan & Mensah, 2009). A Norwegian study have also shown that income gains were associated with diminished behavior problems, especially for low income children between ages 1.5-3 years (Zachrisson & Dearing, 2014). These patterns of association are consistent with Australian research suggesting that family poverty consistently predicted behavior problems at ages 4-5 and that behavior problems risk increase with time spent in poverty (Bor et al., 1997; Davis & Williams, 2011). Another study showed that poverty predicted increased levels of problem behaviors such as delinquency and aggression from childhood to adolescence, between ages 2-14 (Tearne et al., 2014). Lastly, a study relying on a Swedish sample reported that poverty and low family income were strongly associated with conduct problems and inattention-hyperactivity behavior between ages 3-8 (Larsson et al., 2014). Overall, findings indicate that poverty and low-income predict higher levels of behavior problems and that variations in family income, as well as the time spent in poverty are associated with changes in behavior problems from early childhood to adolescence.

2.3.2 Pathways linking poverty to behavior problems

An important question is the degree to which poverty as a distal risk factor to behavior problems is explained by several mechanisms including individual-level, family-level, and environmental-level factors. *Individual-level* factors include child health, temperament, immunological responsiveness, metabolic and neuroendocrine regulation, brain development, and genetics. *Family-level* factors include family structure and roles such as parenting beliefs and practices, parental physical and mental health, household socioeconomic conditions, and household physical environment such as access to nutritious food supplies. *Environmental-level* factors refer to neighborhood characteristics, peer influences, low-performing schools and day-cares, air pollution and toxicity, access to services and social policies. There is evidence that some of these factors are associated directly or indirectly with a large pool of developmental outcomes including behavior problems in relation to poverty. Because of the multifactorial nature of poverty and the complexity of the causal pathways between the mediators, we present three separate research literatures on individual-level, family-level, and environmental-level factors addressing the association between poverty and behavior problems across different stages of development.

We concentrated on studies that were methodologically sound and that presented important findings about pathways from poverty to a host of developmental outcomes, including behavior problems. Findings point to factors that can be considered mechanisms underlying the association between poverty and behavior problems and which, as poverty itself, can be amenable to intervention. Furthermore, we provide two conceptual frameworks incorporating all levels of mechanisms of risk (Komro, Burris, & Wagenaar, 2014; Yoshikawa, Aber, & Beardslee, 2012) (See **Figure 2** and **3**) as compelling rationale for research on poverty and child and youth development. Also, we present a structured approach on targets for interventions toward disadvantaged children (Hackman, Farah, & Meaney, 2010) (See **Figure 4**).

Figure 2 *Conceptual framework for the effects of poverty on child and youth mental, emotional, and behavioral health (yoshikawa et al., 2012)*

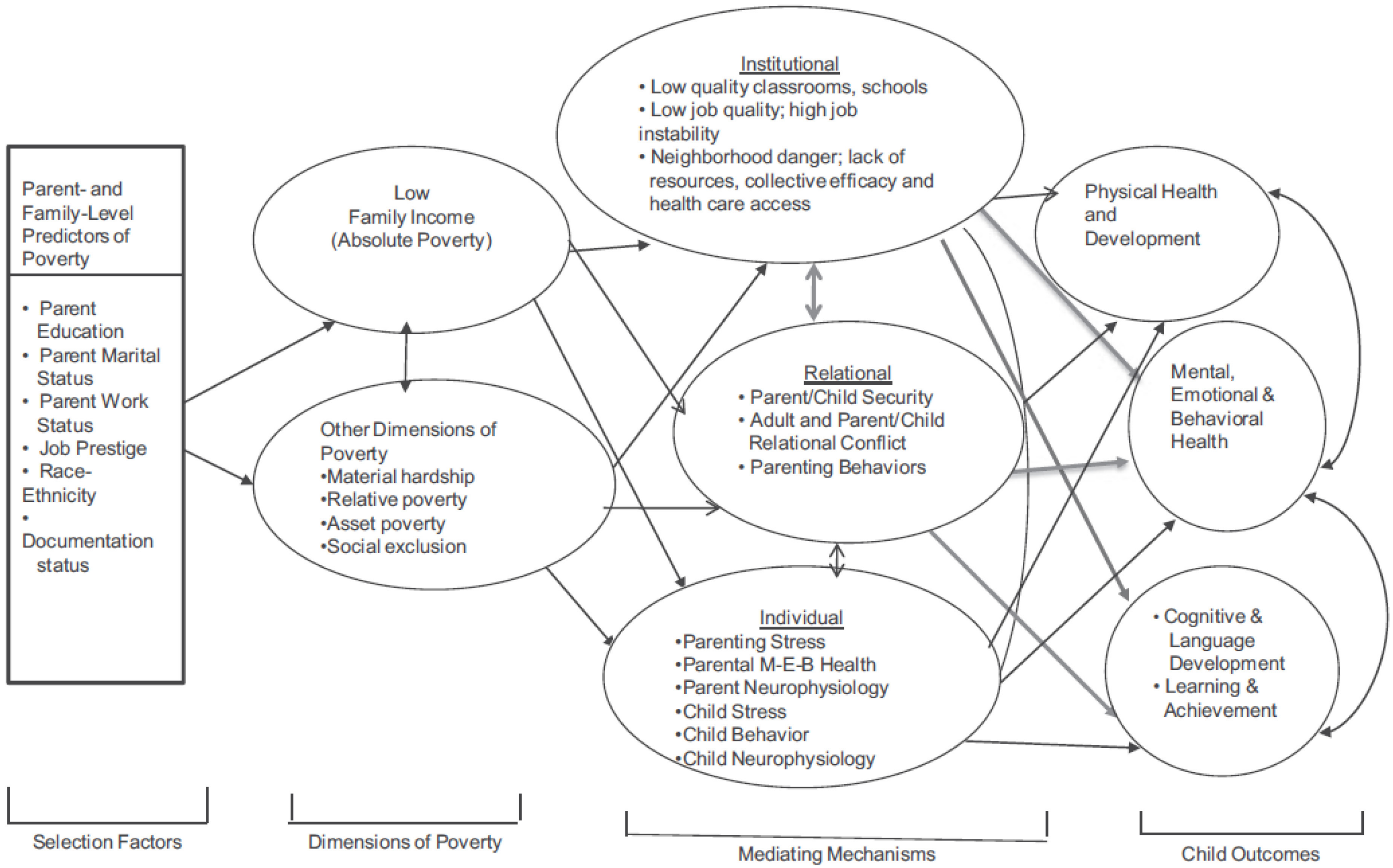


Figure 3 *Economic policy effects on social conditions, environments, health behaviors, and outcomes (komro, burris, & wagenaar, 2014)*

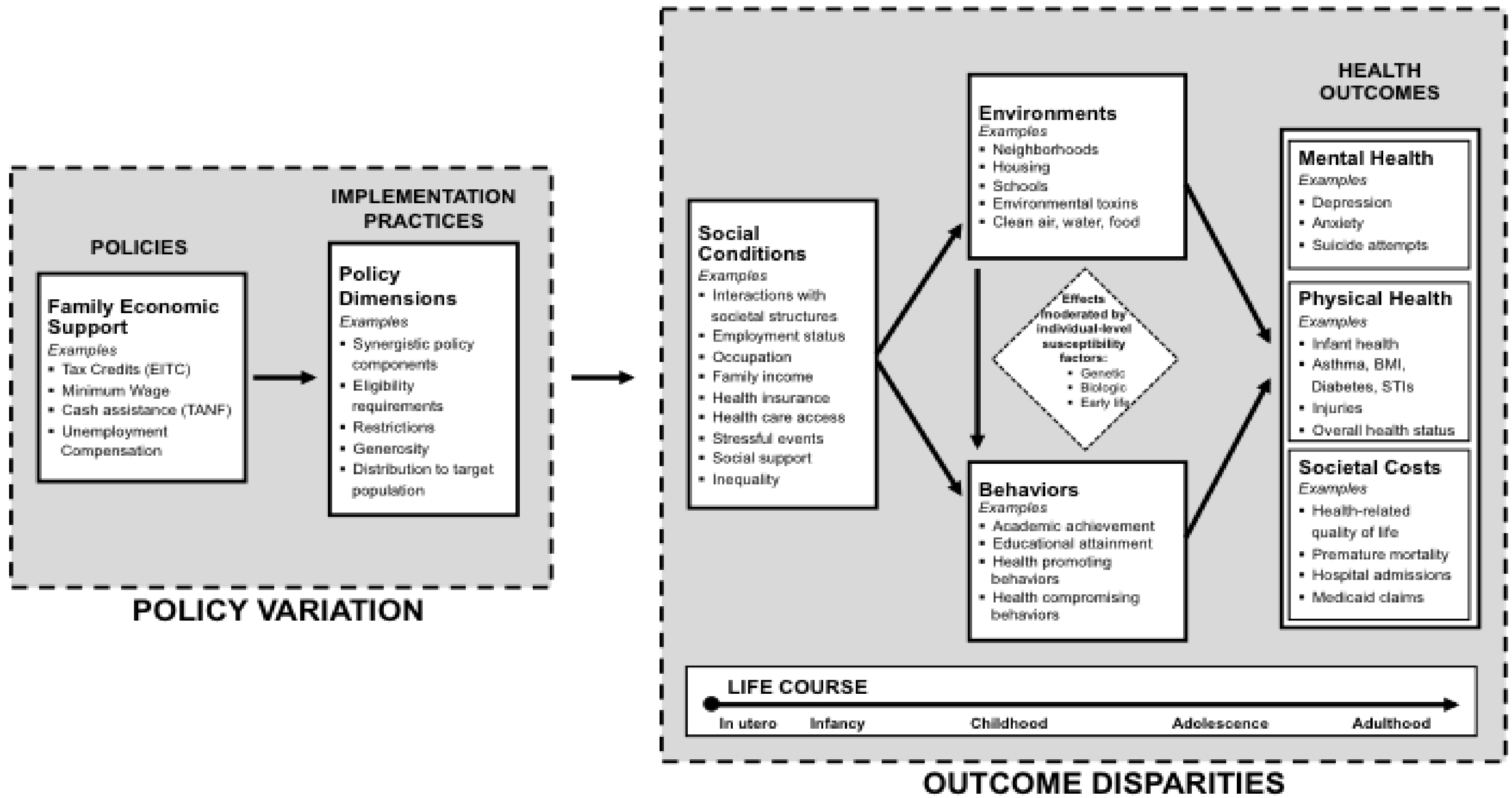
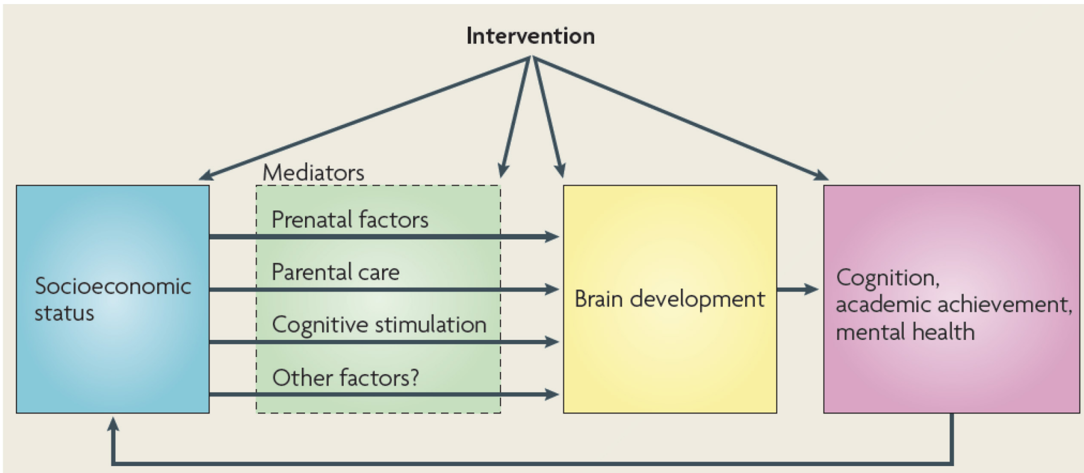


Figure 4 *A promising approach for understanding socioeconomic status -related disparities in neuroscience* (Hackman et al., 2010)



Individual-level factors. It is well established that poverty is associated with multiple aspects of children's development, including stress physiology (Evans & English, 2002; Evans & Kim, 2007). Of more recent interest is the question of how poverty gets under the skin to affect physical and mental health. For instance, low socioeconomic status has been shown to predict higher salivary cortisol levels among children aged 6-10 years (Lupien, King, Meaney, & Mcewen, 2001). Further, socioeconomic status differences were also associated with structural brain variation in research examining potential neural mediators of the link between environmental risk and cognitive skills (Hackman et al, 2010). Other studies showed that low socioeconomic status in childhood was associated with regionally specific differences in brain volume 5-17 years of age (Jednoróg et al., 2012; Noble, Houston, Kan, & Sowell, 2012). Importantly, one study showed that among low income children, small differences in income were associated with relatively large differences in surface area, whereas, among high income children, similar income increases were associated with smaller differences in surface area (Noble et al., 2015).

These patterns of association are consistent with the early childhood literature showing differences in stress physiology and activity of the stress-sensitive Hypothalamic-Pituitary

Adrenocortical (HPA) system by economic deprivation. Evidence shows that perceived economic disadvantage was associated with higher levels of cortisol in infancy (7-48 months) but with a typical decline in cortisol with age at subsequent years (Blair, Raver, Granger, Mills-Koonce, & Hibel, 2011). Similarly, higher level of cortisol (7-24 months) was negatively associated with executive function and IQ at age 3 and shown to partially mediate effects of poverty and parenting on child cognitive abilities (Blair, Granger, et al., 2011) which, in turn, can be linked to behavior problems. Findings also showed that both material and psychosocial (including stress and marital discord) aspects of poverty were relevant to understanding the role of poverty on changes in cortisol levels. A link has also been observed between neighborhood disadvantage and cortisol reactivity and recovery in adolescence (13-18 years) but this association was moderated by sex (Hackman, Betancourt, Brodsky, Hurt, & Farah, 2012). Specifically, more neighborhood disadvantage was associated with higher cortisol reactivity and steeper recovery in boys alone.

Moreover, evidence from quasi-experimental research on income-transfer policies show that increases in family income for family living in poverty was linked to lower salivary cortisol at ages 2-6 (Fernald & Gunnar, 2009). Another study showed that familial adversity (including low income and maternal smoking) was associated with higher cortisol reactivity to stress in twins aged 1.5 years (Ouellet-Morin et al., 2008). Importantly, findings suggest that familial adversity moderated the genetic and environmental contributions to cortisol reactivity. Specifically, for twins living in settings of high familial adversity, shared environmental factors, as opposed to genetic factors, explained their similarity in cortisol reactivity. Thus, differences in cortisol reactivity may be linked to genetic influence and moderated by prenatal and post-natal environmental risk factors. This is particularly relevant given the evidence on the interplay of genetic and environmental factors in the development of behavior problems (Craig & Halton, 2009; Lacourse et al., 2014; Petitclerc, Boivin, Dionne, Pérusse, & Tremblay, 2010). Studies support the allostasis load theory suggesting that the body continuously adjusts its biological processes in response to changing or stressful environment (Carlson & Chamberlain, 2005; Sterling & Eyer, 1988). Taking together, these separate lines of research together form a growing body of research underscoring the role of stress regulation, brain development and epigenetic modifications that could serve as mechanisms mediating the impact of poverty on both physical and mental health.

Family-level factors. One of the leading mechanistic hypotheses about how poverty shapes children's behavioral development is through its impact on parental psychological well-being. Previous studies have primarily focused on the family stress model (Conger, Conger, Elder, Lorenz, Simons, and Whitbeck 1992; Conger, Ge, Elder, Lorenz, and Simons 1994), which posits that economic hardship increases parental distress indirectly affecting children's adjustment through parental mental health and the quality of parenting. Particular, in this model, higher levels of family stress are reflected in reduced nurturing and involved parenting as well as increased family and marital conflicts, parental emotional distress (e.g. depression, anxiety, anger, and alienation) and behavior problems (e.g. substance abuse and conduct problems). In turn, family stress is proposed to be related to higher levels of behavior problems in the offspring. Studies provide three lines of evidence for three types of family mediators that have either a direct or an indirect effect on children's behavior problems.

First, poverty was shown to be associated with behavior problems at ages 2-6 primarily through parenting (Gershoff, Aber, Raver, & Lennon, 2007; Rafferty & Griffin, 2010; Yeung, Linver, & Brooks-Gunn, 2002). In particular, parental supervision was an important mediator of the link between poverty and clinical diagnoses of CD and ODD at ages 9-13 (Costello et al., 2003). Further, maternal warmth and parental monitoring were found to mediate the association between neighbourhood affluence and behavior problems (including physical aggression) from 5-12 years of age (Odgers et al., 2012). Also, the association between poverty and childhood hippocampal development at ages 3-6 has been shown to be partially mediated by caregiving behavior and life stress events (Luby et al., 2013). Findings are consistent with studies on animal models suggesting that the quality of the early environment leads to differences in brain development and behavior (Conradt, Measelle, & Ablow, 2013; Hackman et al., 2010; Meaney & Szyf, 2005; Meaney, 2001)

Second, low-wage employment and financial strain were shown to be associated with behavior problems indirectly through maternal depression among children aged 2-4 years (Jackson, Brooks-Gunn, Huang, & Glassman, 2000; Wadsworth et al., 2013). Similar findings were obtained in mediation analyses revealing indirect effects of low-income on behavior problems at ages 7-8 operating through maternal depression and parenting hassles (Shelleby et al., 2014). The same pattern was found among young children (0-3 years) in which maternal depression, along with disrupted parenting were found to be mediators of the association between economic disadvantage and behavior problems (Rijlaarsdam et al., 2013). In addition, experimental research suggests that changes in maternal depression mediated the association between poverty and behavior problems among children aged 2-3 years (Shaw, Connell, Dishion, Wilson, & Gardner, 2009).

Third, there is evidence that poverty is related to behavior problems indirectly through the home environment including psychosocial and physical factors. One study suggested that poverty and socioeconomic disadvantage were related to higher levels of conduct problems (8-10 years) (Evans & English, 2002) and ADHD risk (9 months-7 years) through increases in family conflict (Russell et al., 2014). Accordingly, the association between poverty and behavior problems (17 years) was found to be mediated by family conflicts in the home environment including violence and family turmoil (Evans & Cassells, 2014). The authors also found the behavior problems-link to be mediated by the physical environment including factors such as noise, crowding, and substandard housing. The latter refers to poor maintenance, cleanliness, physical hazards and air quality. Subsequently, one study suggested children living in low income households may have relatively high exposures to some environmental contaminants such as heavy metals, solvents, mold and pesticide (Evans, 2004). Research supports that metal toxicity in children (3-8 years) predicted higher levels of behavior problems, corresponding to aggressive and destructive behavior (Bellinger, Leviton, Allred, & Rabinowitz, 1994; Sciarillo, Alexander, & Farrell, 1992) as well as ADHD diagnosis (8-17 years) (Nigg et al., 2008) regardless of low-income. The weight of the evidence supports that environmental toxicity should be examined as an important mediator of the association between poverty and behavior problems (Bellinger, 2008). Furthermore, evidence using data from low-income families suggested that behavior problems (3-10 years) increased with the level of food insecurity, as a particular form of material deprivation (Melchior et al., 2009; Whitaker, Phillips, & Orzol, 2006). Importantly, these studies also found that food insecurity was related to behavior problems through nonfinancial factors such as the presence of maternal mental health problems, including major depression episode and generalized anxiety disorder. It is possible that stress arising from food insecurity given uncertain availability of food may not be the only predictor of behavior problems risk. Poor diet and deficiency in nutrimental intake arising from food insufficiency have also been associated with increased levels of behavior problems (Kleinman et al., 2002). In sum, the evidence cited above suggests several family mechanisms including material and psychosocial factors, underlying the association between poverty and behavior problems across a developmental span ranging from early childhood to adolescence.

Finally, it is also worth mentioning that there is evidence that family mediators of the poverty-behavior problem link may vary across different racial/ethnic groups (Pachter, Auinger, Palmer, & Weitzman, 2006). Results suggested that chronic poverty, maternal depression, and parenting have effects on behavior problems between ages 6-9 in white, black, and Latino children, but the mechanisms through which they exert their effects vary among groups. Importantly, poverty was associated with behavior problems through parenting for all ethnic groups. However, differences include the processes through which maternal depression and neighborhood were associated child behavior. The effects chronic poverty through of maternal depression on behavior problems were twofold: (1) maternal depression was partially mediated through parenting in the white and Latino samples but (2) was direct and unmediated through parenting practices in the black sample. Neighborhood effects were present in the white and black samples but were not significant for the Latino sample.

Environmental-level factors. Numerous studies employing a wide array of designs suggest that children's neighborhood of residence is associated with their mental health above and beyond individual- and family-level factors. For instance, exposure to neighborhood poverty during childhood was associated with suicidal thoughts in adolescence (15-16 years and 18-19 years of age) (Bernburg, Thorlindsson, & Sigfusdottir, 2009; Dupéré, Leventhal, & Lacourse, 2009). Using a genetic- informative longitudinal design, a nationwide study of 2-year-old twins showed that children in deprived neighborhoods were at increased risk for emotional and behavioral problems over and above any genetic liability (Caspi, Taylor, Moffitt, & Plomin, 2000). Another study showed that parents who moved from high-poverty to low-poverty neighborhoods reported lower levels of distress than parents who remained in high-poverty neighborhoods. Also, evidence from an experimental study showed that children (11-18 years) who moved to low-poor neighborhoods reported lower levels of anxious/depressive and substance abuse problems compared with their peers in high-poverty neighborhoods and that effects were more pronounced for boys (Leventhal & Brooks-Gunn, 2003). In contrast, a study of the impact of neighbourhood quality on children's development showed that neighbourhood disadvantage was negatively associated with children's behavior problems (i.e. conduct problems and hyperactivity) but that this association was relatively small. The study relied on survey data of nationally representative sample of children and youth in Canada (4-11 years). Interestingly, this study showed that children from well-off families living in disadvantaged neighborhoods displayed lower levels of behavior problems than children from poor families living in advantaged neighborhoods (Boyle & Lipman, 2002). This is important because it suggests that variation in behavior problems levels are better explained by socioeconomic characteristics of families that inhabit certain areas than for neighborhood socioeconomic characteristics.

Evidence from housing mobility research should be interpreted with caution because of selection effects in which a number of individual, familial, and structural characteristics determine patterns of associations. Indeed, in some cases, moving children and adolescents out of impoverished neighborhoods was not effective and even had some iatrogenic effects on children's behavior problems (Jackson, Langille, Lyons, Hughes, Martin, and Winstanley 2009; Odgers, Donley, Caspi, Bates, & Moffitt, 2015). Evidence showed that moving out of high-poverty neighborhoods was associated with increased rates of depression, PTSD, and conduct disorder among boys and reduced rates of depression and conduct disorder among girls between 13-15 years of age (Kessler et al., 2014). Another study suggested that moving from a high-poverty neighborhood to a lower poverty neighborhood was associated with increased mental health problems (including rule-breaking and aggressive behavior) in adolescents (Byck et al., 2015). It is possible that the effects of having grown up in a high-poverty neighborhood accumulates over time, and/or the stress of moving increased most of the mental health outcomes compared to control group participants who consistently lived in the lower poverty neighborhoods.

Overall, research cited above suggests that, in addition to the stress related to being poor, the process of social comparison and the sense of not belonging fostered by the reallocation may affect child outcomes. Yet, there is research showing that more equal societies do better on a wide range of outcomes including child development (Pickett & Wilkinson, 2007) and the objective of reducing social inequalities is still relevant to reduce mental health problems associated with poverty. Furthermore, providing high quality early educational childhood services to families living in impoverished neighbourhoods is a widely accepted strategy for promoting social mobility and reducing poverty in the next generation. Specifically, early childhood education programs targeting low-income children were shown to close income-based gaps in cognitive ability and school readiness (Duncan & Sojourner, 2013; Geoffroy et al., 2010).

Importantly, research points to a variety of specific individual, family and neighborhood characteristics in which mental health (including behavior problems) may be linked to neighborhood economic disadvantage. Three other results are noteworthy. First, neighborhood collective efficacy, defined as community social control and cohesion, was found to mediate the association between concentrated disadvantage and better mental health in children aged 5-11 years (Xue, Leventhal, Brooks-Gunn, & Earls, 2005). Findings posit that socially supportive processes and perceived safety in family, school, and neighborhood are promising targets for interventions to reduce mental health problems in youth. Second, neighborhood poverty and maternal depression were both positively associated with behavior problems from 5-11 and from 12-17 years of age. However, findings showed that living in neighborhoods with higher levels of social capital attenuated the relationship between maternal depression and adolescent behavior problems (Delany-

Brumsey, Mays, & Cochran, 2014). Third, findings from another study showed that the impacts of four welfare reform and antipoverty programs on child outcomes varied by child sex and neighborhood poverty (Snell et al., 2013). Specifically, the strongest positive impacts of four employment and income benefits programs were among boys who lived in high-poverty neighborhoods, with smaller or non-statistically significant effects for boys in lower poverty neighborhoods. Similarly, another study showed that changes in neighborhood poverty were associated with changes in children's behavior problems (6-15 years) and that this link varied by sex. Specifically, results showed that increasing poverty in low-poverty neighborhoods was associated with more violent behavior among boys than stable neighborhood poverty (Leventhal & Brooks-Gunn, 2011). Overall, further investigation on weather different modifiers and mediators factors hold across different ages is warranted.

Moreover, the role of exposure to violence in neighborhoods has received attention in the children's behavioral and academic literature. A review on child maltreatment research indicated a link between neighborhood disadvantage and both internalizing and externalizing behavior problems in children and adolescents was mediated by aggregate rates of abuse (Foster & Brooks-Gunn, 2009). Abuse included parent-to-child physical victimization, inter-parental violence, and community violence. This review also suggested that younger children may be more protected by more proximal family- and school- factors but older children and adolescents may be more vulnerable to community violence effects as they spent more time outside the home.

2.3.3 A life course approach of childhood poverty predicting behavior problems later in life

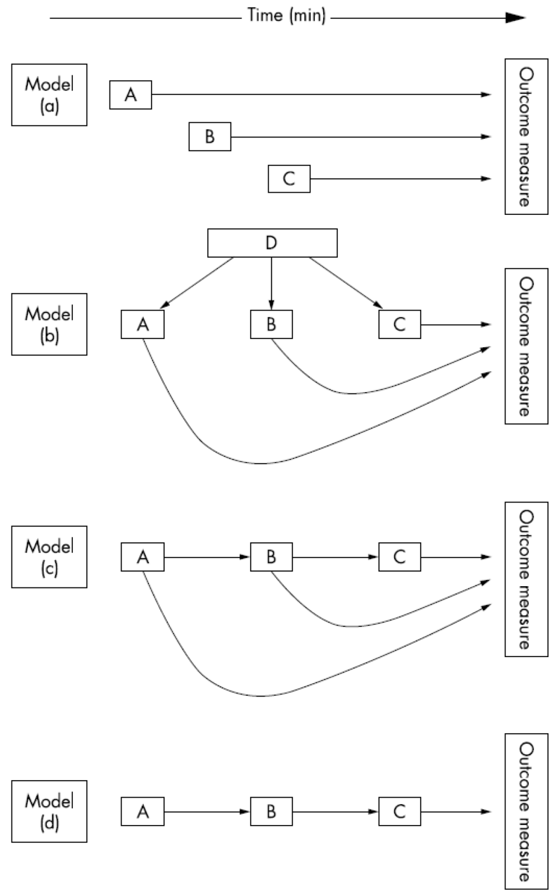
The life course approach investigates how economic and social adversity as well as health status operating at different stages of life influences disease risk later in life and even across generations (Lynch & Smith, 2005). It explicitly incorporates exposures during a particular window of time (i.e. gestation, childhood, adolescence, adulthood) and the duration of exposures in determining disease risk as well as the appropriate time for any preventive interventions. The importance of a life course approach is that, although many diseases are primarily diagnosed in old age, such conditions may reflect damage (or benefits) incurred from exposures much earlier in life (Liu, Jones, & Glymour, 2010). Several etiologic models can be used to understand how exposures at different periods of life influence disease risk (Ben-Shlomo & Kuh, 2002). Life course model are: critical periods, sensitive periods, accumulation of risk and mobility models.

First, *the critical period model* argues that exposure in a certain period of time has irreversible and permanent damage. Under this model, it is possible that risk factors could lead to physiologic and metabolic programing, which subsequently would lead to vulnerabilities to health problems that emerge well into adulthood. For instance, Barker's formulation of the fetal origins hypothesis can be viewed as critical period model of the obesity-cardiovascular disease relationship (Barker, 1995).

Second, the *sensitive period model* advocates that an exposure at a certain window of time has a particularly stronger effect on disease risk than it would at other times. In other words, the same exposure outside this window of time may still be associated with increased disease risk but this association would be weaker than during the sensitive period. Contrary to the critical period model, there is more scope to modify or reverse changes in the biological system during the sensitive period.

Third, the *accumulation of risk model* asserts that persistent adversity accumulates over time leading to a breakdown of biological systems, and to disease occurrence. **Figure 5** below shows distinct *accumulation of risk model* in life course epidemiology (Kuh et al., 2003). Model (a) refers situations of life course exposures being independent so that exposures are uncorrelated insults to disease risk. Model (b) refers to the accumulation model with risk clustering whereby exposures are correlated and cluster together. Model c and d refer to chain of risk model with additive or trigger effects. In model (c), exposure not only increases the risk of the subsequent exposure but also has an independent effect on disease risk irrespective of the later exposure (additive effect). In turn, model (d) refers to situations where earlier exposures have no effect on disease risk without the final link in the chain that precipitates disease onset (trigger effect).

Figure 5 *Life course causal models*



And finally, the *social mobility model* refers to change as an exposure – whether moving up/out of poverty or down/ becoming poor- is stressful and increase disease risk (Hallqvist, Lynch, Bartley, Lang, & Blane, 2004; Liu et al., 2010).

The current thesis builds on the life course framework (Ben-Shlomo & Kuh, 2002; Kuh et al., 2003; Shonkoff, 2009) which describes how poverty-time interactions may provide important insights on the aetiology of behavior problems. Further, the life course approach is an important framework to inform on both distal and proximal factors in the aetiology of behavior problems. We emphasize the need to investigate behavior problems as developmental disorders which are likely to start early in life and to confront differences in behavior problems relative to time and duration of exposure to poverty. This raises the question of whether behavior problems result from exposure to poverty during certain periods of childhood, or from prolonged exposure over the years.

In both adults and adolescents, there is growing evidence that the earliest years of life constitute a sensitive period of future social, behavior, emotional, and physical outcomes (Barker, Kirkham, Ng, & Jensen, 2013; Chen, Cohen, & Miller, 2010; Conroy, Sandel, & Zuckerman, 2010; Duncan, Ziol-Guest, & Kalil, 2010; Nelson, 2013; Raat et al., 2011; Shonkoff, 2010; Shonkoff et al., 2012; Suzuki et al., 2012). However, other studies support that the accumulation of risk model (including poverty and low socioeconomic status) has long-lasting effects on adolescent ability to attend school, stress regulation, and health conditions (Bor et al., 1997; Chen, Martin, & Matthews, 2006; Evans & Kim, 2007).

Regarding behavior problems as the outcomes, numerous studies have addressed life course poverty across development using a variety of research methods. Prior research emphasises the importance of both the accumulation of economic disadvantaged across the lifespan (Evans & Cassells, 2014; Gerard & Buehler, 2004) as well as the exposure to poverty during the earliest years of life (Murray, Irving, Farrington, Colman, & Bloxsom, 2010; Nomura et al., 2008) for increasing the risk for behavior problems among adolescents and criminal behavior among adults. Specifically, there is substantial evidence that the adverse prenatal environment and earliest years of life constitute a sensitive period for the development of later-life behavior problems (Côté et al., 2006; Nagin & Tremblay, 2001; Pingault et al., 2013). Other studies support the accumulation of risk model which states that poverty and low income effects accumulate during childhood and lead to behavior problems in adolescence (McLaughlin, Costello, Leblanc, Sampson, & Kessler, 2012; Rekker et al., 2015).

However, there is little research that simultaneously examines competing life course models of adversity relative to behavior problems. Of the few studies which have examined these models, the evidence is mixed. An Australian study showed that exposure to maternal depression was more important at age 2 than exposure later in life or time spent in poverty in explaining aggressive and delinquent problems at age 9.5 (Giles et al., 2011). Despite the fact that this study did not consider poverty as its measure of adversity, it identified early childhood (i.e. prior to age 5) as a sensitive period of adversity for behavior problems while considering other life course processes such as accumulation of risk. This study is particularly interesting as it reported results using a model-building framework to test for competing life course models (Mishra et al., 2009). Further, one study from the United States provided evidence that later-life behavior problems may not be limited to poverty during early childhood but rather to exposure after age 5 (Tsal et al., 2005). Results showed that low income during childhood (6-12 years) was associated with behavior problems beyond the effect of low income during early childhood (0-5 years), thus providing evidence of accumulation of risk for behavior problems which in turn was better quantified by middle childhood adversity. However, it remains unclear whether the association between childhood poverty and behavior problems in adolescence vary in strength across different periods of time.

2.4 Limitations of extant studies.

Some limitations in the literature regarding the association between poverty and behavior problems should be considered. First, longitudinal studies are limited in terms of comparability due to differences in the age distribution of children, in the measurement and duration of poverty, and in the analytical strategy used to address life course models and mediating mechanisms (e.g. Baron-Kenny procedure versus more modern approaches). Specifically, it is not clear whether mediators identified at one developmental period are the same at another developmental period. For instance, family mediators such as parenting may be more pertinent for younger children compared to older children and adolescents.

Second, most large scale longitudinal studies on this subject have used biennial measurements or have aggregated measurements into developmental periods (e.g., childhood and adolescence) masking essential aspects of behavior problems that might be age-dependent. More empirical data (preferably, repeated and annual measurements) on early years of life can provide valuable information on sensitive period models as well as on behavior problems patterns of change.

A third concern is differentiating common causes (i.e. confounders) and effect-modifiers (i.e. moderators) from mechanisms of risk (i.e. mediators) in which the variable concerns some aspect of the risk process. Detailed description of causal ordering of variables on this subject and the theoretical framework for their interpretation is rarely provided in the literature. This lack of clarity about the causal assumptions is not yet known and may lead to difficulties in providing compelling evidence about mediating mechanisms as well as the validity of the evidence derived from poverty and behavior problems research. For instance, a Swedish study using a quasi-experimental design and a large sample showed that the adverse effect of neighbourhood deprivation on adolescent violent criminality and substance abuse was not consistent with research primarily conducted in the United States possibly due to the lack of control for familial confounding (Sariaslan et al., 2013). To address these issues, causal diagrams are an important tool to tackle methodological challenges regarding causal assumptions and for deciding on covariate adjustment. Specifically**,** Directed Acyclic Graphs (DAGs) provides graphical criteria on hypothetical causal structures and pathways based on prior causal knowledge. DAGs are becoming more popular in etiologic research (including health inequalities research) and are often cited in the literature to guide statistical modeling (Evans, Chaix, Lobbedez, Verger, & Flahault, 2012; Fleischer & Roux, 2008; Glymour, Weuve, & Chen, 2008). For an introduction to DAGs, we refer readers to Glymour, M.M., & Greenland, S. (2008). Causal diagrams. In: Rothman, K.J., Greenland, S., Lash, T.L., eds. *Modern Epidemiology* (183–209). New York: Wolters Kluwer.

Fourth, few studies have distinguished the potential mediational role of a wide range of family factors simultaneously, including different types of parenting practices and maternal depression. One challenge here concerns levels of description and specificity of parenting variables which are often combined into large indexes (e.g. positive and/or negative parenting). Parental psychopathology, parenting, and family structure are important determinants of behavior problems (Frick, 2012; Leve et al., 2005; Wadsworth et al., 2013) and are correlated with poverty (Hope et al., 2014; Rafferty & Griffin, 2010; Riley et al., 2009).

Fifth, few studies have considered different subtypes of behavior problems in relation to poverty (Kessler et al., 2014; Larsson, Sariaslan, Långström, D'Onofrio, & Lichtenstein, 2014). It is important to establish whether the association between poverty and behavior problems holds across different types of behavior problems or is specific to a certain type of behavior problems. Furthermore, poverty increases children's behavior problems, but whether this association is magnified with age across different subtypes remains unclear. Similarly, while is widely accepted that poverty has direct effect on behavior problems, little is known about mediational patterns that may be specific to each subtype of behavior problem. It is possible that poverty would be differentially associated with distinct subtypes of behavior problems, and that different mediators may be more or less pertinent to distinct subtypes. For instance, the socialisation of physically aggressive behavior during early childhood may be more associated with poverty through parenting than other subtype of behavior problems such as hyperactivity, which may be more genetically related (Faraone et al., 2001). There is compelling evidence on the importance of distinguishing subtypes of behavior problems because they have different developmental trajectories and require specific corrective interventions (Tremblay, 2010). Distinguishing between subtypes of behavior problems is important not only because it suggests that poverty is an important and a common risk factor, but also because of the implications for intervention would be quite different if mediation patterns are restricted to a specific subtype of behavior problem.

Sixth, most studies investigating the association between poverty, directly or indirectly, and developmental outcomes (including behavior problems) come from The United States where poverty rates are higher than in most high-income countries (Caminada et al., 2012; Goudswaard & Caminada, 2010; Heuveline & Weinshenker, 2008; UNICEF Innocenti Research Centre, 2012). Furthermore, antipoverty measures in The United States are mostly based on providing poor families with education and income-policies whereas other high-income countries (e.g. European Union countries, Canada) focus on providing social insurance and support programs (e.g. universal health care, child-care assistance benefits, paid parental leave, etc.) (Moss, 2000). Thus, evidence using data from countries other than The United States may provide insights on the poverty-behavior problems link coming from a less severe economic deprivation and unequal context.

Finally, few studies have addressed selection bias due to differential data loss over time. To our knowledge, no study has investigated the role of selection bias as a result of differential attrition among the poorest and those more likely to have higher levels of behavior problems, in association between poverty, behavior problems, and age. Failure to handle differential attrition leaves the results susceptible to selection bias, which in turn may lead to underestimation of the association between poverty and behavior problems because of retention of the wealthier and healthier participants.

In sum, the present study extends the current literature by addressing three general objectives regarding the association between poverty and behavior problems spanning from birth to early adolescence. Each objective of this thesis corresponds to a research paper, so that a total of three research papers are to be expected. First, the present thesis sought to extend our understanding of the role of chronic poverty and family mediators through which long-term poverty shapes behavior problems. Here, we tested whether the association between chronic poverty and behavior problems is mediated simultaneously by parenting, family dysfunction and maternal depression symptoms during early childhood. The second objective was to estimate potential variations in the link between poverty and three subtypes of behavior problems (i.e., hyperactivity, physical aggression and opposition), by examining whether the poverty gap is initiated early and whether it widens as children grow older. The third objective was to examine the differential effects of the timing of poverty between birth and late childhood on behavior problems in early adolescence as a function of competing lifecourse models, namely the sensitive periods, accumulation of risk and social mobility models.

Researching beyond the simple dichotomy of early versus late exposure, we examine multiple time point exposures to better understand the aetiology of behavior problems. We used a population-based cohort of children (N=2120) followed from 5 months to 13 years of age. Outcome variables are three subtypes of behavior problems that have high prevalence rates from childhood to adolescence (Costello et al., 2005; Polanczyk et al., 2015) and which have been associated with poverty in previous studies: hyperactivity, physical aggression, and opposition. Outcomes are available from 1.5-13 years of age. We used a relative measure of poverty based on LICOs and defined as a function of household income. Using the Canadian LICOs, a family was considered poor (i.e. family income below or at the LICOs) when attributing 20% or more than the average Canadian family to food, shelter, and clothing. Household income on the basis of the LICOs is available yearly in the study. These topics are discussed in detailed in the following chapter.

CHAPTER 3

Methodology

Our methodology section is organized into four parts. Before moving on to describe the methodology, the first part outlines the objectives corresponding to the three research papers forming the main body of this dissertation. The second part focuses on study design and describing the Quebec Longitudinal Study of Childhood Development (QLSCD). The third section explains in detail outcomes, exposure and confounders measurements for each of the three research papers. Then, statistical analyses employed in each of the three research papers are presented.

3.1 Objectives of the current work

The overall aim of the present work is to assess the behavior problems risk and underlying mechanisms related to poverty exposure acting at various times during development, from birth to early adolescence. General and specifics objectives and corresponding hypotheses of this dissertation can be summarized as:

Article 1

<u>Objective 1</u>: to assess the extent to which the association between chronic poverty and behavior problems during early childhood is mediated by specific types of family mediators. Specific objectives were (1) to estimate the associations between chronic poverty from 5 months to 3.5 years of age and high levels of behavior problems from 1.5 to 5 years of age, and (2) to examine whether the association between poverty and behavior problems is mediated simultaneously by parenting (self-efficacy, parental impact, coercion, and overprotection), family dysfunction and maternal depression symptoms. Three main hypotheses were generated from previous research. First, poverty would be associated with all subtypes of behavior problems. Second, parenting, family dysfunction and maternal depression symptoms would be associated with all behavior problems. And finally, the association between poverty and behavior problems would be mediated by parenting, family dysfunction, and/or maternal depression symptoms.

Article 2: Poverty-behavior problems associations and patterns of change

Objective 2: To investigate whether the association between poverty and behavior problems is age-dependent. Specific objectives were (1) to examine whether poverty predicts changes in behavior problems between 1.5 and 8 years of age, and (2) to estimate potential selection bias on the association between poverty, behavior problems, and age. We hypothesized that exposure to poverty would increase behavior problems levels over time. When testing for selection bias, we also hypothesized that poverty estimates over time would be smaller due to retention of the healthier and wealthier participants in the study.

Article 3: How timing of exposure to childhood poverty relates to behavior problems in early adolescence.

Objective 3: To examine the timing and duration of childhood poverty in association with behavior problems in early adolescence. Specific objectives were: (1) to model life course models of childhood poverty (0 to 12 years) predicting to behavior problems at 13 years, corresponding to sensitive periods, accumulation of risk, and mobility models (2) to identify the life course model that best describes the poverty-behavior problem link. We hypothesized that prolonged exposure to childhood poverty and possibly exposure during sensitive periods, such as the early childhood (i.e. before age 5 years), would increase behavior problems in early adolescence. We also hypothesized that the identification of life course models would differ across subtypes of behavior problems due to variations of behavior problems trajectories over time.

3.2 The Quebec Longitudinal Study of Child Development (QLSCD)

3.2.1 Study Design and participants

The QLSCD is an ongoing population-based longitudinal study of children born in 1997-1998 and followed-up prospectively between the ages of 5 months and 15 years. The last completed data collection of the children was in 2015, referred to as the 17 year assessment. The specific objectives of the QLSCD are: (1) to increase knowledge about the risk and protective factors that trigger or prevent socio-affective disorders in early childhood (ages 5 months to 4 years); (2) to understand children's success in primary school in relation to their life experiences (5 to 12 years); (3) To assesses different aspects of adolescent social and school adaptation (13 to 17 years), currently in progress (Groupe de recherche sur l'inadaptation psychosociale chez l'enfant, n.d.). Determinants of particular interest include birth conditions, pregnancy and childbirth, type of child care, family environment, socioeconomic environment, community environment, school environment, reading habits, physical health, relationships with peers, parents and teachers, sleep; language, nutrition, social adjustment, mental health, siblings, cognitive development, victimization, academic achievement and motivation, risk behaviours, work across three important developmental periods (early childhood, childhood and adolescence).

The QLSCD protocol was approved by the Quebec Institute of Statistics and the Sainte-Justine Hospital Research Center ethics committees. The QLSCD study follows strict ethical guidelines, in that all matters relating to confidentiality and informed consent have been observed. So that, written informed consent was obtained from all respondents and data were coded for confidentiality at each assessment. See **Appendix I** and **II** for ethical approvals and **Appendix III** for informed consent form.

The QLSCD target population included singleton infants who were 3-8 months old (mean age of 5 months) at the first data collection and born to mothers residing in each geographic area of the Canadian province of Quebec. Infants born in Northern Quebec, Cree Territory, Inuit Territory and Aboriginal reserves (2.2% of all births) as well as those whose gestational age was unknown and those born before 24 weeks (1.3% of all births) were excluded from the study (Jetté & Groseilliers, 2000). So that, the study population in this stage was approximately 96.5% of the total target population. The Quebec Master Birth Registry of the Ministry of Health and Social Services was used to select a representative sample of 2917 infants. Within this, 689 families were considered non-respondent (e.g. unreachable, not able to participate as they were not fluent in the study language, refused to participate for various reasons) and 8 families did not meet the inclusion criteria of the target population (e.g. twins, infant deaths). This sample was reduced to 2120 infants (response rate of 72.7%) who participated in the first assessment and were followed up yearly until age 17 years. Table 1 in **Appendix IV** provides response rates of QLSCD at baseline according to demographics characteristics.

Data were collected yearly during the first 8 years of life when the interview schedule shifted to a biennial design. Interviews were conducted by trained research assistants through home interviews and directed to the person most knowledgeable about the child (mothers in 98% of cases). QLSCD data also incorporates on data obtained from multiple informants including teachers (at 6, 7, 8, 10 and 12 years) and participants' self-reports (10, 12, 13, 15 and 17 years).

The present dissertation draws on data originated from the QLSCD (N=2120) collected between 1998 and 2011. We used 12 assessments points conducted when children aged in average: 0.5, 1.5, 2.5, 3.5, 4.5, 5, 6, 7, 8, 10, 12, and 13 years. When participants were 13 years of age, 1290 participants from the initial sample remained in the study (i.e. 60.8% of retention rate). Respondents were defined as participating if they completed all or part of the Interviewer Completed Computerized Questionnaire (ICCQ). The ICCQ is the prime instrument of the QLSCD and it was used as the denominator to calculate the participation rates (Jetté & Groseilliers, 2000). It comprises about 600 variables. ICCQ was partially completed when participants refused or lacked information (i.e. "I don't know") regarding a certain variable. Specifically, responses indicating "DON'T KNOW" or "REFUSAL" were coded as missing values. Characteristics of the QSLCD sample for 13 years assessment are also presented in the **Appendix IV** (see Table 2).

3.2.2 Attrition and Non- participation

In this present dissertation we refer to attrition as participants who drop out of a study during a particular assessment and never return and situations where participants have interrupted response over follow-up period (Mostafa & Wiggins, 2015). Despite the fact that the QLSCD retention rate was high until children aged 4.5 years (91.7%), there was a substantial drop in sample size between ages 5-13 years. Attrition ranged between 17%-39.2% between ages 5-13 years. Table 3 in **Appendix IV** presents changes in sample composition and how sample declines in the QLSCD after 13 years of follow-up.

For wave nonresponse, participants who responded in all 12 assessments points (since 1998) were 46.2% of the initial sample. Non-monotonic patterns of response were high for participants who missed ≥ 6 assessments points (19.7%). **Table 4** shows the number of time participants missed a wave (i.e. wave nonresponse) from 0.5 to 13 years of age.

The highest attrition rates were observed for respondents living in poverty, of low education background (i.e., who had a high school diploma or less), as well as in single-parent and immigrant families. Specifically, the proportion of participants exposed to poverty at age 0.5 was 24.1% but only 7.1% using participants at age 13 years. This, in turn, indicates differential study attrition as QLSCD drops respondents of a particular type. So that, attrition rates were not considered to be a random process and were addressed in our analytical strategy.

3.3 Developmental periods

For the purpose of the present dissertation and following QLSCD specific objectives, we defined developmental periods corresponding to three age groups: (a) early childhood between ages 0-5 years, (b) childhood between ages 6-12 years; and (c) early adolescence at age 13. Also, age ranges approximates conceptualizations of developmental periods such as proposed by the Centre of Disease Control (CDC, childhood between ages 4-11) and the Diagnosis Statistical Manual of Mental Disorders (DSM, American Psychological Association; childhood between ages 7-12). Age ranges were also based on the acquisition of cognitive structures (Piaget, 1964) as well as transition periods in school settings (e.g. from child care to school entry at age 6, or from elementary to high school at age 13).

Developmental periods deviated slightly from the World Health Organization definitions whereby early childhood is referred to a much broader period ranging from prenatal period to 8 years of age and adolescence indicating individual ages 10-19 years. However, child health research is often reported by two age bands within the early childhood period, under age 2 or under age 5 years (e.g. child mortality reports).

3.4 Description of variables

3.4.1 Main outcomes

The primary outcomes are: (1) hyperactivity, physical aggression, and opposition behavior as perceived by parents and teachers at 8 assessments points from early childhood to adolescence. Specifically, behavior assessments were obtained at ages 1.5, 2.5, 3.5, 4.5, 5, 6, and 8 via maternal reports and at age 13 years via teacher reports.

Mothers and teachers rated completed the Behavior Scale Questionnaire - the BEH regarding the target child. The questionnaire incorporates items from the Canadian National Longitudinal Study of Children and Youth (Statistics Canada, 1996). This tool incorporates items from the Child Behavior Checklist (Achenbach & Edelbrock, 1991), the Ontario Child Health Study Scales (Byles, Byrne, Boyle, & Offord, 1988), a modified version of the Children's Behaviour Questionnaire (Behar, 1977); and the Preschool Behaviour Questionnaire (Tremblay, Vitaro, Gagnon, Piché, & Royer, 1992).

Mothers rated their child on a frequency scale indicating whether the child never (0), sometimes (1), or often (2) exhibited a given behavior problem. When the participants were aged 13 years, his/her teacher completed the BEH also on a three-point scale ranging from never (0), sometimes (1), or often (2). Then, teachers mailed back the questionnaire to the Quebec Institute of Statistics. A global score was derived for each type of behavior problems based on a set of symptoms. Higher scores represented greater levels of behavior problems. Table 1 in **Appendix V** presents a detailed description of primary outcomes.

Also, see Table 2 in **Appendix V** for the distribution of behavior problems from 1.5 to 13 years of age according to informant source.

Main outcomes measures and their respective items are presented in detail below according to the three research papers derived from present dissertation.

Article 1

Outcome variables were high trajectories of physical aggression and hyperactivity from 1.5 to 5 years of age. Mothers rated their child's physical aggression and hyperactivity behavior five times across early childhood, between 1.5, 2.5, 3.5, 4.5, and 5 years of age. Using the BEH, mothers rated their child's on a frequency scale of whether the child never (0), sometimes (1), or often (2) exhibited physical aggression and hyperactivity. Items used for physical aggression were: a) hits, bites, kicks; b) fights; and c) bullies others (range 0 to 6). The items were summed into a physical aggression score that ranged minimum of 0 and a maximum of 6. For hyperactivity, items were: a) can't sit still, is restless, is hyperactive; b) fidgets; c) is impulsive; d) has difficulty waiting turn; and e) cannot settle for hyperactivity. The items were summed into a hyperactivity score that ranged minimum of 0 and a maximum of 10. Cronbach's alphas ranged between 0.72 and 0.75 across assessments for physical aggression ratings and between 0.74 and 0.75 for hyperactivity ratings.

For the purpose of this article, aggression and hyperactivity continuous measures from 1.5 to 5 years of age were summarized using group-based trajectory models (Daniel Nagin, 2005). Models were estimated separately for each subtype of behavior problem. We decided to apply group-based trajectory models to summarize selected outcomes over time because it identifies different patterns of growth given variability within our study population by modeling distinctive clusters of individual trajectories. Also, by identifying trajectories of different shapes (e.g. high, stable, low, etc.), this approach classifies individuals into distinct groups or categories of children with typical versus atypical patterns of response for the phenomena under investigation.

We used a semi-parametric mixture model approach (using software package Statistical Analysis System Trajectory Procedure – SAS Proc Traj) to model behavioral profiles of physical aggression and hyperactivity, represented by different combinations of the trajectories (Jones & Nagin, 2007). This modelling approach allows identifying groups of children with distinct levels of a given behavior over time, (2) estimating the proportion of children in each of the identified trajectory groups, and (3) estimating the patterns of stability and variations in trajectories. Further, this procedure assigns individuals to categories on the basis of a posterior probability rule. Resulting groups are approximations of probabilities used to classify the participant in the trajectory group he or she most likely belongs to (Nagin, 2005). Specifically, each participant is assigned to the trajectory group for which he or she had the largest probability estimate. For instance, a participant with high physical aggression scores throughout early childhood will have a high probability of being classified in the high physical aggression trajectory.

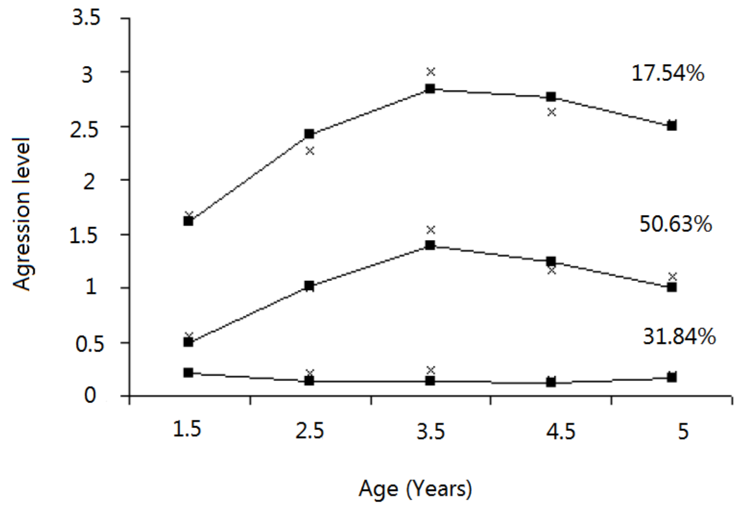
At least 4 data points were available to estimate behavioral trajectories for 94.8% of the study sample. Models with 2 to 4 trajectories groups were estimated. The selection of the final model was based on: A) Two statistical indexes: the model that maximized the Bayesian Information Criterion (BIC, i.e. closer to 0) and maximized entropy (i.e. the extent to which groups are well separated) (Schwarz, 1978) and B) the size of the trajectory groups. That is, the selected model had a sufficient proportion of children in the different groups to be usable in prediction analyses. There are no set cut-off criteria for deciding whether the size of the trajectory groups is reasonably sufficient. However, using simulations, Nylund, Asparouhov, and Muthén (2007) reported that modeling trajectories where there was a very small group (i.e. 5%) might lead to convergence problems and misspecified models. To avoid this, we specified a cut-off criterion of 10% of the sample for determining the size of the trajectory groups.

For both subtypes of behavior problems, 2-trajectory group models had the highest BIC but the proportion of children in each group was nearly the same, indicating that groups were not substantially different in the identified trajectories. For 4-trajectory group models, BIC values were smaller than other models with a low proportion of children in one of the trajectory groups. Thus, the best fitting model comprised 3-trajectory groups for both physical aggression and hyperactivity. Table 3 in **Appendix V** shows BIC statistics and intercept estimates for models with 2, 3, and 4 trajectory groups. For the 3-trajectory group model, the average probability for group membership ranged between 0.83 and 0.88 for physical aggression and 0.88 and 0.90 for hyperactivity, thereby indicating a good fit of the model (i.e. higher than .80) (Nagin, 2005). Further, high trajectories group included a sufficiently small number of children to reflect an atypically elevated levels of behavior problems based on the criterion of the sufficient proportion of children of 10%.

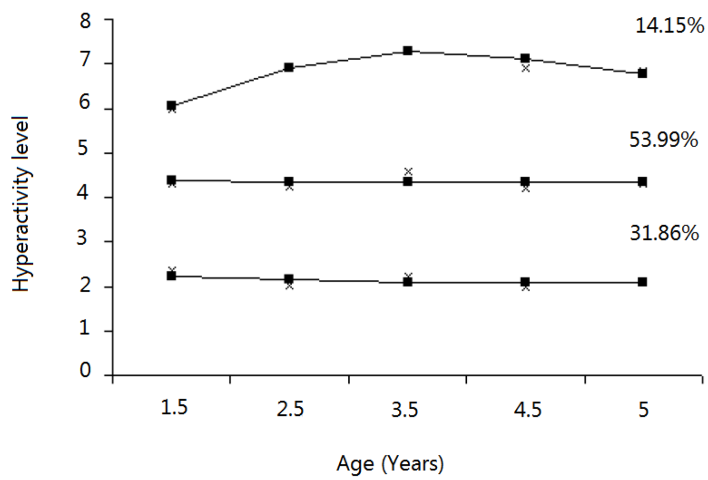
The three physical aggression trajectories were as follows: high (17.54%), moderate (50.63%), and low (31.84%). The three hyperactivity trajectories were as follows: high (14.15%), moderate (53.99%), and low (31.86%). **Figure 5** below shows the 3-trajectory groups models. High trajectory groups of physical aggression and hyperactivity were treated as a dichotomous variables (1=yes; 0=no, i.e. when children followed a low/moderate groups) and used as main outcomes in subsequent statistical models. The rational for comparing children belonging to the high trajectory group to all other groups was to identify children with atypically high levels of behavior problems. Previous research has shown that physical aggression and hyperactivity are common and normative during early childhood studies (Côté et al., 2007; Olson et al., 2013) and that it is those with atypically high and stable levels who are at greater risk for psychosocial maladjustment and psychopathology later in life.

Figure 6 *Developmental trajectories of physical aggression (A) and hyperactivity (B) from 1.5 to 5 years of age*

(A)



(B)



Note. ' ▪' is to the estimated value and 'x' is the average value based on the observations.

Article 2

Outcome variables were maternal reports of physical aggression, opposition and hyperactivity behavior across early childhood and childhood periods. Using the BEH, mothers rated their child's behavior problems between 1.5, 2.5, 3.5, 4.5, 5, 6, and 8 years of age. For hyperactivity, items used were: 1) "cannot sit still", 2) "is restless or hyperactive", 3) "is impulsive, acts without thinking", 4) "has difficulty waiting his/her turn", and 5) "cannot settle down to do anything for more than a few moments". Higher scores indicated greater levels of hyperactivity. Alpha levels ranged from 0.67 to 0.77 across assessments. The items were summed into a hyperactivity score that ranged minimum of 0 and a maximum of 10. Items used to rate opposition were: 1) "is defiant or refuses to comply with adults request or rules?", 2) "does not seem to feel guilty after misbehaving?", and 3) "punishment doesn't change his/her behavior?". Higher scores indicated greater levels of opposition. Alpha levels were ranged between 0.46 and 0.65 across assessments. The items were summed into an opposition score that ranged minimum of 0 and a maximum of 6. Physical aggression items were as follow: 1) "gets into fights?", 2) "physically attacks others", and 3) "hits, bites, kicks other children". Higher scores indicated greater levels of physical aggression (range 0 to 6). The items were summed into a physical aggression score that ranged minimum of 0 and a maximum of 6. Alpha levels ranged between 0.63 and 0.76 across assessments.

Article 3

Outcome variables were teacher's reports of hyperactivity, physical aggression, and opposition behavior in early adolescence. Using the BEH, teachers rated participants' behavior problems at 13 years of age. For hyperactivity (Cronbach's α =0.87), items used were: 1) "cannot sit still, is restless", 2) "is impulsive, acts without thinking", 3) "has difficulty waiting his/her turn", and 4) "cannot settle down to do anything for more than a few moments". For opposition (Cronbach's α=0.85), items used were: 1) "is defiant or refuses to comply with adults' request or rules?", 2) "does not seem to feel guilty after misbehaving?", and 3) "punishment doesn't change his/her behavior?". For physical aggression (Cronbach's α=0.84), items were as follow: 1) "gets into fights?", 2) "physically attacks others", and 3) "hits, bites, kicks other children". A global score was derived for each type of behavior problem and calculated using: Score = mean score on items * number of items. The score was rounded to two decimal places and then standardized to a 10-point scale (Jetté & Groseilliers, 2000). So that, behavior problems scores ranged minimum of 0 and a maximum of 10.

3.4.2 Exposure to poverty

First, mothers reported their "best estimate of the total income before taxes and deductions of all household members from all sources" (Santé Québec). Poverty was defined on the basis of the LICOs calculated by Statistic Canada. The calculation is based on family income, the number of people in the household, and the level of urbanisation of the place of residence in the past 12-months (Giles, 2004). A family was considered poor (i.e. household income below or at the LICOs) when attributing 20% or more of their household income than the average Canadian family to food, shelter, and clothing. For example, in 2012 LICOs were $ 30 250, $ 34 414, $ 37 610, and $ 43 942 (CAD) for a family of four living in rural areas, towns (< 30,000 inhabitants), towns between 30,000 and 99,999 inhabitants, or large cities (> 500,000 inhabitants) respectively (Statistics Canada, 2013). Poverty status was coded as (1) when children lived in household whose income was below or at the LICOs and (0) otherwise.

LICOs were available yearly in the QLSCD, with the exception of the 4.5 years of age assessment. The QLSCD does not include a measurement of poverty based on LICOs at 4.5 years of age (calendar year of 2002) because of changes in the data collection calendar. By the time data collection had started in 2002, LICOs fixed yearly by Statistics Canada had not yet been released for the same year. Table 4 in **Appendix V** presents descriptive statistics on poverty from ages 0.5 to 13 years.

Our multiple poverty assessments (ages 0.5-12 years) were operationalized according to each research paper forming the main body of this dissertation and corresponding objectives. In *article 1,* we used four poverty measurements obtained at ages 0.5, 1.5, 2.5, and 3.5 and summarized in terms of chronic poverty. We created a variable identifying children living in families who have been exposed to poverty on 2-4 occasions when children aged between 0.5 to 3.5 years of age. Poverty was treated as a dichotomous variable (1= chronic; 0=otherwise). In *article 2,* we used six poverty measurements obtained at ages 1.5, 2.5, 3.5, 5, 6, and 8 years and treated separately as dichotomous variables (1= poor; 0=otherwise). In article 3, we used ten poverty measurements obtained at ages 0.5, 1.5, 2.5, 3.5, 5, 6, 7, 8, 10 and 12 years and grouped into three time periods.

They were: a) exposure at least once between ages 0-3 years (P1 and coded 1=yes; 0=otherwise); b) exposure at least once between ages 5-7 years (P2 and coded 1=yes; 0=otherwise); and c) exposure at least once between ages 8-12 years (P3 and coded 1=yes; 0=otherwise).

3.4.3 Potential Mediators (Article 1)

For mediation models in *article 1,* we selected, in our own data, all potential mediators pertinent to the family stress model (Conger et al., 1992; Conger et al., 1994) as well as those suggested in literature regarding the poverty-behavior problem link. In the current work, mediators or intermediate variables implied the chain X→M→Y indicating that causal effect from X to Y is entirely or partially mediated through M. These mediators included four types of perceived parenting (self-efficacy, perceived impact, coercive, and overprotection), family dysfunction and maternal depression symptoms. Variables were assessed between 1.5 and 2.5 years of age and based on maternal reports as the person most knowledge about the child. Scores were computed for each construct, whereby items were summed and then standardized to a 10-point scale (Jetté & Groseilliers, 2000).

Family dysfunction was assessed using the general functioning scale of MacMaster family activity questionnaire (Byles et al., 1988). Mothers completed this scale when the child was 1.5 years of age. This scale measured family conflict based on communication, problem resolution, and control of disruptive behavior, showing and receiving affection (e.g. there are lots of bad feelings in our family”). Higher values indicated greater family dysfunction (range 0 to 10 and α=0.83).

Maternal depression symptoms (when the child was 1.5 years of age) were assessed through 8-item abridged version of the Diagnostic Interview Schedule (Robins, Cottler, Bucholz, & Compton, 1995; Roy et al., 2005). An interviewer asked mothers questions regarding depression symptoms and entered responses in a computer. Higher scores indicate greater levels of depressive symptoms (range 0 to 10 and α=0.81).

When the child was 1.5 and 2.5 years of age, mothers completed a parenting questionnaire using the Parental Cognitions and Conduct toward the Infant Scale (PACOTIS) (Boivin et al., 2005b). Parenting constructs reflecting mother's perceptions in the context of their interactions with their child their infant were: (1) Self-efficacy: the perceived ability to carry out tasks associated with the role of a parent (e.g. "I feel that I am very good at keeping my baby amused"; α=0.62 at 1.5 years of age and 0.95 at 2.5 years of age). (2) Parental impact: mother's evaluation of the effect of his/her behavior on the child (e.g. "My behavior has little effect on the personal development of my child"; α=0.58 at 1.5 years of age and 0.78 at 2.5 years of age). (3) Coercion: mother's hostile and restrictive responses to children's difficult behaviors (e.g. "I have been angry with my baby when he or she was particularly fussy"; α=0.69 at 1.5 years of age and 0.85 at 2.5 years of age). (4) Overprotection: an excessive concern for the safety and protection of the child (e.g. "I insist upon keeping my baby close to me at all times, within my eyesight and in the same room as I am"; α=0.70 at 1.5 years of age and 0.68 at 2.5 years of age). Mean scores for parenting constructs measured at 1.5 and 2.5 years of age were computed. For all parenting constructs, higher scores indicated higher levels of perceived parenting (range 0 to 10).

Table 5 in **Appendix V** presents all items used to measure family functioning, depression symptoms and our four types of parenting variables. Table 6 presents descriptive statistics on potential mediators and Table 7 presents correlations of variables used in *article 1* (**Appendix V**).

3.4.4 Confounders

We selected confounders on the basis of their putative association with poverty and behavior problems in the literature (Archer & Côté, 2005; S. Côté et al., 2006; Davis & Williams, 2011; Essex et al., 2006; Flouri, Midouhas, & Joshi, 2014; Kim-Cohen, Moffitt, Taylor, Pawlby, & Caspi, 2005; Reiss, 2013; Tremblay et al., 2004) as well as on statistical criteria of their association with behavior problems and poverty in bivariate analyses.

In *article 1*, models adjusted for the child's sex, low maternal education, and family structure. Specifically, sex of the child was treated as a dummy variable (1=boys and 50.2% of the sample; 0=girls). Confounders measured at multiple time points were: (a) low maternal education referred to mothers who did not complete high-school when the child was 5 years of age (coded as 1=yes and 18% of the sample; 0=no) and; (b) family structure referred to living arrangements of children in households with one *versus* two biological parents at least twice from ages 0.5 to 5 years of age (coded as 1=yes 17.1% of the sample; 0=no). Specifically, it indicates children whose family was not intact (i.e. children not living with both their biological parents; coded as 1) versus children whose family was intact, i.e. children living with both their biological parents regardless of the type of marital status (coded as 0).

In *article 2*, we used a Directed Acyclic Graph (DAG) illustrating the hypothesized causal structure and underlying cofounders of our research objective, see **Appendix V** (Figure 1**).** Briefly, the selection of confounders was based on: 1) factors influencing two or more variables shown in the DAG grounded on their reported association in the literature and 2) factors that were not in the causal pathway between poverty and behavior problems. The selection criteria imply the notion of common causes in causal diagrams theory (Hernán, Hernández-Díaz, Werler, & Mitchell, 2002) and can be described as the following chains of associations:

(a) X←Z→Y where Z is a direct cause of X indicating a back-door path or open biasing path between X and Y due to a hidden effect of Z; and

(b) X←Z←U→Y where U is a direct cause of Z and Y indicating a back-door path or open biasing path between X and Y due to hidden effects of Z and U.

We considered only minimal adjustments to block the biasing paths from poverty to behavior problems. We used information on both baseline and time-varying confounders. Baseline confounders included child sex and maternal immigration status, and maternal history of antisocial behavior. Sex of the child was treated as dummy variable (1=boys and 50.2% of the sample; 0=girls). Immigration status was coded (1 and 8.4% of the sample) when the mother was immigrant and (0) otherwise. Maternal history of antisocial behavior was assessed retrospectively when children aged 0.5 year (i.e. QLSCD baseline) and referred to the time before the end of high school. A total of 5 items regarding different conduct problems were used: 1) “Before the end of high school, did you more than once swipe things from stores or from other children, or steal from your parents or from anyone else?”, 2) “Before the end of high school, did you more than once get into fights that you had started?”, 3) “Before the end of high school, were you ever involved with Social Services (Department of Youth Protection), in trouble with the police or arrested because of your misbehaviour”, 4) “Before the end of high school, did you ever skip school at least twice in one year?”, and 5) “Before the end of high school, did you ever run away from home overnight?”. The items were summed into an antisocial behavior score that ranged minimum of 0 and a maximum of 5 (mean = .82; SD = .94). Time-varying confounders were assessed seven times at ages 1.5, 2.5, 3.5, 4.5, 5, 6, and 8 years, and included maternal education and family structure. Education referred to mothers who did not complete high-school (coded as 1=yes; 0=no). Family structure distinguished children whose parents were separated or single (coded as 1=yes; 0=no).

In *article 3*, we also used a DAG to illustrate the hypothesized causal structure and underlying cofounders and corresponding research objective, see **Appendix V** (Figure 2**).** Only minimal adjustments were considered to block the biasing paths from childhood poverty to behavior problems. Confounders assessed at baseline included: (a) immigration status (1=immigrant mother and 8.4% of the sample; 0=otherwise); (b) maternal history of antisocial behavior (as described in the paragraph above for *article 2*); and (c) child’s sex (1=boys and 46.7% of the sample; 0=girls). For confounders measured at multiple time points, we used low maternal education and family structure at ages 0.5, 3, and 8 years. The decision to use assessments at ages 0.5, 3.5 and 8 years was made because 0.5 years is QLSCD baseline, 3.5 years refer to the mid-point in early childhood (0.5 to 5 years), and 8 years is the mid-point in childhood (6 to 12 years). Low maternal education indicated if mothers did not complete high-school a (1=yes and 44.4% of the sample at age 5 months, 40.2% at age 3, and 24.7% at age 8; 0=no). Family structure corresponded to children whose biological parents were separated or single (coded as 1; 8.4% at age 5 months, 13.2% at age 3 years, and 19.2% at age 8 years) vs children living with both their biological parents regardless of their marital status (coded as 0).

For a summary of all variables used in the current work by research paper, please see Tables 8-10 in **Appendix V.**

3.5 Analytical strategy

This section discusses statistical methods employed in longitudinal study designs and how these methods were applied to the current work. A total of three statistical methods are presented in detail and corresponding to each research paper forming the body of this dissertation. Then, we present statistical approaches dealing with QLSCD sample attrition.

3.5.1 Multiple mediation analyses

In *article 1*, we applied a mediation approach based on Baron and Kenny's proposed decomposition of direct and indirect effects (1986) to examine weather poverty is associated with behavior problems through pathways of perceived parenting, family dysfunction, and maternal depression symptoms. In this approach, a variable functions as a mediator when it meets the following conditions: (1) variations in levels of the independent variable significantly account for variations in the presumed mediator (i.e., path a), (2) variations in the mediator significantly account for variations in the outcome variable (i.e., path *b),* and (3) when Paths *a* and *b* are controlled, a previously significant relation between the independent and outcome variables (path *c*) is no longer significant (total mediation) or reduced (partial mediation). These statistical conditions are tested using multiple regression analyses (both linear and logistic). Furthermore, the use of regression-based techniques to test indirect and direct effects requires several key assumptions. Assumptions needed are (MacKinnon, Fairchild, & Fritz, 2007; Valeri &

VanderWeele, 2013; VanderWeele & Vansteelandt, 2009): 1) No unmeasured X (independent variable) to Y (outcome) confounders given covariates; 2) No unmeasured M (mediators) to Y confounders given covariates; 3) No unmeasured X to M confounders given covariates; 4) There is no effect of X that confounds the M to Y relation; and finally, 5) Homogeneous effects across subgroup, so that the relation from X to M and from M to Y are homogeneous across subgroups or other characteristics of participants in the study (i.e. no effect-modification).

Specifically, we used a single-step multiple mediation model using PROCESS (Hayes, 2013) to estimate pathways from poverty to children's high trajectories of behavior problems. In this model (Preacher & Hayes, 2008), X is hypothesized to have indirect effects on Y simultaneously through $M_1, M_2, ... M_j$ where Y is the outcome, X is the independent variable, and $M_1, M_2, ... M_j$ are mediators. As an example, in a model with two mediators, this method involves estimating equations [$M_1 = d_1 + a_1X$] and [$M_2 = d_2 + a_2X$] for both mediators (M_1 and M_2) and equation [$Y = e + c'X + b_1M_1 + b_2M_2$] for the outcome (Y), and computing the product of coefficients *a* and *b* to obtain indirect effects a_1b_1 and a_2b_2. Path *a* represents the regression coefficient for X in a model predicting M from X. Paths b_1, b_2 and c' are regression coefficients in a model predicting Y from M_1, M_2 and X, respectively. Path c' quantifies the direct effect of X on Y adjusting for M_1 and M_2. And, the total effect of X on Y is the regression coefficient *c* in a simple model predicting Y from X [$Y = f + cX$]. To test for simultaneous multiple indirect effects, we used the product-of-coefficients method or the Sobel test (Baron & Kenny, 1986) based on the standard error of the product of paths *a* and path *b* (*ab*), with the p-value derived from the standard normal distribution. However, it is well known that the distribution of the *ab* product is skewed (Preacher & Hayes, 2008), so a bootstrapping resampling procedure is needed to better control Type I error. When a mediator is demonstrated in partial or complete mediation it suggests a path linking risk (or protective) factors across time periods to the outcome; multiple mediators suggest multiple paths.

The analyses in *article 1* were conducted in three steps. First, Multiple logistic regression models were used to examine whether poverty was associated with a child's membership in the high trajectory groups versus other groups (path *c*). Second, linear regression models was used to test whether poverty was associated with a total of 6 potential mediators (i.e. self-efficacy, parental impact, coercion, overprotection, maternal depression symptoms, and family dysfunction), and (2) logistic regression models to test whether potential mediators were associated with a child's membership in the high trajectory groups of physical aggression and hyperactivity using backward selection method. Mediators were retained for multiple mediation models if meeting the requirements of mediation analyses (i.e. being associated with poverty - path *a* and with behavior problems or path *b*). Only 2 were included in multiple mediation models because only 2 (i.e. overprotection and maternal depression symptoms) met the requirements of mediation analyses. Finally, multiple mediation models were based on linear regression models because the mediators M_1 and M_2 were continuous as well as logistic regressions models because our outcomes were dichotomous while including all selected mediators to estimate multiple mediation effects.

From the multiple mediation models described above it was possible to produce four regression models, in which overprotection and maternal depression were estimated in the same model. Specifically, these four regression models refer to:

(1) Two multiple regression models predicting both mediators from poverty. In our case, one regression model predicting overprotection from poverty (Path $a_{\text{overprotection}}$) and another regression model predicting maternal depression from poverty(Path $a_{\text{maternal depression}}$);
(2) One multiple regression model predicting the outcome from both mediators (Path $b_{\text{overprotection}}$ and Path $b_{\text{maternal depression}}$) and poverty (Path *c'* or the direct effect);
(3) One multiple regression model predicting the outcome from poverty without the inclusion of mediators (Path *c* or the total effect).

The procedure was applied for each outcome adjusting for child's sex, low maternal education, and family structure. Given that we used two mediator variables, the indirect effect through a given mediator refers to a specific indirect effect. The total effect of X on Y is equal to the direct effect and the sum of the specific indirect effects (i.e. $c=c'+a_1b_1+a_2b_2$). Due to skewed distributions for indirect effects a_1b_1 and a_2b_2 bootstrap procedures (here, 5000 bootstrap resamples) were used to obtain 95% confidence intervals (CIs) for direct, indirect, and total effects (Imai, Keele, & Tingley, 2010).

P-values were based on two-tailed tests. Analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 21 software. Threshold for statistical significance was set at $p<.05$

Furthermore, all analyses were weighted to correct for non-participation and non-response over time. Each participant was given a weight that was inversely proportional to the probability of being drawn from the initial target population (i.e., at 5 months). The purpose of using weights was to infer the results to the entire target population by taking into account certain demographics characteristics of non-respondents and non-participants such as low income households, mothers who spoke languages other than French or English at home, one-parent families, mothers who had less than a high school diploma, and mothers younger than 25 years of age (Jetté & Des Groseilliers, 2000). The weight variable was provided by the Quebec Institute of Statistics when children were 5 years of age.

3.5.2 Linear Mixed Models

In *article 2*, we used linear mixed models (LMMs) with random intercept and trend (random effects models) to estimate individual growth curves for children's behavior problems over time in relation to poverty. Growth curve models can be defined as multilevel, random-effects model assuming that the growth trajectories of all individuals can be adequately described using a single estimate of growth parameters (Raudenbush & Bryk, 2002).

In LMMs, responses from a subject refer to the sum of fixed and random effects plus random error. In this two-stage modeling framework, fixed effects parameters refer to the effect of the independent variable X associated with the population mean of the outcome Y whereas random effects parameters refer to an effect that is associated with individual factors (e.g. subject or random effect). Fixed effects represent the mean of the trajectory pooling of all the individuals within the sample, and the random effects represent the variance of the individual trajectories around the population mean (Curran, Obeidat, & Losardo, 2010). Specifically, individual trajectories or within-subject change may vary in terms of the initial status (intercepts) and rates of change (slopes). Also, between-subject parameters of the individual trajectories vary as a function of differences between subjects in background characteristics, instructional experiences, and possibly experimental treatments (Bryk & Raudenbush, 1987).

Importantly, LMMs are particularly suitable for growth curve models attempting to estimate between- subject differences in within-subject change regarding repeated measures of individuals observed over time. A key assumption here is that all individuals are drawn from a single population with common parameters, including intercept, functional form (e.g. linear, quadratic), and slopes. Also, LMMs assumes that the repeated measures are continuous and normally distributed. The multilevel model aspect of LLMs is due to a hierarchy of levels applied to repeated measures on a group of individuals whereby multiple-point measurements are nested within each individual (Curran et al., 2010). So that, the top level units are organized as individuals (Level 2) and the lower level units are organized around repeated observations over time (Level 1). LMMs are a promising alternative to general linear models when analysing longitudinal data for several reasons. They are as follow: (a) it addresses correlated data and unequal variances from repeated measures of the outcome Y, (2) it accommodates partially missing data by taking advantage of individuals with incomplete data, and (3) it allows for the modeling of repeated measures of the covariates (time-varying covariates) on individual growth. Given these concerns and the fact that they are particular salient in longitudinal designs, we decided to apply LLMs in the present dissertation.

Specifically, LMMs conducted in *article 2* were based on participant's age as the time scale. We compared models including exposure, baseline and time-varying confounders, age and age^2 with models excluding the quadratic term accounting for curvilinear shape of children's behavior problems patterns of change. Models are described using a two-level structure under which measurements were observations in time (Level 1) nested in children (Level 2). The following equation describes the simplest model (Model 1) using a random intercept and linear trend LMM where the quadratic age effect representing time was considered in the fixed effects:

$$Y_{ij} = [\beta_0 + \beta_1 t_{ij} + \beta_2 t^2_{ij}] + [b_{0i} + b_{1i} t_{ij} + \varepsilon_{it}]$$

where the first bracket contains the fixed effects and the second bracket the random effects. Y_{ij} is the outcome variable for a child i at time j. Among the fixed effects, β_o, β_1 and β_2 are the population intercept, the linear trend and the quadratic trend. Among the random effects, b_{0i} and b_{1i} are the individual intercepts and trends, and ε_{ij} are the errors. Model 2 added the exposure variable and its interaction with age. Model 3 added baseline confounders. Model 4 introduced time-varying confounders. Finally, Model 5 represented the best fit and most parsimonious model built using the log-likelihood ratio test, employing a backward approach to retain variables below the threshold for significance. Table 3 below presents full sequence of models. We used a first order autoregressive correlation structure assuming a steep decrease in correlation coefficients when the time interval between measurements increases (Twisk, 2013). Further, simple t-tests were performed at each age to identify when age-related changes began to appear due to poverty and its interaction term with age. For missing data, LMMs take advantage of all available data points to estimate mean growth trajectories between- and within-subject. Thus, individuals with incomplete data were not dropped from the analysis.

Table 1 Sequence of models using a random intercept and linear trend LMM.

Model	Variables
1 (Time effects)	Age + Age^2
2 (Exposure)	Model 1 + Poverty + Poverty*Age

3 (Baseline confounders)	Model 2 + Immigration status + Maternal antisocial behavior + Child's sex
4 (Time-varying confounders)	Model 3 + Maternal education + Family structure
5 (Best fit and most parsimonious)	Model 4

For clarity, we were unable to calculate the proportion of change in behavior problems for poor and non-poor children at age 4.5 years because poverty was unavailable at that assessment-point. However, all other variables available at age 4.5 years were taken into account to model within-subject or individual differences over time, including behavior problems and confounders. Thus, it reflects individual differences in behavior problems between the ages of 1.5 to 4.5 years.

3.5.3 A structured approach to modelling the effects of binary exposure variables over the life course

In *article 3*, we applied a structured modelling approach (Mishra et al., 2009) as a model-building framework to model life course models of poverty predicting behavior problems. The structured modelling approach is a model selection procedure that presents several life course models and their operationalization based on binary exposures, measured over the life course, and done within linear regression analysis. Testable life course hypotheses and the use of appropriate statistical techniques to select life course models are presented as well as regression parametrization.

This approach is based on a continuous outcome (Y), a binary explanatory variable in the form of S_1, S_2 and S_3, which is measured at the three distinct time points in the form of t_1, t_2, t_3. With this formulation, life course models can be compared using S_1, S_2 and S_3 whereby the order and value of the binary variable at each time point influence the outcome *Y*.

The authors introduce regression parameterizations based on all possible permutations between S_1, S_2 and S_3 representing all possible trajectories or sequences of exposure that may influence the outcome *Y*. Specifically, this approach examines the extent to which different combinations of the time that exposure occurred (i.e. S_1, S_2 and S_3) have a different outcome mean. Permutations are as presented by the notation below:

> Y_{000}, Y_{100}, Y_{010}, Y_{001}, Y_{110}, Y_{101}, Y_{011}, and Y_{111}, where *Y* refers to the outcome under investigation given exposure periods t_1, t_2, and t_3 (coded as 1= exposure to the explanatory variable at time t; 0=otherwise).

For instance, Y_{100} refers to the expected value of *Y* given exposure to poverty only in t_1 but not in t_2 and t_3. This, in turn, corresponds to a total of eight parameters used to express a set of hypothesized life course models representing the accumulation of risk, social mobility and critical period models.

From these considerations, there follows distinct definitions of life course hypotheses that include critical period model, accumulation of risk and social mobility models. The critical period model refers to exposure in a given period of time t that has an effect on the outcome *Y*, irrespective of other time periods. The critical period hypothesis can be encoded by as many possible exposure variables as there are time points. So that, t_1 can be expressed as an early critical period of exposure to the outcome *Y*, over later time point; as can t_2 and t_3 can assume equivalent specifications of critical periods. For instance, when t_1 is considered to be a critical period model's assumptions are represented by the notation below:

> $Y_{111} = Y_{101} = Y_{110} = Y_{100} = Y_{1**}$ and $Y_{011} = Y_{001} = Y_{010} = Y_{000} = Y_{0**}$, where * refers to unspecified exposure in t_2 and t_3 that can assume the values of 0 or 1 for no exposure and being exposed, respectively.

The following linear regression equations describe the sensitive period models corresponding to S_1, S_2 and S_3 respectively:

$$Y = \alpha + \beta_1 S_1$$

$$Y = \alpha + \beta_2 S_2$$

$Y=\alpha + \beta_3 S_3$

The accumulation of risk model implies an effect of prolonged exposure on the outcome *Y*. Thus, longer periods of exposure are harmful to the outcome *Y*. This model assumes a direct and linear effect of exposed periods. The assumption of the cumulative effect of exposure on the outcome *Y* over t_1, t_2 and t_3 are represented by the notation below:

$Y_{011} > Y_{001}$ and $Y_{111} > Y_{011}$, where changes in the outcome mean depends on the total number of exposed periods.

Further, accumulation of risk model may be formulated as:

(a) *Accumulation of risk* <u>*strict*</u> referring to a cumulative sum of the exposure over the life course represented by the total number of exposed periods (i.e. a life time score). This model can be described by the linear regression equation:

$$Y=\alpha + \beta (S_1 + S_2 + S_3)$$

(b) *Accumulation of risk* <u>*relaxed*</u> referring to the amount of exposure that is stronger in a particular period of time, with no equality constraints, described by the linear regression equation:

$$Y=\alpha + \beta_1 S_1 + \beta_2 S_2 + \beta_3 S_3$$

The social mobility model refers to the effect of changes in exposure across time periods on the outcome *Y*. Here, transitions in exposure between time periods are contrasted with the absence of transition found in two stable groups. Stable groups correspond to individuals who were never exposed and those who were always exposed across time periods. Social mobility hypotheses may combine a variable encoding positive change (from 1 to 0) with a variable encoding negative change (from 0 to 1), or variables encoding change in different pairs of measurement occasions over the life course. Social mobility models are twofold:

(a) *Social mobility between t_2 and t_3*, where mobility is presented as change in exposure solely between t_2 and t_3. In this model, negative changes between t_2 and t_3 (from 0 to 1) would be harmful to the outcome Y, and positive changes (from 1 to 0) would be beneficial, irrespective of exposure in t_1. And hence,

$Y_{101}=Y_{001}= Y_{*01}$ representing negative changes and,
$Y_{110}= Y_{010}= Y_{*10}$ representing positive changes, where * refers to unspecified exposure in t_1 assuming the values of 0 or 1.

Because only transitions between t_2 and t_3 are relevant to changes in mean outcome Y, a second assumption is that no exposure at both times t_2 and t_3 has equal expected means as those who were exposed at both time points t_2 and t_3 or $Y_{*00} = Y_{*11}$. This model can be tested by fitting the linear regression below:

$$Y=\alpha + \beta_2 S_2+ \beta_3 S_3+ \theta_{23} S_2 S_3, \text{ with constraint that } \theta_{23} = - (\beta_2 + \beta_3)$$

(b) *General social mobility*, where mobility is presented as change in exposure between t_1, t_2 and t_3. In model, any negative or positive changes on in exposure between t_1, t_2, and t_3 are equally harmful or beneficial to changes in mean outcome *Y*. Assumptions in this model can me represented as follow:

$Y_{001} = Y_{011}$ representing negative changes, and
$Y_{110} = Y_{100}$ representing positive changes.

And given that transitions between t_1, t_2 and t_3 are relevant to changes in mean outcome Y, a second assumption is that no exposure across all time periods has equal expected means as those who were exposed consistently from t_1 to t_3 or $Y_{000} = Y_{111}$. The regression model corresponding to this hypothesis is as presented below:

$Y=\alpha + \beta_1 S_1+ \beta_2 S_2+ \beta_3 S_3+ \theta_{12} S_1 S_2+\theta_{23} S_2 S_3$, with constraints that $\beta_2 = (\beta_1 + \beta_3)$ and $\theta_{12} = \theta_{23} = - \beta_2$

Next, the three general life course models mentioned above (cumulative exposure, critical period and social mobility) are treated as unstructured models nested within a saturated linear model in the prediction of Y. The latter is a more complex model with as many regression parameters as there are possible trajectories of combinations of exposures (i.e. all main effects and interaction terms). The following equation describes the saturated model using all three main effects for S_1, S_2 and S_3 and their two-way interaction terms as well as the three-way interaction term:

$$Y=\alpha + \beta_1 S_1+ \beta_2 S_2+ \beta_3 S_3+ \theta_{12} S_1 S_2+\theta_{13} S_1 S_3+ \theta_{23} S_2 P3+\theta_{123} S_1 S_2 S_3$$

With this formulation, β_1, β_2 and β_3 are slope parameters of all three main effects. The second parameterization is the expression of all possible main effects interactions and referred as θ_{12}, θ_{13}, θ_{23} and θ_{123}. Another parameterization is α for the variation around the outcome mean given no exposure to the explanatory variable over the three time periods and representing the simplest model (null model or intercept only-model). A summary on life course models linear regression specification given a binary exposure over three time periods is presented in Table 2. For an overview of nested models and the saturated model given all possible trajectories of combinations of exposures, see Table 1 in **Appendix V.**

Table 2 Overview of life course models specifications given a binary exposure over three time periods.

Model	Equations	Constraints

No effect	$Y=\alpha$	
Accumulation of risk		
Strict	$Y=\alpha + \beta (S_1+ S_2+ S_3)$	
Relaxed	$Y=\alpha + \beta_1 S_1+ \beta_2 S_2+ \beta_3 S_3$	
Critical period		
S1	$Y= \alpha + \beta_1 S_1$	
S2	$Y= \alpha + \beta_2 S_2$	
S3	$Y= \alpha + \beta_3 S_3$	
Social mobility		
Mobility S2 to S3	$Y=\alpha + \beta_2 S_2+ \beta_3 S_3+ \theta_{23} S_2 S_3$	$\theta_{23} = - (\beta_2 + \beta_3)$
Any mobility	$Y=\alpha + \beta_1 S_1+ \beta_2 S_2+ \beta_3 S_3+ \theta_{12} S_1 S_2+\theta_{23} S_2 S_3$	$\beta_2 = (\beta_1 + \beta_3)$ and $_{12} {}_{=}\theta_{23} = - \beta_2$

Regarding model selection, partial F-tests are used to compare goodness-of-fit of life course models with a saturated model to assess which model is most consistent with the data in explaining the greatest amount of variation in the outcome Y. Non-significant partial F-tests (p>.05) indicate that a given nested life course models did not differ from saturated model in fitting the data. Hence, the corresponding life course model is supported by the data as the added variables in the saturated model would not improve significantly the accuracy of the model. This procedure allows retreating towards a simpler and more parsimonious model that, in turn, is more interpretable than a complex hypothesis that involves several interactions terms (i.e. saturated model).

The decision to apply the structure modeling approach to the current dissertation was based on the nature of our research question. In *article 3*, we sought to compare a set of pre-defined life course hypotheses (Mishra et al., 2009) based on a single exposure measured at multiple points in explaining the most variance of the outcome of interest. However, with exposure grouped into three time periods, it would be possible to test for all possible direct and indirect effects in mediation analysis given the temporal ordering of the multiple exposures (S_1, S_2, and S_3) and the outcome Y. Typically, the structured modeling approach has been used when the exposure and mediator are measures of the same construct from different time points over the life course; whereas in mediation approaches, the earlier measure is considered the exposure and the later measure can be considered the mediator (Howe et al., 2016). The degree to which the association between exposure and outcome is explained indirectly by a later measure of the exposure is not within the scope of this research paper. Further, we sought to compare more complex causal structures that included 2- and 3-way interactions terms that are readily integrated in the structured modelling approach but not in mediation analyses.

By applying the structure modeling approach in *article 3*, analyses were conducted in two steps: (1) Modeling competing life course models of the association between poverty across three time periods (i.e. P1, P2 and P3) and behavior problems at 13 years of age; and (2) Selecting the life course model that best described the association between childhood poverty and behavior problems in early adolescence. Analyses were conducted with SPSS v.22.0 and R software. We used a threshold for significance at $p < .05$.

First, we used separate multiple linear regressions allowing for variation around the outcome mean given a binary exposure measured at three time points (in our case, P1, P2 and P3) as well as all possible permutations between exposures. A total of eight possible permutations corresponded to each combination of timing periods P1, P2 and P3. Second, to test for rival life course models given P1, P2 and P3, we compared a set of nested/reduced models - corresponding to the accumulation of risk, sensitive periods for P1, P2 and P3 and mobility models - to a saturated/complete model. Life course models of childhood poverty predicting behavior problems were as follows:

(a) Three sensitive period models assuming that the association between poverty and behavior problems is particularly stronger during a certain time period (in our case, P1, P2, or P3) than it would be at other time periods.

(b) Two accumulation of risk models:

- *Accumulation of risk strict* assuming that the longer the time spent in poverty, regardless of the time period, the higher the risk for behavior problems. The causal parameter of interested here is represented by the sum of exposure to poverty across three time periods (range 0 to 3) and assumes all three time points contribute equally to the risk for behavior problems. Specifically, for this model no exposure to poverty was compared to those who were poor >=1 time period. And,

- A*ccumulation of risk relaxed* assuming that all three time points increase the risk for behavior problems but not necessarily in an equal manner (i.e. no equality constraint).

(c) Two social mobility models:

- *Mobility P2 to P3* assuming that downward changes (i.e. becoming poor) would equally increase behavior problems risk whereas upwards changes (i.e. moving out of poverty) would equally decrease behavior problems risk between P2 and P3, irrespective of early exposure poverty (i.e. P1). Hence, those exposed to poverty in both P2 and P3 would have equal expected means to those who remain non-poor in both P2 and P3. And,

- *Any mobility* assuming that upwards changes decreases behavior problems risk and that downwards changes increases behavior problems risk in an equal manner given P1, P2 and P3. Specifically, this model suggests that all upwards changes preceding downwards changes (Y_{010}, where Y is the outcome variable given exposure to P1, P2 and P3 that can take the values of 0 and 1) decreases behavior problems risk as would downwards changes preceded by upwards changes (Y_{101}) increase behavior problems risk. Also, those never exposed to P1, P2 and P3 would have equal expected means as those who remained poor across all time periods.

The selection of the best fit and most parsimonious life course model was based on two criteria: a) the largest p-value resulting from a partial F-test given a life course model against the saturated model; and b) only life course models tested against the saturated model with significant poverty estimates. All models were successively adjusted for confounders using the log-likelihood ratio test and employing a backward approach to retain variables below the threshold for significance.

3.5.4 Statistical approaches dealing with sample attrition

Because of the high attrition rates in the QLSCD as well as differential attrition among those living in poverty (i.e. who were more likely to be lost to follow-up), we conducted multiple imputation analysis as the primary method to deal with sample attrition. This technique is based on the assumption that data is missing at random (MAR) as opposed to missing not at random (MNAR). This method creates a number of imputed datasets based by replicating the incomplete dataset multiple times and replacing the missing data in each replicate with plausible values drawn from an given imputation model (Hayati Rezvan, Lee, & Simpson, 2015). Then, each imputed dataset is analysed to obtain a corresponding set of estimates of interest. And finally, estimates from all imputed datasets are combined together producing a single pooled estimate and standard errors to fully account for variability in the missing data. Thus, unknown missing values were replaced with an overall estimate that combines estimated values drawn from imputed datasets.

Imputations are created on the basis of regression equations fitted to the observed data and applied to predict missing values. Careful attention is needed to select which variables should be included in the imputation model as potential predictors of missingness in order to avoid model misspecification. Multiple imputation is considered to be effective in reducing the bias resulting from item missingness when the magnitude of the bias is high and the imputation models are well specified (Mostafa & Wiggins, 2015; Rubin, 2004).

In the present dissertation, we imputed values for our initial sample (N=2120) allowing for the inclusion of individuals with missing data in the analyses for *article 1*, *2* and *3*. The proportion of observations with at least one missing variable varied by research paper: 17% for *article 1*, 31% for *article 2* and 39% for *article 3*. Multiple imputation was conducted as the primary analysis in *article 1* and *3* and as secondary or sensitive analysis in *article 2* in order to compare the robustness of the study results when no missing data treatment was employed. First, we ran an exploratory analysis to verify patterns of missing values in the data before imputation. We found a nonmonotone missing data whereby missing patterns were arbitrary and we adopted a MAR mechanism for missing data. Imputation was done conditionally on all variables and performed using Fully Conditional Specification (FCS) or Multiple Imputation by Chained Equations (MICE) in SPPS statistical software (van Buuren & Groothuis-Oudshoorn, 2011).

A number of imputations were performed to replicate the incomplete QLSCD dataset multiple times. Specifically, a total of 5 imputed datasets (m) was generated using 10 sampling iterations from the marginal starting values in each research paper. The decision to fix $m = 5$ as opposed to $m = 20$ (Graham, Olchowski, & Gilreath, 2007; White, Royston, & Wood, 2011) was based on research indicating that they were reasonably sufficient in terms of statistical efficiency to combine estimates from multiple imputed datasets and obtain stable results (van Buuren, Brand, Groothuis-Oudshoorn, & Rubin, 2006; Schafer & Olsen, 1998). We computed and compared the relative efficiencies based on 5 and 20 imputations respectively between QLSCD assessments points from 1.5 to 13 years old. Results showed relative efficiencies varied from 0.993 to 0.927 and from 0.998 to 0.981 with 5 and 20 imputations, respectively (see **Appendix V,** Table 2). The ratios (m=5/m=20) of these relative efficiencies varied from 0.995 to 0.945. So, in the worst case (at 13 years old), our relative efficiency represented 94.5% of the relative efficiency we would have obtained with 20 imputations. This suggests that 5 imputations can be considered as acceptable. Comparing analyses were based on the relative efficiency involving the fraction of missing information (γ) for the parameter being estimated (m) given by $(1+ \gamma / m)^{-1}$ (Rubin, 1987).

Explanatory variables used in the impute missing values were behavior problems, poverty and all confounders variables as included in main analyses of each research paper. Finally, diagnostic checks employed and sensitivity analyses around the imputation process (i.e.

article 2 and *3*) are further detailed in relation to findings of each research paper in next section, Chapter 4.

CHAPTER 4

Results

Chapter 4 contains three published research papers forming the main body of the present dissertation. They are presented in chronological order given their acceptance in their corresponding peer-reviewed journals. Supplementary material referring to complementary analyses, DAGs and other relevant information in each article was published online in a supplementary section.

4.1 Article 1

Mazza, J.R.., Pingault, J-B., Booij, L., Boivin, M., Tremblay, R.E., Lambert, J., Zunzunegui, M.V, & Côté, S.M. (2016). Poverty and behavior problems during early childhood: The mediating role of maternal depression symptoms and parenting. *International Journal of Behavioral Development*, 0165025416657615.

The supplementary material is available at http://ijbd.sagepub.com/supplemental

4.2 Article 2

Mazza, J.R.S., Boivin, M., Tremblay, R.E., Michel, G., Salla, J., Lambert, J., Zunzunegui, M.V, & Côté, S.M. (2016). Poverty and behavior problems trajectories from 1.5 to 8 years of age: Is the gap widening between poor and non-poor children? *Social Psychiatry and Psychiatric Epidemiology*, *51*(8), 1083-1092.

The supplementary material is available at doi:10.1007/s00127-016-1252-1

4.3 Article 3

Mazza, J.R.S., Lambert, J., Zunzunegui, M.V., Tremblay, R.E., Boivin, M., & Côté, S.M. (2017). Early adolescence behavior problems and timing of poverty during childhood: A comparison of lifecourse models. *Social Science & Medicine, 177*, 35-42.

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4.1 Article 1

Poverty and behavior problems during early childhood: The mediating role of maternal depression symptoms and parenting

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Abstract

Poverty is a well-established risk factor for behavior problems, yet our understanding of putative family mediators during early childhood (i.e. before age 5 years) is limited. The present study investigated whether the association between poverty and behavior problems during early childhood is mediated simultaneously by perceived parenting, family dysfunction and/or maternal depression symptoms. Outcomes measures were high trajectories of physical aggression and hyperactivity between 1.5 and 5 years. Poverty was defined as living 2-4 years below the low-income thresholds defined by Statistics Canada. Using data from the first five rounds of the Quebec Longitudinal Study of Child Development, logistic regressions models showed that poverty was associated with a higher likelihood of being assigned to the high trajectory of physical aggression and hyperactivity. Overprotection and maternal depression symptoms mediated observed associations. Interventions targeting maternal depression, parenting, and poverty should help reducing children's risk for early behavior problems.

Introduction

Poverty is a well-established risk factor for behavior problems across development (Amone-P'Olak et al., 2009; Dearing, McCartney, & Taylor, 2006). This association is robust across high-income countries with different health care and social policy contexts (Kiernan & Mensah, 2009; Spencer, 2003). One of the leading mechanistic hypotheses about how poverty shapes children's behavioral development is through its impact on parental psychological well-being. Previous studies have primarily focused on the family stress model (Conger & Donnellan, 2007), which posits that economic hardship increases parental distress indirectly affecting children's adjustment through parental mental health and the quality of parenting. The family stress model remains understudied with regard to poverty and child development during early childhood (i.e. first five years of life), a period characterized by children's high levels of dependence on caregivers and vulnerability to adverse and stressful environmental conditions.

Why poverty should be associated with behavior problems? The family stress model

The family stress model posits that economic hardship is related to higher levels of family stress (Conger & Donnellan, 2007). In this model, higher levels of family stress are reflected in reduced nurturing and involved parenting as well as increased family and marital conflicts, parental emotional distress (e.g. depression, anxiety, anger, and alienation) and behavior problems (e.g. substance use and antisocial behavior). In turn, family stress is proposed to be related to higher levels of behavior problems in the offspring. Hyperactivity and physical aggression are two subtypes of behavior problems which are prevalent during early childhood, a time period in which children learn to inhibit or control such behaviors within a supportive family environment (Côté, Vaillancourt, LeBlanc, Nagin, & Tremblay, 2006; Tremblay, 2010). In the present study we test the hypothesis that family stress interferes with children's learning to control behavior problems such as hyperactivity and physical aggression.

Empirical evidence on the direct or indirect associations between poverty and behavior problems

Evidence on the association between poverty and behavior problems from quasi-experimental research (e.g. testing the impact of supplemental income) suggest that poverty is related to children's behavior problems across childhood (Akee, Copeland, Keeler, Angold, & Costello, 2010; D'Onofrio et al., 2009). Most of quasi-experimental studies focus on children aged 4-12 years. The exception being a Swedish study supporting an association between low family income and Attention Deficit/Hyperactivity Disorder during children's first five years of life (Larsson, Sariaslan, Långström, D'Onofrio, & Lichtenstein, 2014).

With such associations established through both longitudinal and experimental studies, researchers have focused on mechanisms by which poverty is linked to behavior problems. Studies provide three lines of evidence for three types of family mediators that have a either direct or indirect effect on children's behavior problems. First, poverty was shown to be associated with children's behavior problems (2-6 years of age) primarily through less-supportive parenting and family conflict (Rafferty & Griffin, 2010). In particular, parental supervision was found to be an important mediator of the link between poverty and clinical diagnoses of conduct and opposition-defiant disorders at ages 9-13 years (Costello, Compton, Keeler, & Angold, 2003). Further, maternal warmth and parental monitoring were found to mediate the association between neighbourhood affluence and antisocial behavior from 5-12 years of age (including physical aggression) (Odgers et al., 2012). Second, economic deprivation was shown to be associated with behavior problems indirectly through maternal depression among children aged 2-4 years (Wadsworth et al., 2013). Similar findings were obtained in mediation analyses revealing indirect effects of low-income on behavior problems (7-8 years of age) operating through maternal depression and parenting hassles (Shelleby et al., 2014). The same pattern was found among young children (0-3 years) in which maternal depression, along with disrupted parenting were found to be mediators of the association between economic disadvantage and behavior problems (Rijlaarsdam et al., 2013). In addition, experimental research suggest that changes in maternal depression mediated the association between poverty and behavior problems among children aged 2-3 years (Shaw, Connell, Dishion, Wilson, & Gardner, 2009). Third, research has suggested that poverty was related to higher levels of conduct problems (8-10 years) through increases in family conflicts (Evans & English, 2002). For instance, the association between poverty and behavior problems (age 17 years) was found to be mediated by family conflicts in the home environment including violence and family turmoil (Evans & Cassells, 2014). Together these findings indicate that the stress accompanying poverty may lead to harsher and less responsive parenting, conflicted family interactions as well as feelings of hopelessness due to lack of choices in life and, consequently, depressive symptoms. These factors, in turn, may be harmful to children's behavioral development.

Limitations of past studies

Some limitations in the literature regarding the family stress model and the poverty-behavior problem link should be considered. First, very few studies have tested the mediating role of family processes in the association between poverty in the first year of life and behavior problems in early childhood. Second, there is compelling evidence on the importance of distinguishing subtypes of behavior problems because they have different developmental trajectories and require specific corrective interventions (Tremblay, 2010), but few studies have made distinctions between behavioral subtypes. Indeed, it is possible that different mediators may be more or less pertinent to different subtypes of behavior problems. For instance, the socialisation of physically aggressive behavior during early childhood may be more associated with poverty through parenting than other subtype of behavior problems such as hyperactivity, which may be more genetically related (Faraone, Doyle, Mick & Biederman, 2014). Third, few studies have distinguished the potential mediating role of different types of parenting constructs simultaneously. One challenge here concerns levels of description and specificity of parenting constructs. Finally, little is known about chronic or long-term poverty and behavior problems during early childhood. Studies have shown that poverty is most strongly associated with child outcomes when it is chronic (Nikiéma, Gauvin, Zunzunegui, & Séguin, 2012; Roy & Raver, 2014), but the association between chronic poverty and behavior problems before age 5 years has not been examined.

Objectives of the present study

The present study sought to extend our understanding of family mediators through which poverty shapes behavior problems by addressing two objectives: (1) to estimate the associations between chronic poverty from 5 months to 3.5 years of age and high levels of physical aggression and hyperactivity from 1.5 to 5 years of age, and (2) to examine whether the association between poverty and behavior problems is mediated simultaneously by perceived parenting (self-efficacy, parental impact, coercion, and overprotection), family dysfunction and maternal depression symptoms. Previous research have shown that these parenting constructs are linked to behavior problems (Côté, Boivin, et al., 2007; Galéra et al., 2011). Thus, perceived parenting, family dysfunction and maternal depression may be important independent pathways of the poverty-behavior problems link during early childhood. Three main hypotheses were generated from previous research: 1) poverty would be associated with all behavior problems; 2) perceived parenting, family dysfunction and maternal depression symptoms would be associated with all behavior problems; and 3) the association between poverty and behavior problems would be mediated by perceived parenting, family dysfunction and/or maternal depression symptoms. The additional value of this study resides in informing the time and targets for interventions to limit the detrimental impact of poverty on behavior problems, and providing policy recommendations to further reduce poverty in families with young children.

Methods

Data

Data were obtained from the Quebec Longitudinal Study of Childhood Development. The protocol was approved by the Quebec Institute of Statistics and the Sainte-Justine Hospital Research Center (Montreal) ethics committees. The sample was born from 1997- 1998 and was drawn from the Quebec Birth Registry using a stratified procedure based on living area and birth rate. Families were included if the pregnancy lasted 24 to 42 weeks and the mother could speak French and/or English. Data were collected yearly through home interviews conducted with the person most knowledgeable about the child (mothers in 98% of cases). Written informed consent was obtained from all participating families. Assessments were conducted at: 5 months, 1.5, 2.5, 3.5, 4.5, and 5 years. The initial sample comprised of 2120 children aged 3-8 months (mean age 5 months). When children were 5 years of age, 1759 participants from the initial sample remained in the study (i.e. 83% of retention rate). All analyses were weighted to correct for non-participation and non-response over time. Each participant was given a weight that was inversely proportional to the probability of being drawn from the initial target population (i.e. at 5 months). The purpose of using weights was to infer the results to the entire target population by taking into account certain demographics characteristics of non-respondents and non-participants such as low-income households, mothers who spoke languages other than French or English at home, one-parent families, mothers who had less than a high school diploma, and mothers younger than 25 years of age (Jetté & Des Groseilliers, 2000). The weight variable was provided by the Quebec Institute of Statistics when children were 5 years of age.

Of the 2120 participants in the initial sample, we selected for the present study only those with 4 or more time points that included behavior problems and poverty data as well as those with weight variable (N=1759). From those, 63 were excluded due to non-response on at least one of variables used in analyses. Missing values ranged between 0.6–5.2%. No significant difference was noted between the two samples.

Measures

Outcome variables: *High trajectories of physical aggression and hyperactivity.* Mothers rated their child's behavior five times between 1.5 and 5 years of age using the early childhood behavior scale from the Canadian National Longitudinal Study of Children and Youth (Statistics Canada, 1996). This tool incorporates items from the Child Behavior Checklist (Achenbach & Edelbrock, 1991), the Ontario Child Health Study Scales (Byles, Byrne, Boyle, & Offord, 1988), a modified version of the Children's Behaviour Questionnaire (Behar, 1977); and the Preschool Behaviour Questionnaire (Tremblay, Vitaro, Gagnon, Piché, & Royer, 1992). Mothers rated the frequency scale of their child's behavior problems, namely whether the child never (0), sometimes (1), or often (2) exhibited physical aggression and hyperactivity. Items used were: a) hits, bites, kicks; b) fights; and c) bullies others for physical aggression (range 0 to 6); and a) can't sit still, is restless, is hyperactive; b) fidgets; c) is impulsive; d) has difficulty waiting turn; and e) cannot settle for hyperactivity (range 0 to 10). Cronbach's alphas ranged between 0.72 and 0.75 across assessments for physical aggression ratings and between 0.74 and 0.75 for hyperactivity ratings. Mean levels of behavior problems by age are presented in **Table 1.**

We used a semi-parametric mixture model approach (using software package Statistical Analysis System Trajectory Procedure – SAS Proc Traj) to examine behavioral profiles of physical aggression and hyperactivity, represented by different combinations of the trajectories (Jones & Nagin, 2007). The modeled trajectories allow (1) identifying groups of children with distinct levels of a given behavior over time, (2) estimating the proportion of children in each of the identified trajectory groups, and (3) estimating the patterns of stability and variations in trajectories. This procedure assigns individuals to categories on the basis of a posterior probability rule. Resulting groups are approximations of probabilities used to classify the participant in the trajectory group he or she most likely belongs to (Nagin, 2005). Specifically, each participant is assigned to the trajectory group for which he or she had the largest probability estimate. For instance, a participant with high physical aggression scores throughout early childhood will have a high probability of being classified in the high physical aggression trajectory. At least 4 data points were available to estimate behavioral trajectories for 94.8% of the study sample. Models with 2 to 4 trajectories groups were estimated. The selection of the final model was based on: A) Two statistical indexes: the model that maximized the Bayesian Information Criterion (BIC, i.e. closer to 0) and maximized entropy (i.e. the extent to which groups are well separated) (Schwarz, 1978) and B) the size of the trajectory groups. That is, the selected model had a sufficient proportion of children in the different groups to be usable in prediction analyses. In addition, the high trajectory group included a sufficiently small number of children to reflect an atypically elevated developmental pattern. There are no set cut-off criteria for deciding whether the size of the trajectory groups is reasonably sufficient. However, using simulations, Nylund, Asparouhov, and Muthén (2007) reported that modeling trajectories where there was a very small group (i.e. 5%) might lead to convergence problems and misspecified models. To avoid this, we specified a cut-off criterion of 10% of the sample for determining the size of the trajectory groups.

Table 2 shows BIC statistics and the percentages of participants for models with 2 to 4 trajectories groups. For both subtypes of behavior problems, 2-trajectory group models had the highest BIC but the proportion of children in each group was nearly the same, indicating that groups were not substantially different in the identified trajectories. For 4-trajectory group models, BIC values were smaller than other models with a low proportion of children in one of the trajectory groups. When considering the criterion of the sufficient proportion of children in different trajectory groups, the best model comprised 3-trajectory groups for both physical aggression and hyperactivity. For the 3-trajectory group model, the average probability for group membership ranged between 0.83 and 0.88 for physical aggression and 0.88 and 0.90 for hyperactivity, thereby indicating a good fit of the model (i.e. higher than .80) (Nagin, 2005). Further, intercept estimates for models with varying number of trajectory groups are presented in Appendix A (**Table S1**).

The three physical aggression trajectories were as follows: high (17.54%), moderate (50.63%), and low (31.84%). The three hyperactivity trajectories were as follows: high (14.15%), moderate (53.99%), and low (31.86%). **Figure 1** shows the 3-trajectory groups models. High trajectory groups of physical aggression and hyperactivity were treated as a dichotomous variables (1=yes; 0=no, i.e. when children followed a low/moderate groups). The rational for comparing children belonging to the high trajectory group to all other groups was to identify children with atypically high levels of behavior problems.

Independent variable: *Poverty.* We used a measure of relative poverty. Mothers reported the total annual household income before taxes in the past 12-months. Poverty was established as a function of living in a household with annual income below the Canadian low income cut-offs. Low income cut-offs were calculated by Statistics Canada and available yearly in the sample, with the exception of the 4.5 years of age assessment. The calculation is based on family income, the number of people in the household, and the level of urbanisation of the place of residence in the past 12-months (Giles, 2004). A family at or below the low income cut-offs attributes 20% or more of their household income than the average Canadian family to food, shelter, and clothing. For example, in 2008, low income cut-offs were $ 22,724, $ 26,007, $ 29,013; $29,378 and $ 34,738(CAD) for a family of four living in rural areas, towns (< 30,000 inhabitants), towns between 30,000 and 99,999 inhabitants, towns between 100,000 and 499,999 inhabitants, large cities (> 500,000 inhabitants) respectively (Statistics Canada, 2012). In the present study, poverty was defined as chronic poverty, where families lived at or below low income cut-offs on 2-4 occasions when children aged 5 months to 3.5 years (26.8% of the sample). Poverty was treated as a dichotomous variable (1=chronic; 0=otherwise).

Potential mediators: *Family dysfunction, perceived parenting, and maternal depression symptoms.* Maternal ratings of family dysfunction (when the child was 1.5 years of age) assessed family conflict based on communication, problem resolution, control of disruptive behavior, showing and receiving affection (Byles et al., 1988) (e.g. "there are lots of bad feelings in our family"). Higher values indicated greater family dysfunction (range 0 to 10 and α=0.83). Maternal depression symptoms (when the child was 1.5 years of age) were assessed through 8-item abridged version of the Diagnostic Interview Schedule (Robins, Cottler, Bucholz, & Compton, 1995; Roy et al., 2005). An interviewer asked mothers questions regarding depression symptoms and entered responses in a computer. Higher scores indicate greater levels of depressive symptoms (range 0 to 10 and α=0.81). When the child was 1.5 and 2.5 years of age, mothers completed a parenting questionnaire using the Parental Cognitions and Conduct toward the Infant Scale (PACOTIS) (Boivin et al., 2005). Parenting constructs reflecting the mother's perceptions towards their infant were: (1) Self-efficacy: the perceived ability to carry out tasks associated with the role of a parent (e.g. "I feel that I am very good at keeping my baby amused"; α=0.62 at 1.5 years of age and 0.95 at 2.5 years of age). (2) Parental impact: mother's evaluation of the effect of his/her behavior on the child (e.g. "My behavior has little effect on the personal development of my child"; α=0.58 at 1.5 years of age and 0.78 at 2.5 years of age). (3) Coercion: mother's hostile and restrictive responses to children's difficult behaviors (e.g. "I have been angry with my baby when he or she was particularly fussy"; α=0.69 at 1.5 years of age and 0.85 at 2.5 years of age). (4) Overprotection: an excessive concern for the safety and protection of the child (e.g. "I insist upon keeping my baby close to me at all times, within my eyesight and in the same room as I am"; α=0.70 at 1.5 years of age and 0.68 at 2.5 years of age). Mean scores for parenting constructs measured at 1.5 and 2.5 years of age were computed. For all parenting constructs, higher scores indicated higher levels of perceived parenting (range 0 to 10). All items used to measure self-efficacy, parental impact, coercion, overprotection, family functioning, and depression symptoms are available in Appendix A (**Table S2**).

Control variables. We selected confounders on the basis of their putative association with low family income and behavior problems in previous studies (Burt, Barnes, McGue, & Iacono, 2008; Côté et al., 2007; 2006; Essex et al., 2006; Tremblay et al., 2004). Models adjusted for the child's sex, low maternal education, and family structure. Low maternal education referred to mothers who did not complete high-school when the child was 5 years of age (coded as 1=yes; 0=no). Family structure referred to children whose parents were single or separated at least twice from 5 months to 5 years of age (coded as 1=yes; 0=no). Sex of the child was treated as a dummy variable (1=boys; 0=girls).

Analytic design

The analyses were conducted in three steps: (1) testing the association between poverty and children's high trajectories of physical aggression and hyperactivity; (2) selecting potential mediators; (3) testing potential mediators. We used *z*-standardized ratings for all potential mediators. We imputed values for our study sample (N=1759) allowing for the inclusion of 63 individuals with missing data in the analyses. A total of 5 imputed datasets were produced. Then, estimates from imputed datasets were combined together producing a single estimate and standard errors for subsequent analyses. Results addressing the modeling of the association between poverty and behavior problems were reported using imputed data. P-values were based on two-tailed tests. Analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 21 software. Threshold for statistical significance was set at $p<.05$.

Multiple logistic regression models were used to examine whether poverty was associated with a child's membership in the high trajectory groups versus other groups. The two outcomes were: (1) belonging to a high physical aggression trajectory; and (2) belonging to a high hyperactivity trajectory. Models were adjusted for confounders including child's sex, low maternal education, and family structure.

To select potential mediators, we used (1) linear regression models to test whether poverty was associated with potential mediators (i.e. self-efficacy, parental impact, coercion, overprotection, maternal depression symptoms, and family dysfunction), and (2) logistic regression models to test whether potential mediators were associated with a child's membership in the high trajectory groups of physical aggression and hyperactivity using backward selection method. Mediators were retained for multiple mediation models if meeting the requirements of mediation analyses (i.e. being associated with poverty and with behavior problems).

Pathways from poverty to children's high trajectories of behavior problems were estimated in a single-step multiple mediation model using PROCESS (Hayes, 2013). In this model (Preacher & Hayes, 2008), X is hypothesized to have indirect effects on Y simultaneously through $M_1, M_2, ...M_j$ where Y is the outcome, X is the independent variable, and $M_1, M_2, ...M_j$ are mediators. To test for simultaneous multiple indirect effects, we used the product-of-coefficients method based on the standard error of the product of paths *a* and path *b* (*ab)* (Preacher & Hayes, 2008). As an example, in a model with two mediators, this method involves estimating equations [$M_1 = d_1 + a_1X$] and [$M_2 = d_2 + a_2X$] for both mediators (M_1 and M_2) and equation [$Y = e + c'X + b_1M_1 + b_2M_2$] for the outcome (Y), and computing the product of coefficients *a* and *b* to obtain indirect effects a_1b_1 and a_2b_2. Path *a* represents the regression coefficient for X in a model predicting M from X. Paths b_1, b_2 and c' are regression coefficients in a model predicting Y from M_1, M_2 and X, respectively. Path c' quantifies the direct effect of X on Y adjusting for M_1 and M_2. And, the total effect of X on Y is the regression coefficient *c* in a simple model predicting Y from X [$Y = f + cX$]. First, we used linear regression models because the mediators M_1 and M_2 were continuous. Then, we used logistic regressions models because our outcomes Y were dichotomous while including all selected mediators to estimate multiple mediation effects. The procedure was repeated for each outcome adjusting for child's sex, low maternal education, and family structure. Due to skewed distributions for indirect effects a_1b_1 and a_2b_2 bootstrap procedures (here, 5000 bootstrap resamples) were used to obtain 95% confidence intervals (CIs) for direct, indirect, and total effects (Imai, Keele, & Tingley, 2010)

Results

Table 3 describes the demographic characteristics of our study sample. Further, changes in the sample composition from 5 months to 5 years are available on Appendix A (**Table S3**).

The association between poverty and behavior problems

Table 4 presents the results of unadjusted and adjusted logistic regressions of poverty predicting a child's membership in the high trajectory groups of physical aggression or hyperactivity. After adjusting for confounders (i.e. child's sex, low maternal education, and family structure), we found a 43% increased odds of being assigned to the high physical aggression trajectory (Odds Ratio; OR=1.43 [CI 1.26; 1.62]) following exposure to poverty and a 76% increased odds of being assigned in high hyperactivity trajectory (OR=1.76 [CI 1.55; 2.00]).

Selecting potential mediators

Table 5 provides the results of selected potential mediators of the link between poverty and children's high trajectories of physical aggression and hyperactivity. Using multiple linear regression models, poverty was associated with greater levels of maternal depression symptoms, family dysfunction, overprotection, self-efficacy and lower levels of parental impact. Coercion was not associated with poverty; hence this variable was excluded in subsequent multiple mediation models. Next, variables were entered all at once into multiple logistic regressions predicting both outcomes. Family dysfunction and parental impact were found to be unrelated to both outcomes; hence, these variables were also excluded in subsequent multiple mediation models. Because maternal depression symptoms, self-efficacy and overprotection were related to both outcomes ($p<.05$), they were retained in multiple mediation models. Both models were significant (Wald χ^2=422.34, $p<.001$ for children's high physical aggression trajectory; Wald χ^2=528.65, $p<.001$ for children's high hyperactivity trajectory). See Appendix A (**Table S4-S5**) for bivariate analyses between poverty, behavior problems, and potential mediators.

Testing potential mediators

High physical aggression trajectory. Overprotection and maternal depression symptoms mediated the association between poverty and children's high physical aggression trajectory. Self-efficacy did not emerge as a significant mediator (-0.007 [CI -0.02; 0.01]). Poverty was associated with children's high physical aggression trajectory (i.e. path *c*; $p<.001$ [CI 0.23; 0.49]). Using the product-of-coefficients strategy (Preacher & Hayes, 2008), we found the specific indirect effects from poverty to children's high physical aggression trajectory to be mediated by overprotection (-0.088 [CI -0.12 ;-0.06]) and by maternal depression (0.059 [CI 0.04; 0.08]). Specifically, overprotection reduced the likelihood of membership in the high physical aggression trajectory, whereas maternal depression increased the likelihood of membership in the high physical aggression trajectory. After adding mediators, the direct effect of poverty on children's high physical aggression trajectory remained significant and was even strengthened (i.e. path *c'*; $p<.001$ [CI 0.26; 0.54]). **Figure 2** illustrates total, direct, and indirect effects from poverty to children's high physical aggression trajectory through mediators.

High hyperactivity trajectory. Overprotection (0.111 [CI 0.08; 0.14]) and maternal depression symptoms (0.039 [CI 0.03; 0.06]) mediated the association between poverty and children's high hyperactivity trajectory. Self-efficacy was not a significant mediator (-0.011 [CI -0.03; 0.17]). Poverty was associated with the children's high hyperactivity trajectory (i.e.

path ***c***; p<.001 [CI 0.43; 0.70]). Poverty was associated with higher levels of overprotection and maternal depression symptoms, which in turn increased the likelihood of membership in the high hyperactivity trajectory group. After including mediators in the model, the direct effect of poverty on children's high hyperactivity trajectory remained significant (i.e. path *c'*; p<.001 [CI 0.30; 0.59]). **Figure 3** illustrates total, direct, and indirect effects from poverty to children's high hyperactivity trajectory through mediators.

Complementary analyses

The following analyses aimed to examine the association between duration of poverty (i.e. never poor, transiently poor and chronically poor) and high trajectories of behavior problems. Logistic regression models adjusted for confounders including child's sex, low maternal education, and family structure. We used dummy coding to refer to transient and chronic poverty based on the number of episodes of household income below low income cut-offs for each participant and used 'never poor' as the reference category. Models showed that children living in transient poverty were more likely to belong to the high physical aggression trajectory (OR=1.54 [CI 1.31; 1.82]) than children who were never poor. However, they were not more likely to belong to the high hyperactivity trajectory (OR=1.03 [CI 0.85; 1.25]). With chronic poverty, children were more likely to belong to the high physical aggression trajectory (OR=1.74 [CI 1.52; 1.99]) and to the high hyperactivity trajectory (OR=1.77 [CI 1.54; 2.04]) than children who were never poor. Associations remained significant when accounting for transient poverty. Please see Appendix A, **Table S6**.

Further, we tested for mediation models using poverty at 5 months of age as a predictor of behavior problems from 3.5 to 5 years of age through selected mediators at 1.5 and 2.5 years of age to account for the lack of temporally ordered data in mediation models using chronic poverty. Mean levels of behavior problems were computed from 3.5 to 5 years of age and used as the outcome variable. Pathways from poverty at 5 months to children's behavior problems at 3.5 to 5 years of age were estimated in a single-step multiple mediation model using PROCESS (Hayes, 2013). Specifically, results showed that poverty at 5 months was associated with physical aggression from 3.5 to 5 years of age (i.e. path *c*; p<.001[CI 0.09; 0.20]), and both maternal depression symptoms and overprotection mediated this association. The specific indirect effects from poverty at 5 months to physical aggression through overprotection was -0.046 (CI -0.06; -0.04) and through maternal depression symptoms was 0.034 (CI 0.03; 0.04). For the hyperactivity outcome from 3.5 to 5 years of age, poverty at 5 months was directly associated with the children's hyperactivity (i.e. path *c*; p<.001[CI 0.16; 0.34]), and both maternal depression symptoms and overprotection were significant mediators. The specific indirect effects from poverty at 5 months to hyperactivity from 3.5 to 5 years of age through overprotection was 0.039 (CI 0.02; 0.06) and through maternal depression symptoms was 0.034 (CI 0.03; 0.04). For physical aggression and hyperactivity from 3.5 to 5 years of age, patterns of associations were similar to previous mediation models in that we found chronic poverty from 5 months to 3.5 years was associated with children's high behavior problems trajectories from 1.5 to 5 years of age through maternal depression symptoms and overprotection. See Appendix A, **Figure S1** and **Figure S2** for regression estimates of total, direct, and indirect effects from poverty at 5 months of age to children's mean levels of behavior problems from 3.5 to 5 years of age through mediators at 1.5 and 2.5 years of age.

Discussion

Grounded on the family stress model, we examined the associations between chronic poverty and children's high trajectories of physical aggression and hyperactivity during early childhood and tested weather family processes such as perceived parenting, family functioning or maternal depression symptoms mediated these associations. Our findings indicate that children exposed to chronic poverty are more likely to exhibit high levels of physical aggression and hyperactivity between 1.5 and 5 years than children not exposed, or children exposed to transient poverty. Only overprotection and maternal depression symptoms emerged as significant mediators of the association between poverty and children's high trajectories of behavior problems. Contrary to previous studies among older children, coercion and family dysfunction were not identified as mediators of the poverty-behavior problems link (Evans & Cassells, 2014; Shelleby et al., 2014).

The finding that maternal depression symptoms mediated the association between poverty and behavior problems is consistent with previous research linking parental mental health to children's behavior problems (Kim-Cohen et al., 2005). Also, experimental research suggests that clinical depression as well as less severe depressive symptoms are prevalent and particularly likely to persist beyond the postpartum period into the child's second and third year of life among low income mothers (Beeber et al., 2013).

Differentiated patterns of mediation were obtained for overprotection. Specifically, while overprotection mediated the association between poverty and both subtypes of behaviors problems, higher levels of overprotection were related to higher hyperactivity scores but unexpectedly, to lower physical aggression scores. Hence, the results suggest that overprotection is a mechanism through which poor families support children's capacity to inhibit physical aggression. However, overprotection is also a mechanism through which poor families may foster hyperactive behavior. The finding for physical aggression is consistent with previous work indicating that parental separation anxiety (more overprotective behavior) is associated with less physical aggression during early childhood (Casas et al., 2006). Yet, this overprotective behavior may lead to poor engagement and distractibility by disrupting the child, rather than facilitating, the infant's own self-initiated interest in the environment, and result in more hyperactive behavior (Morrell & Murray, 2003; Sarsour et al., 2011). Further investigation is needed to replicate the opposite indirect effects linking poverty, overprotection and subtypes of behavior problems.

Overall, our findings are consistent with prior research showing that poverty is associated with children's mental health both directly and indirectly through mediators such as maternal depression symptoms and perceived parenting (Conger, Conger, & Martin, 2010; Shelleby et al., 2014). Although indirect effects from poverty to both subtypes of behavior problems through overprotection and maternal depression symptoms were small, any observed association is potentially important in understanding how sustained deprivation during a sensitive period of life is associated with the early onset of psychopathology. The results of this study also provide additional evidence to the existing literature on the role of chronic poverty in the aetiology of behavior problems (Najman et al., 2010).

Strengths and limitations

This study includes several strengths. The first is the study's reliance on a high quality and large longitudinal data base of a representative birth cohort. A second strength relies on the repeated measures, collected at multiple points over the first 5 years of life, of poverty, parenting constructs and children's behavior problems. Repeated measures were particularly useful for the measurement of behavior problems for which the distinction between typical and atypical development is important during early childhood. Behavior problems were modeled using a semi-parametric trajectory approach, which allowed to distinguish children on an atypically elevated trajectory and as such, reduced measurement error in the classification of children as highly disruptive. Third, this data base provide the ability to control for several confounders described in the literature and to explore simultaneously several types of parental factors rarely considered in the literature. Finally, the detailed measures of behavior problems allowed the examination of two subtypes of behavior problems separately

Limitations should be considered regarding our results. First, associations in main mediation models may be bidirectional due (1) to the correlational design of the study and (2) to the lack of temporally ordered data. Reassuringly, complementary analysis showed that models respecting temporal ordering of variables replicated patterns of associations found in main mediation models. Second, the sole reliance on maternal ratings to assess children's behavior problems, maternal depression, family dysfunction and parenting constructs means that associations between these measures are likely inflated by shared method variance (Affrunti & Woodruff-Borden, 2015). Ideally, children's behavior problems should be assessed by multiple informants (e.g. parents and teachers). However, we focused on maternal ratings as mothers were systematically identified as the person being most knowledgeable about the child and because mothers could provide information across early childhood, which is not the case for teacher's ratings (available after age 5 years). Furthermore, our sample is a representative population-based cohort. Such samples generally have low base rates of clinically severe mental health problems, especially during early childhood. Also, because our objective was to model normal variations in behavior problems, clinical assessments are not appropriate in this population to study our research questions. Third, despite the fact that we used weighted data to correct for non-participation and non-response, lost to follow-up could underestimate the observed associations if attrition was dependent on both being poor and having high levels of behavior problems. Finally, mothers who did not speak French or English were not included in the study. Therefore, results cannot be inferred to children whose mothers were unable to communicate in either English or French.

Conclusions

Study findings indicate that poverty is a key risk factor for behavior problems and highlight the importance of family mediating factors. In this paper we identify two potential targets for intervention and prevention efforts at the family level: overprotection and maternal depression. Results add specificity to the family stress model at least through age 5 years. Our findings support antipoverty policies directed at reducing child poverty. Support may be at the family level in the form of service delivery such as child care and parental interventions or at societal level through public policy for the redistribution of wealth and the reduction of poverty in families with young children. For instance, studies on the same sample have shown that early and regular out of home child care services for mothers with low education (Geoffroy et al., 2010; Laurin et al., 2015) or depressed mothers (Herba et al., 2013) play a protective role in children's social development. These findings, together with experimental research showing a positive impact of financial benefits on children's behaviors problems (Duncan, Morris, & Rodrigues, 2011), suggests that relieving economic pressure among families with young children may offer the largest benefit in lowering children's risk for behavior problems.

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Table 1. Mean levels of physical aggression and hyperactivity by age from 1.5 to 5 years of age.

Age	Hyperactivity	Physical aggression
	Mean [95%CI]	Mean [95%CI]
1.5 years	4.00 [3.88; 4.12]	1.35 [1.28; 1.42]
2.5 years	3.98 [3.87; 4.09]	1.94 [1.86; 2.02]
3.5 years	4.25 [4.15; 4.35]	1.40 [1.33; 1.47]
4.5 years	3.93 [3.83; 4.03]	1.12 [1.06; 1.18]
5 years	3.98 [3.88; 4.08]	1.09 [1.03; 1.15]

Note. Behavior problems coded so that higher scores indicated higher levels of behavior problems (range 0 to 10 for hyperactivity and range 0 to 6 for physical aggression). Analyses were conducted on our study sample (n=1759).

Table 2. BIC statistics and the percentage of participants for models with 2, 3, and 4 trajectory groups

	Physical Aggression				
	BIC	Low (%)	Moderate (%)	High (%)	High-rising (%)
Model					
2-trajectory	-13419.05	45.28	54.72	-	-
3-trajectory	-13257.30	31.84	50.63	17.54	-
4-trajectory	-13245.14	8.81	30.22	44.82	16.14

	Hyperactivity				
	BIC	Low (%)	Moderate (%)	High (%)	High-rising (%)
Model					
2-trajectory	-20537.29	55.22	44.78	-	-
3-trajectory	-20216.69	31.86	53.99	14.15	-
4-trajectory	-20133.29	14.34	43.45	34.21	8.0

Note. The table presents a comparison between models with 2, 3, and 4 trajectory groups based on the 2045 participants with data available for behavior problems from 1.5 to 5 years of age.

Table 3. Characteristics summarizing 1759 participants present in the QLSCD at 5 years of age by exposure to chronic poverty.

Variables	Full sample	Poverty			
		Not chronic	Chronic		Sig.†
n, (%)					
		1286(73.0)	473(27.0)		<.001
Male sex	881(50.1)	629(71.4)	252(28.6)		.046
Separated or single parents	312(17.7)	113(36.2)	199(63.8)		<.001
No high school diploma	317(18.0)	137(43.2)	180(56.8)		<.001
Mean [95%CI]				Cohen' s *d*	
Maternal depression symptoms	1.43 [1.37; 1.50]	1.27 [1.20; 1.34]	1.88 [1.73; 2.01]	.043	<.001
Self-efficacy	8.29 [8.23; 8.34]	8.27 [8.21; 8.33]	8.33 [8.21 ; 8.45]	.005	.384
Parental impact	8.25 [8.17; 8.33]	8.49 [8.41; 8.57]	7.58 [7.39 ; 7.76]	.051	<.001
Coercive parenting	3.82 [3.72; 3.92]	3.82 [3.70; 3.94]	3.82 [3.62 ; 4.02]	.001	.827
Overprotection	4.40 [4.29; 4.50]	4.04 [3.93; 4.15]	5.37 [5.12; 5.61]	.059	<.001
Family dysfunction	1.34 [1.28; 1.41]	1.24 [1.17; 1.31]	1.63 [1.48 ; 1.78]	.029	<.001

Note. Poverty coded so 1=chronic and 0=otherwise. Maternal depression symptoms coded so that higher scores indicated at risk of depression or in need of treatment (range 0 to 10). Parenting constructs coded so that higher scores indicated higher levels of perceived parenting (range 0 to 10). Family dysfunction coded so that higher scores indicated higher levels of family conflict (range 0 to 10).

†P-value determined using X^2 test (categorical variables) or analysis of variance F-test (continuous variables).

Table 4. Logistic regression models of poverty predicting a child's membership in the high trajectory groups of physical aggression and hyperactivity.

	Physical aggression				Hyperactivity			
Poverty	OR	P-value	95%CI	Log-likelihood	OR	P-value	95%CI	Log-likelihood
Unadjusted model	1.56	<.001	1.40; 1.74	9626.2	2.25	<.001	2.02; 2.52	8617.6
Adjusted model	1.43	<.001	1.26; 1.62	9332.1	1.76	<.001	1.55; 2.00	8406.8

Note. Poverty coded so 1=chronic and 0=otherwise. Trajectories of behavior problems coded so 1=high group and 0=low/moderate groups. Adjusted models controlled for child's sex, low maternal education, and family structure. Analyses were conducted on our study sample (n=1759).

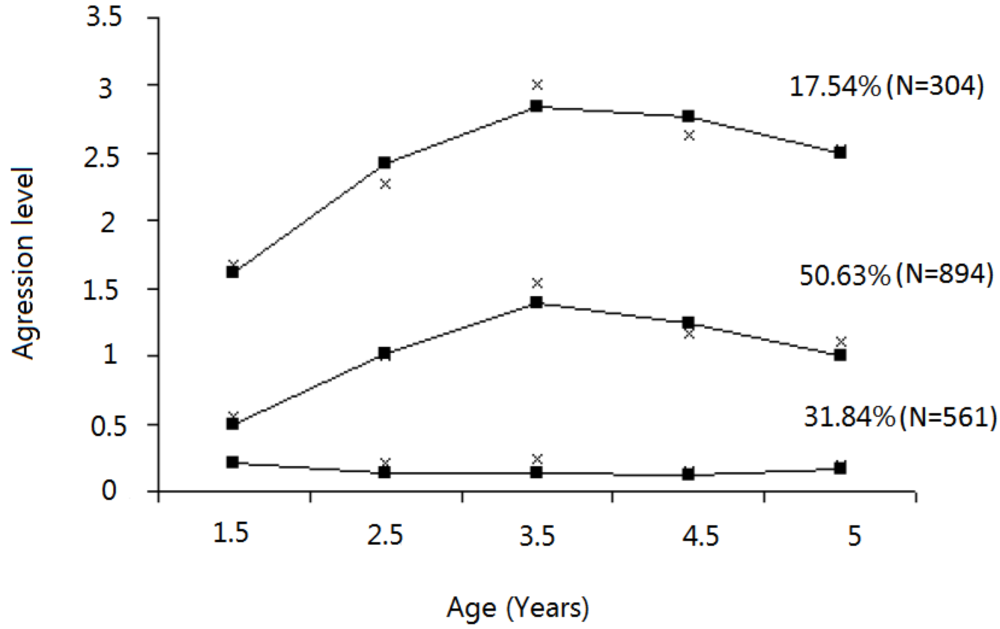
Table 5. Multiple logistic and linear regressions models for selecting potential mediators.

Variable	Poverty			Hyperactivity			Physical aggression		
	B	P-value	95%CI	OR	P-value	95%CI	OR	P-value	95%CI
1. Family dysfunction	0.39	< .001	0.33; 0.44	1.01	.592	0.97; 1.06	1.01	.652	0.97; 1.05
2. Self-efficacy	0.06	.020	0.01; 0.11	0.81	<.001	0.77; 0.85	0.88	<.001	0.84; 0.92
3. Parental impact	-0.91	< .001	-0.98; -0.84	0.98	.280	0.95; 1.02	0.94	<.001	0.91; 0.97
4. Coercive parenting	-0.01	.784	-0.10; 0.08	1.22	<.001	1.18; 1.25	1.16	<.001	1.13; 1.19
5. Overprotection	1.32	< .001	1.23; 1.41	1.17	<.001	1.14; 1.20	0.91	<.001	0.89; 0.94
6. Maternal depression symptoms	0.60	< .001	0.54; 0.66	1.10	<.001	1.05; 1.14	1.17	<.001	1.13; 1.22

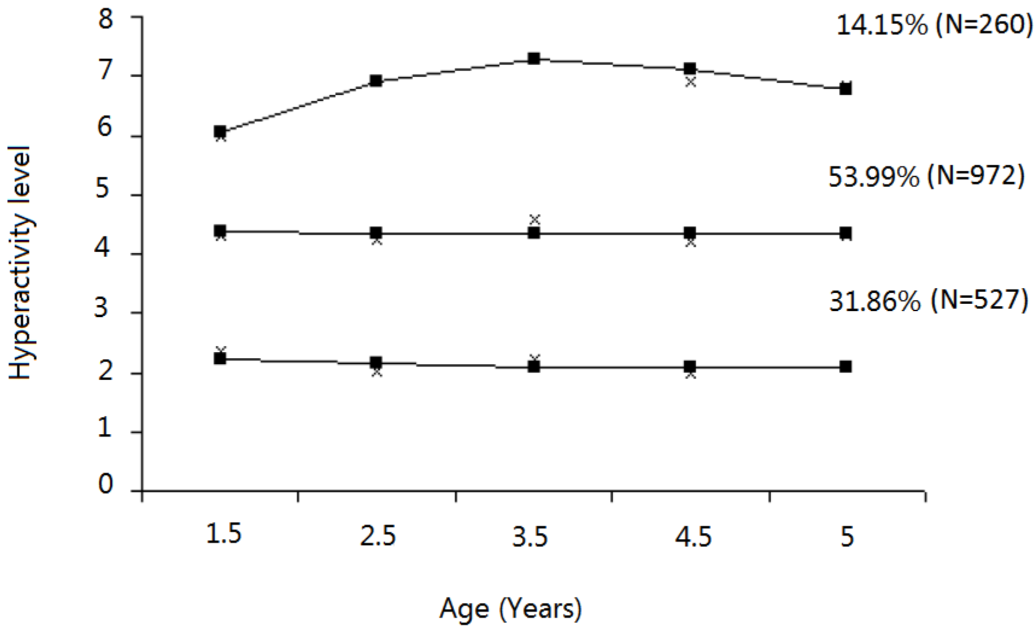
Note. Poverty coded so 1=chronic and 0=otherwise. Trajectories of behavior problems coded so 1=high group and 0=low/moderate groups. Maternal depression symptoms coded so that higher scores indicated at risk of depression or in need of treatment (range 0 to 10). Parenting constructs coded so that higher scores indicated higher levels of perceived parenting (range 0 to 10). Family dysfunction coded so that higher scores indicated higher levels of family conflict (range 0 to 10). Analyses were conducted on our study sample (n=1759).

Figure 1. Developmental trajectories of physical aggression (A) and hyperactivity (B) from 1.5 to 5 years of age.

(A)

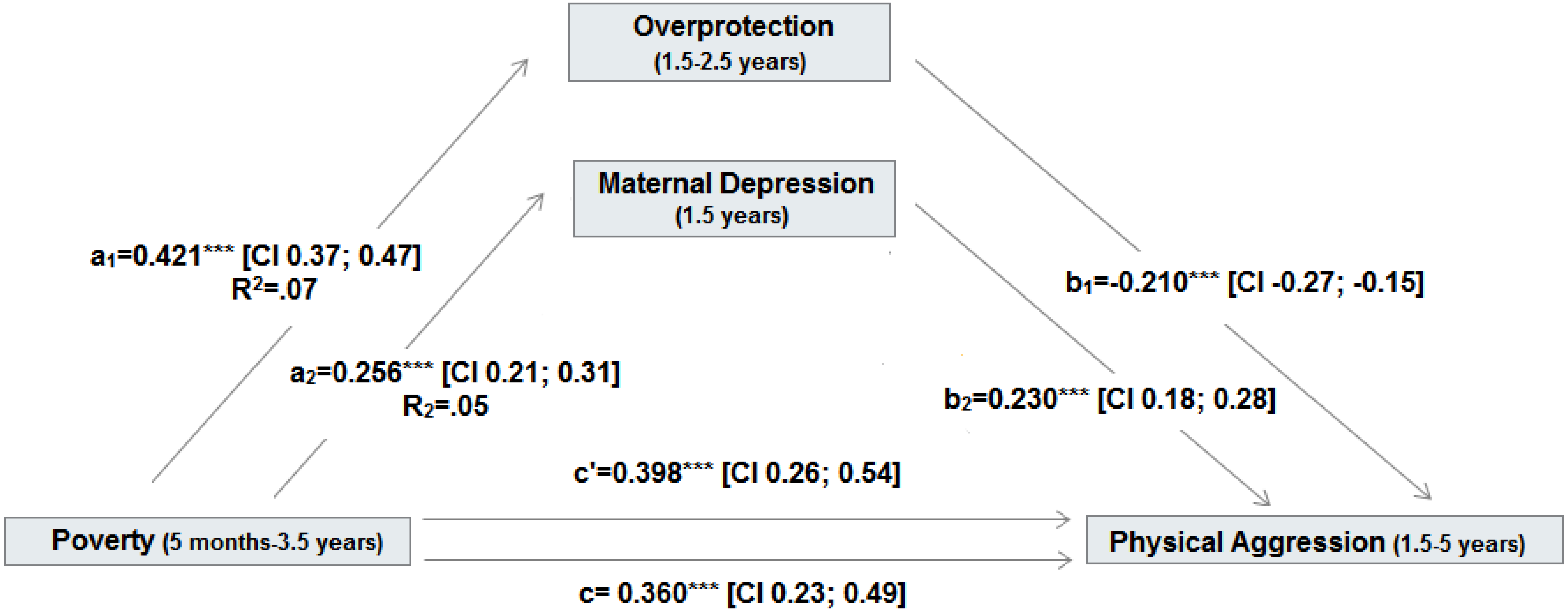


(B)



Note. ' ▪' is to the estimated value and 'x' is the average value based on the observations. The figure presents behavior problems trajectories based on analyses conducted on our study sample (n=1759).

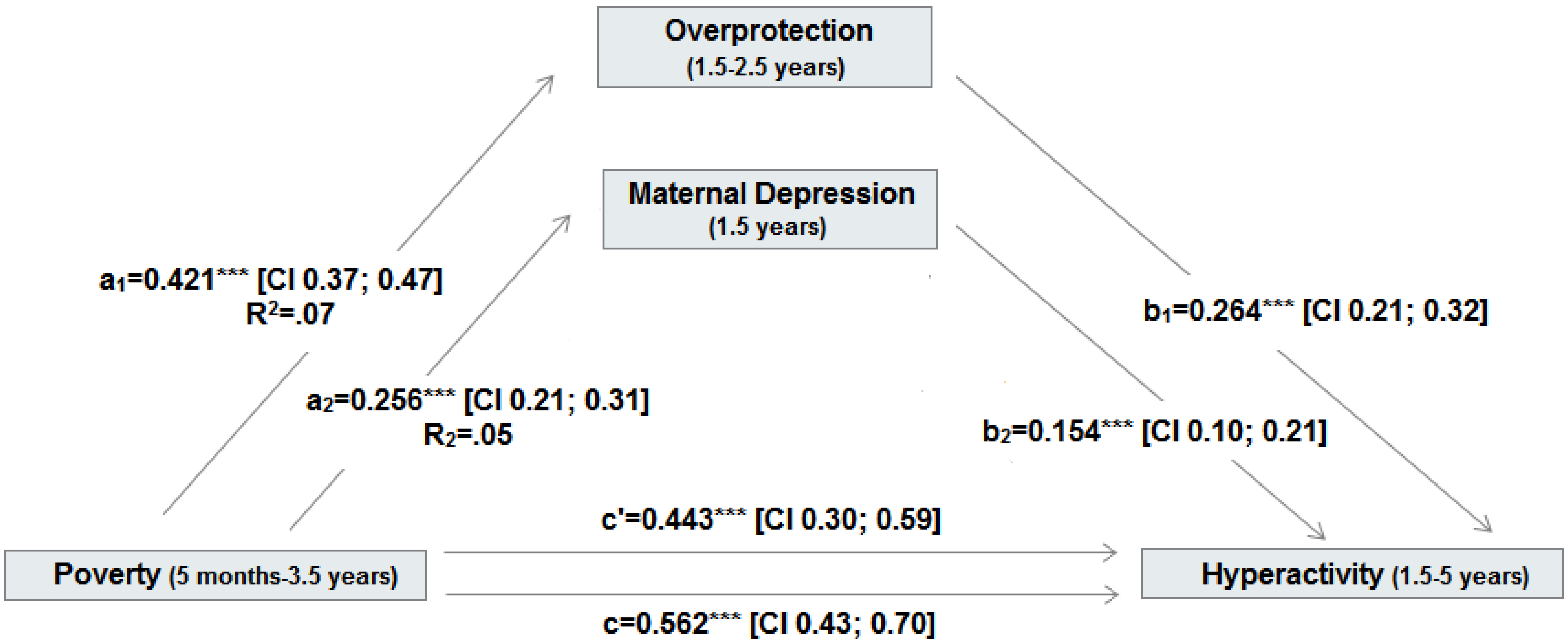
Figure 2. Overprotection and maternal depression symptoms as mediators of the association between poverty and children's high physical aggression trajectory.



Note. Path c=Total effect of poverty on physical aggression (Log-likelihood = 9005.5). Path c'=Direct effect of poverty on physical aggression adjusting for overprotection and maternal depression symptoms (Log-likelihood=8789.1). All models were adjusted for child's sex, low maternal education, and family structure. Analyses were conducted on our study sample (n=1759).

*p < .05. ** p < .01. *** p < .001.

Figure 3. Overprotection and maternal depression symptoms as mediators of the association between poverty and children's high hyperactivity trajectory.



Note. Path c=Total effect of poverty on hyperactivity (Log-likelihood = 8077.5). Path c'=Direct effect of poverty on hyperactivity adjusting for overprotection and maternal depression symptoms (Log-likelihood = 7826.2). All models were adjusted for child's sex, low maternal education, and family structure. Analyses were conducted on our study sample (n=1759).

*p < .05. ** p < .01. *** p < .001.

Appendix A: Supplementary material

Table S1. BIC statistics and intercept estimates for models with 2, 3, and 4 trajectory groups.

	Physical Aggression				
	BIC	Low	Moderate	High	High-rising
Model					
2-trajectory	-13419.05	-1.01	-2.01	-	-
3-trajectory	-13257.30	-1.35	-2.78	-0.26	-
4-trajectory	-13245.14	-8.73	-0.71	-3.00	-0.07

	Hyperactivity				
	BIC	Low	Moderate	High	High-rising
Model					
2-trajectory	-20537.29	2.69	4.75	-	-
3-trajectory	-20216.69	1.98	3.95	5.14	-
4-trajectory	-20133.29	1.28	3.25	4.99	4.38

Note. Analyses were conducted on the 2045 participants with data available for behavior problems.

Table S2. Items of family functioning, depression symptoms and perceived parenting.

Measurement	**Items**
Family functioning (7)	Individuals (in the family) are accepted for what they are. We express feelings to each other.(R) There are lots of bad feelings in our family. We feel accepted for what we are. (R) We are able to make decisions about how to solve problems.(R) We don't get along well together. We confide in each other. (R)
Depression symptoms (9)	I felt depressed. I felt that everything I did was an effort. I felt hopeful about the future. My sleep was restless. I was happy.(R) I felt lonely. I enjoyed life. I had crying spells. I felt that people disliked me.
Self-efficacy (7)	I feel that I am very good at keeping my baby amused. I feel that I am very good at calming my baby down when he/she is upset, fussy or crying. I feel that I am very good at keeping my baby busy while I am doing other things. I feel that I am very good at attracting the attention of my baby. I feel that I am very good at feeding my baby, changing his/her diapers, and giving him/her a bath. In general, do you think you are ‘a good mother/a good father’?

Parental impact (5)	My behavior has little effect on the personal development of my baby.(R) Regardless of what I do, my baby will develop on his/her own.(R) My behavior has little effect on the intellectual development of my baby.(R) My behavior has little effect on the development of emotions (for example, happiness, fear, anger) in my baby. (R) My behavior has little effect on how my baby will interact with others in the future. (R)
Coercion (7)	I have been angry with my baby when he/she was particularly fussy. When my baby cries, he/she gets on my nerves. I have raised my voice with or shouted at my baby when he/she was particularly fussy. I have spanked my baby when he/she was particularly fussy. I have lost my temper when my baby was particularly fussy. I have left my baby alone in his/her bedroom when he/she was particularly fussy. I have shaken my baby when he/she was particularly fussy.
Overprotection (5)	I insist upon keeping my baby close to me at all times, within my eyesight and in the same room as I am. I consider myself a 'real mother hen.' I prefer that my baby sleeps in the same room as me at night. When I leave my baby with a baby-sitter, I miss him/her so much that I cannot enjoy myself. I can never bring myself to leave my baby with a baby-sitter.

Note. (R) Reverse-coded.

Table S3. QLSCD remaining participants by behavior problems and poverty status from 5 months to 5 years of age (N=2120).

Age	Hyperactivity	Physical aggression	Poverty	
			Poor	Non-Poor
	n (Mean ±SD)	n (Mean ±SD)	n (%)	
5 months	-	-	511(24.1)	1571(74.1)
1.5 years	2045 (3.92 ± 2.40)	2045 (1.33 ± 1.53)	416(19.6)	1599(75.4)
2.5 years	1997 (3.91 ± 2.38)	1997 (1.88 ± 1.72)	398(17.4)	1598(75.4)
3.5 years	1948 (4.22 ± 2.15)	1949 (2.29 ± 2.26)	319(15.0)	1594(75.2)
4.5 years	1942 (3.88 ± 2.15)	1942 (1.82 ± 2.08)	-	-
5 years	1759 (3.99 ± 2.09)	1759 (1.77 ± 2.10)	298(14.1)	1438(67.8)

Note. N refers to the total participants in the QLSCD; n refers to the number of participants in the QLSCD depending on the data available at each time point. Behavior problems were not available at 0.5 months of age and coded so that higher scores indicated higher levels of behavior problems (range 0 to 10 for hyperactivity and range 0 to 6 for physical aggression). Poverty coded so 1= families lived at or below low income cut-offs and 0=otherwise. Poverty status was not available at 4.5 years of age because of changes in the data collection calendar. By the time data collection had started in 2002, low income cut-offs fixed yearly by Statistics Canada had not yet been released for the same year (Des Groseillers, Plante, & Courtemanche, 2000b).

Des Groseillers, L., Plante, N., &t Courtemanche, R. (2000b). Étude longitudinale du développement des enfants du Québec (ÉLDEQ). Transition E4-E5. Document de travail, Direction de la méthodologie et des enquêtes spéciales, Institut de la statistique du Québec.

Table S4. Correlation matrix between poverty, behavior problems, and potential mediators.

Variables	1	2	3	4	5	6	7	8	9
1. Physical aggression	1								
2. Hyperactivity	.228**	1							
3. Poverty	.079**	.142**	1						
4. Self-efficacy	-.104**	-.113**	.021	1					
5. Parental impact	-.053*	-.088**	-.242**	.163**	1				
6. Coercion	.149**	.150**	-.001	-.128**	-.095**	1			
7. Overprotection	-.058*	.114**	.266**	.061*	-.288**	-.066**	1		
8. Maternal depression	.119**	.121**	.193**	-.202**	-.173**	.180**	.185**	1	
9. Family dysfunction	.062*	.075**	.132**	-.261**	-.156**	.087**	.095**	.388**	1

Note. Poverty coded so 1=chronic and 0=otherwise. Trajectories of behavior problems coded so 1=high group and 0=low/moderate groups. Maternal depression symptoms coded so that higher scores indicated at risk of depression or in need of treatment (range 0 to 10). Parenting constructs coded so that higher scores indicated higher levels of perceived parenting (range 0 to 10). Family dysfunction coded so that higher scores indicated higher levels of family conflict (range 0 to 10). Analyses were conducted on our study sample (n=1759).

* $p < .01$. ** $p < .001$.

Table S5. Correlation matrix between behavior problems measurements at each time point from 1.5 to 5 years of age.

Variables	1	2	3	4	5	6	7	8	9	10
1. Hyperactivity 1.5 years	1									
2. Hyperactivity 2.5 years	.501**	1								
3. Hyperactivity 3.5 years	.395**	.576**	1							
4. Hyperactivity 4.5 years	.348**	.498**	.619**	1						
5. Hyperactivity 5 years	.358**	.493**	.604**	.644**	1					
6. Physical aggression 1.5 years	.270**	.172**	.196**	187**	.163**	1				
7. Physical aggression 2.5 years	.244**	.364**	.291**	.292**	.261**	.456**	1			
8. Physical aggression 3.5 years	.173**	.204**	.343**	.282**	.260**	.367**	.484**	1		
9. Physical aggression 4.5 years	.134**	.156**	.257**	.320**	.275**	.305**	.395**	.539**	1	
10. Physical aggression 5 years	.115**	.156**	.230**	.243**	.324**	.281**	.373**	.495**	.543**	1

Note. Behavior problems coded so that higher scores indicated higher levels of behavior problems (range 0 to 10 for hyperactivity and range 0 to 6 for physical aggression). Analyses were conducted on our study sample (n=1759).

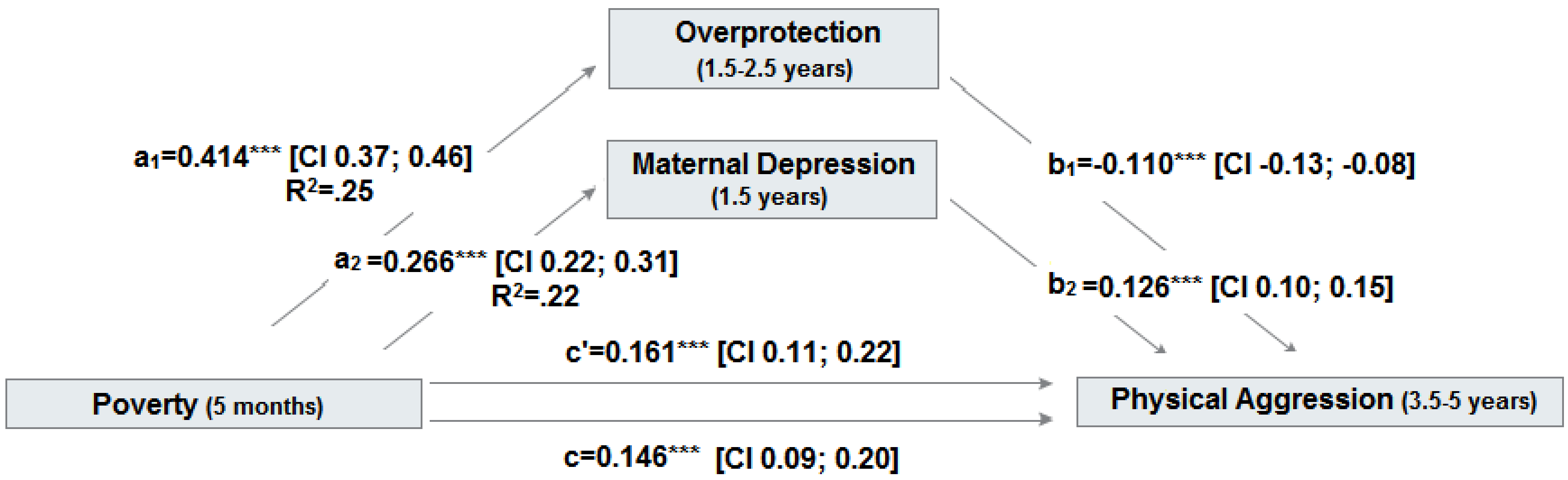
* p < .01. ** p < .001.

Table S6. Logistic regression models of transient and chronic poverty predicting a child's membership in the high trajectory groups of physical aggression and hyperactivity.

	Physical aggression			Hyperactivity		
	OR	P-value	95%CI	OR	P-value	95%CI
Never Poor	1			1		
Transient Poverty	1.54	<.001	1.31-1.82	1.03	.738	0.85-1.25
Chronic Poverty	1.74	<.001	1.52-1.99	1.77	<.001	1.54-2.04
Log-likelihood			9294.6			8396.3

Note: Transiently poor was coded so 1= living below the LICOs once and 0=otherwise. Chronically poor coded so 1= living below the LICOs 2-4 times and 0=otherwise. Models were adjusted for child's sex, low maternal education, and family structure. Analyses were conducted on our study sample (n=1759).

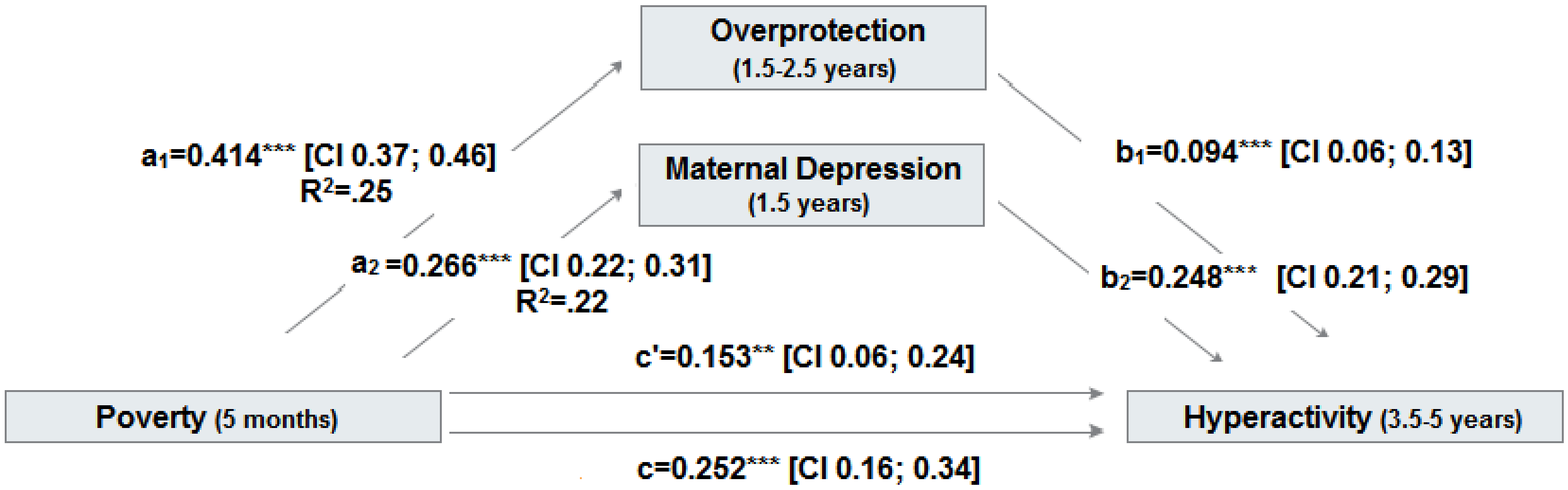
Figure S1. Overprotection and maternal depression symptoms (1.5-2.5 years) as mediators of the association between poverty (5 months) and mean levels of physical aggression (3.5 to 5 years).



Note. Path c=Total effect of poverty on physical aggression (R^2= .18); Path c'=Direct effect of poverty on physical aggression adjusting for mediators (R^2= .25). All models were adjusted for child's sex, low maternal education, and family structure. Analyses were conducted on our study sample (n=1759).

*p < .05. ** p < .01. *** p < .001.

Figure S2. Overprotection and maternal depression symptoms (1.5-2.5 years) as mediators of the association between poverty (5 months) and mean levels of mean levels of hyperactivity (3.5 to 5 years).



Note. Path c=Total effect of poverty on hyperactivity (R^2= .22); Path c'= Direct effect of poverty on hyperactivity adjusting for mediators (R^2= .31). All models were adjusted for child's sex, low maternal education, and family structure. Analyses were conducted on our study sample (n=1759).

*p < .05. ** p < .01. *** p < .001.

4.2. Article 2

Poverty and behavior problems trajectories from 1.5 to 8 years of age: Is the gap widening between poor and non-poor children?

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Competing interest None

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Abstract

Purpose Poverty has been associated with high levels of behavior problems across childhood, yet patterns of associations over time remain understudied. This study aims: a) To examine whether poverty predicts changes in behavior problems between 1.5 and 8 years of age; b) To estimate potential selection bias for the observed associations.

Methods We used the 1998-2006 waves of the Quebec Longitudinal Study of Child Development (N=2120). Main outcomes were maternal ratings of hyperactivity, opposition and physical aggression between 1.5 and 8 years of age. Linear mixed-effects models were used to assess the longitudinal association between poverty and behavior problems. Models were re-estimated adjusting for wave nonresponse and using multiple imputation to account for attrition.

Results Poverty predicted higher levels of behavior problems between 1.5 and 8 years of age. Poverty predicted hyperactivity and opposition in a time dependent manner. Hyperactivity ($B_{poverty*age}$= .052; CI 95% [.002; .101]) and opposition ($B_{poverty*age}$= .049; CI 95% [.018; .079]) increased at a faster rate up to age 5 years, and then decreased at a slower rate for poor than non-poor children. Physical aggression decreased at a steady rate over time for all children ($B_{poverty*age}$ = -.030; P=.064). Estimates remained similar when accounting for attrition.

Conclusion Poverty predicted higher levels of behavior problems between 1.5 and 8 years of age. The difference between poor and non-poor children was stable over time for physical aggression, but increased with age for hyperactivity and opposition. Attrition among poor children did not compromise the validity of results.

Keywords*:* Hyperactivity · Opposition · Physical aggression · Poverty · Attrition

Introduction

Poverty is a well establish risk factor for children's behavior problems [1]. This association is robust across several high-income countries with different health care and social policy contexts [2,3]. However, little is known about how early in life this association starts operating, leading to differences in behavior problems levels between poor and non-poor children, and whether these putative difference increases with age. A life course framework [4,5] to cumulative disadvantage posits that persistent adversity accumulates over time leading to increased heterogeneity in health trajectories with development [6,7]. Grounded on this framework, the present study examined whether poverty between 1.5 and 8 years of age is associated with developmental changes in three prevalent behavior problems during childhood [8,9]: hyperactivity, opposition, and physical aggression. Behavior problems are of concern because they may persist across development in the form of a wide range of adverse psychosocial outcomes [10,11].

Studies from The United States suggest that changes in family income predict changes in behavior problems from early-to-middle childhood (2-5 years and 4-14 years), particularly for poor and low income families [12-15]. Specifically, one study showed that differences in behavior problems (4-14 years) between high- and low income families increased over time [14]. Another study showed that the number of years living in poverty was associated with higher trajectories of behavior problems during those years between ages 5-9 years [15]. Similarly, studies from the United Kingdom suggest that associations between low income and behavior problems increased with age (3-7 years) [16,17]. A Norwegian study have also shown that income gains was associated with diminished behavior problems, especially for low income children from 1.5 to 3 years of age [18]. Studies were based on global measures of behavior problems capturing specific aggressive and delinquent behaviors. Overall, findings indicate that variations in family income, as well as the time spent in poverty are associated with changes in behavior problems over time.

Previous studies essentially focused on early or middle childhood (i.e. before and after age 5 years), but did not provide information about changes in behavior problems across developmental periods. Nor did they examine whether poverty predicts increasing disparities in behavior problems from early-to-middle childhood, as previous studies were mostly based on income gains. Another limitation of previous studies is that they were not based on annual measurements, which constrains the analysis of developmental change in behavior problems. Regular, annual assessments in the early years can provide valuable information on early onset of behavior problems and their patterns of change. Further, few studies have considered different subtypes of behavior problems in relation to poverty. Poverty heightens the risk of children's behavior problems, but whether this association is magnified with age across different subtypes remains unclear. It is important to distinguish subtypes of behavior problems because they have different developmental trajectories [19]. Finally, few studies, if any, have addressed selection bias regarding differential attrition affecting the poorest and children displaying high levels of behavior problems.

The present study addressed these issues using a birth cohort in which data was available between 1.5 and 8 years of age. There were two primary objectives to the study. First, we wanted to examine whether poverty predicts changes in behavior problems between 1.5 and 8 years of age. The goal was to extend previous research by estimating potential variations in the link between poverty and three subtypes of behavior problems. The distinct contribution of the study resides in examining whether the poverty gap that is initiated early and whether it is widening over time. We hypothesized that poverty would increase behavior problems with age. The second objective was to estimate potential selection bias on the association between poverty, behavior problems, and age. When testing for selection bias, we also hypothesized that predicted poverty estimates would be smaller due to retention of the healthier and wealthier participants in the study.

Methods

Data

We used the 1998-2006 waves of the Quebec Longitudinal Study of Child Development (QLSCD). Ethics approval was obtained from the Quebec Institute of Statistics and Sainte-Justine Hospital. The target population was singleton infants born in 1997-1998 and whose mothers reside in Quebec, Canada [20]. The initial sample comprised of 2120 children aged 3-8 months (mean age 5 months). Data were collected yearly until 2005 when the interview schedule shifted to a biennial design. Interviews were conducted by trained research assistants through home interviews and directed to the person most knowledgeable about the child (mothers in 98% of cases). Written informed consent was obtained from all respondents. We used seven assessments points in which information on maternal ratings of children's behavior problems were available. Assessments were conducted at: 1.5, 2.5, 3.5, 4.5, 5, 6 and 8 years. When children were 8 years of age, 1451 participants from the initial sample remained in the study (i.e. 69% of retention rate). Our analytic sample (N=2045) included study participants with at least one score for either behavior problems.

Attrition and non- participation

Attrition between baseline and follow-up at 4 years of age was low (8.8%). Attrition increased for assessments conducted at 5, 6 and 8 years of age (i.e. 17%, 29.6% and 29.4 %, respectively). Specifically, poor children, mothers who were not sufficiently fluent in either French and English, one-parent families, mothers who had less than a high school diploma, and mothers younger than 25 years of age were more likely to be lost to follow-up[20]. Table 1shows the distribution of behavior problems and poverty over sampling period and how sample declines with age. Table 2 shows the number of time participants missed a wave (i.e. wave nonresponse) from 1.5 to 8 years of age. Respondents were defined as participating if they completed all or part of the Interviewer Completed Computerized Questionnaire (ICCQ).

Measures

Outcome variables: hyperactivity, opposition and physical aggression

Mothers rated their child's behavior problems between 1.5 and 8 years of age using the early childhood behavior scale from the Canadian National Longitudinal Study of Children and Youth [21]. Mothers rated the frequency scale of their child's behavior problems, namely whether the child never (0), sometimes (1), or often (2) exhibited hyperactivity, physical aggression and opposition. Hyperactivity items were: 1) "cannot sit still", 2) "is restless or hyperactive", 3) "is impulsive, acts without thinking", 4) "has difficulty waiting his/her turn", and 5) "cannot settle down to do anything for more than a few moments". Higher scores indicated higher levels of hyperactivity (range 0 to 10). Cronbach's alphas ranged from 0.67 to 0.77 across assessments. Opposition items were: 1) "is defiant or refuses to comply with adults request or rules?", 2) "does not seem to feel guilty after misbehaving?", and 3) "punishment doesn't change his/her behavior?". Higher scores indicated higher levels of opposition (range 0 to 6). Alpha levels were ranged between 0.46 and 0.65 across assessments. Physical aggression items were: 1) "gets into fights?", 2) "physically attacks others", and 3) "hits, bites, kicks other children". Higher scores indicated higher levels of physical aggression (range 0 to 6). Alpha levels ranged between 0.63 and 0.76 across assessments.

Exposure to poverty

First, mothers reported their best estimate of the total income before taxes and deductions of all household members when the child aged between 1.5 to 8 years. Poverty was defined according to the Canadian Low Income Cut-Offs (LICOs) calculated by Statistic Canada. LICOs were available yearly in the QLSCD, with the exception of the 4.5 years of age assessment. The calculation is based on family income, the number of people in the household, and the level of urbanisation of the place of residence in the past 12-months [22]. A family was considered poor (i.e. household income below the LICOs) when attributing 20% or more of their household income than the average Canadian family to food, shelter, and clothing. For example, in 2012 LICOs were $ 30 250, $ 34 414, $ 37 610, and $ 43 942 (CAD) for a family of four living in rural areas, towns (< 30,000 inhabitants), towns between 30,000 and 99,999 inhabitants, or large cities (> 500,000 inhabitants) respectively [23]. Poverty status was coded as (1) when children lived in household whose income was below the LICOs and (0) otherwise.

Baseline and time-varying confounders

Baseline confounders included: (a) immigration status (1= immigrant mother; 0=otherwise); (b) maternal history of antisocial behavior assessed when children aged 5 months (range 0 to 5 and Mean = .82; SD = .94), where higher scores indicate higher levels of antisocial behavior (e.g. “Before the end of high school, did you more than once get into fights that you had started?”); and (c) child’s sex (1=boys and 50.2% of the sample; 0=girls).Time-varying confounders assessed seven times over sampling period included: (a) maternal education (1= mothers who did not complete high-school; 0=otherwise); (b) family structure (1=children whose parents were separated or single; 0=otherwise). These confounders were selected based on their reported association in the literature [24-26] as well as to their association with behavior problems and poverty in bivariate analyses. For a Directed Acyclic Graph (DAG) illustrating the hypothesized causal structure and underlying confounding bias of our research question, see Appendix (Figure S1).

Statistical analysis

We conducted two sets of analyses: (1) Testing whether poverty predicted changes in behavior problems between 1.5 and 8 years of age; and b) Estimating potential selection bias on the association between poverty, behavior problems, and age. Analyses were conducted with SPSS v.22.0. We used a threshold for significance at $P < .05$.

In the first set of analyses, we used linear mixed models (LMMs) with random intercept and trend (random effects models) to estimate individual growth curves for behavior problems over time in relation to poverty. Models are described using a two-level structure under which measurements were observations in time (Level 1) nested in children (Level 2). The following equation describes the simplest model (Model 1) using a random intercept and linear trend LMM where the quadratic age effect was considered in the fixed effects:

$$Y_{ij} = [\beta_0 + \beta_1\, t_{ij} + \beta_2\, t^2_{ij}] + [b_{0i} + b_{1i}\, t_{ij} + \varepsilon_{it}]$$

where the first bracket contains the fixed effects and the second bracket the random effects. Y_{ij} is the outcome variable for a child i at time j. Among the fixed effects, β_o, β_1 and β_2 are the population intercept, the linear trend and the quadratic trend. Among the random effects, b_{0i} and b_{1i} are the individual intercepts and trends, and ε_{ij} are the errors. Model 2 added the exposure variable and its interaction with age. Model 3 added baseline confounders. Model 4 introduced time-varying confounders. Finally, Model 5 represented the best fit and most parsimonious model built using the log-likelihood ratio test, employing a backward approach to retain variables below the threshold for significance. Table 3 presents full sequence of models. Further, simple t-tests were performed at each age to identify when age-related changes began to appear due to poverty and its interaction term with age.

In the second set of analyses, we estimated potential selection bias in a three-staged analysis: (1) re-estimating models accounting for the number times participants missed a wave (Table 2); (2) re-estimating models using Multiple Imputation (MI) [27,28]. The explanatory variables used in the imputation process are: behavior problems (1.5 to 8 years), poverty (1.5 to 8 years) and both baseline and time-varying confounders. The motivation behind this decision was that individual missing values is likely depend on observed data (i.e. missing at random, MAR). A total of 5 imputed datasets were produced. Finally, we restricted the analyses to a sub-sample of the cohort with complete data. Then, we compared coefficients across this three-staged analysis to those from the initial analysis. Variations in the poverty predictive estimates from these models were taken to analyse the nature and magnitude of selection bias.

Results

Table 4 displays the longitudinal associations between poverty and behavior problems. For all outcomes, results indicate that a quadratic trend with age best represented patterns of change between 1.5 and 8 years of age. Negative values indicate that behavior problems declined with age. However, the interpretation of the overall variation with age must take into account its linear and quadratic effects together. The same type of interpretation must be applied to poverty due to its interaction with age. Further, given that models relied on cross-sectional associations between poverty and behavior problems at each time point, the difference in the proportion of change between poor and non-poor children could not be estimated at age 4.5 years. Rather, it reflects individual differences in behavior problems between the ages of 1.5 to 4.5 years. Results are as follow:

Testing whether poverty predicts changes in behavior problems over time

For hyperactivity, a simple t-test indicated that initial levels at 1.5 years of age were significantly higher for poor than non-poor children (Δ= -.056 units; p=.034). Figure 1 illustrates the predicted average change for hyperactivity between 1.5 and 8 years of age. The main contribution of poverty to hyperactivity was time dependent. Models revealed that the gap between hyperactivity trajectories of poor and non-poor children widened over time at a rate of .052 units (see also Table 4). The linear and quadratic terms for age show that hyperactivity trajectories peaked at age 5 years and started declining afterwards with poverty producing greater divergence with age. Specifically, poor children exhibited an increase in hyperactive behavior at a faster rate until age 5 years and later showed slower declines than non-poor children. All confounders were retained in the final model.

For opposition, a simple t-test showed that initial levels at 1.5 years of age did not differ significantly between poor and non-poor children (Δ= -.012 units; p=.671). Figure 2 illustrates the predicted average change for opposition among poor and non-poor children between 1.5 and 8 years of age. As for hyperactivity, the main contribution of poverty to opposition was time dependent. Opposition trajectories peaked at age 5 years, and then declined, but with increased divergence as a function of poverty (i.e., rate of .049 units with age; see also Table 4). Compared to non-poor children, poor children exhibited an accelerated increase in oppositional behavior until age 5 years, and then a slower decline. All confounders were retained in the final model, with the exception of education.

For physical aggression, a simple t-test indicated that initial levels at 1.5 years of age were significantly higher for poor than non-poor children (Δ= -.097 units; p<.001). Figure 3 illustrates the predicted average change for physical aggression between 1.5 and 8 years of age. Compared to non-poor children, poor children showed higher levels of physical aggression by about .212 units (see also Table 4). This difference remained constant across age ($B_{Poverty*Age}$= -.030; P=.064). Hence, the decline with age in physical aggression was uniform regardless of poverty. All confounders were retained in the final model, with the exception of family structure and immigration.

Estimating selection bias on the behavior problems trajectories

Table 5 presents re-estimated LMMs accounting for wave nonresponse (Model 2), using MI (Model 3) and restricting analysis to a sub-sample with complete data (Model 4) to estimate potential selection bias in observed associations. Model 1 represent LMMs as presented in Table 4.

For hyperactivity, Models 1 to 3 were nearly identical but Model 4 showed slightly higher p-values. Specifically, Model 4 showed that the poverty interaction term was no longer significant, and revealed instead that the gap between trajectories was maintained with age. Changes in the interaction coefficient were consistently small in magnitude across all models.

For opposition, changes in poverty main contribution and its interaction coefficients remained similar in Models 1 to 3. Model 4 generated the lowest estimate for poverty main contribution and the highest coefficient for its interaction term. This suggests that when considering only a sub-sample with complete data, the gap between opposition trajectories widened at a faster rate for children exposed to poverty.

For physical aggression, Models 1 to 3 showed similar results. Model 4 generated the lowest estimate for poverty main contribution, suggesting that the gap between trajectories was narrower than in Models 1 to 3. This suggests that when considering only a sub-sample with complete data, the quadratic term for age disappeared from results in Model 4.

Overall, results from Models 1 to 3 comparing findings accounting for attrition were, by and large, similar for all outcomes. Therefore, wave nonresponse, as unit nonresponse is relatively unimportant to our findings. Further, poverty main contribution decreased across all outcomes when restricting analysis to a sub-sample with complete data. Indeed, results deviated substantially from Model 1 suggesting a less accurate model due to severe loss of observations. Particularly, poverty was no longer a significant predictor of hyperactivity trajectories. Results from Model 4 suggest that restricting analyses to a sub-sample with complete data without any adjustments to deal with missingness will lead to biased estimates due to attrition.

Discussion

The aim of the present study was to examine whether poverty predicted changes in hyperactivity, opposition and physical aggression between 1.5 and 8 years of age, and then examine the potential impact of selection bias on the pattern of results. Findings revealed that poverty predicted higher trajectories of behavior problems over time, and that patterns of poverty-age interactions differed according to subtypes of behavior problems. Specifically, children who remained poor at all seven years exhibited increasing levels of hyperactivity and opposition at a faster rate up to 5 years and decreasing levels at a slower rate afterwards. In contrast, physical aggression levels decrease overtime at a stable rate for both poor and non-poor children. Findings are consistent with prior research showing there is a general tendency for behavior problems to decrease or stabilize with age [29-31]. Further, selection bias did not appear to compromise the validity of results as estimates remained similar when accounting for attrition. Differences between hyperactivity/opposition and physical aggression trajectories and the effect of time of poverty point to the importance of distinguishing between different types of behavior problems in future studies.

The finding that the association between poverty and hyperactivity/opposition varied by age is consistent with previous studies on the association between economic deprivation and changes in behavior problems [13,15,31]. The results from the present study extend previous findings by showing that the gap in hyperactivity/opposition between poor and non-poor children increases from early-to-middle childhood. Thus, it seems that hyperactivity/opposition disparities between poor children and others increases over the length of time spent in poverty. Further, the acceleration of hyperactivity/opposition over time for persistently poor children not only mirrors what was suggested by a previous study, but now extends poverty-time association over a longer period.

Importantly, the gap in physical aggression trajectories between poor and non-poor children can be observed as early as age 1.5 years. However, the association between poverty and physical aggression, rather than increasing with age, remained constant from early-to-middle childhood. This could be due to the early and time-varying interplay of genetic and environmental factors [32-34]. Twin studies and other genetically-informed studies have shown the importance of Gene x Environment interactions in the aetiology of aggressive behavior [35]. Taken together, studies suggest that individual differences in physical aggression may be linked to genetic influence and moderated by prenatal and post-natal environmental risk. It is possible that children are born with biological susceptibilities to physical aggression, and that these susceptibilities develop as a function of environmental adversities, including poverty.

Selection bias is an important issue in poverty research because of nonrandom exclusion of the most disadvantaged participants due to lack of resources, illness and other factors that might influence attrition. We have considered a number of rival models to adjust for selection bias and found similar results in models accounting for attrition. For the majority of outcomes, estimates of the attrition-adjusted models were slightly smaller than corresponding estimates of non-adjusted models. Our results demonstrate that the gap between behavior problems trajectories linked to poverty disappear when restricting analyses to a sub-sample of children that were present at all assessments points in study. Thus, the gap between behavior problems trajectories linked to poverty disappear when restricting analyses to a sub-sample of children that were present at all assessments points in study. This suggests that excluding participants with incomplete data or those lost to follow-up may lead to an underestimation of the true growth in behavior problems linked to poverty.

Strengths and limitations

This study has several strengths, including high quality prospective data and repeated and robust measures of exposure to poverty using national thresholds (i.e. LICOs). To our knowledge, LICOs are the most widely accepted measure of economic deprivation in Canada [36]. Second, we used validated behavior problems scales assessed yearly during early childhood and starting as early as age 1.5 years. Third, we minimized selection bias by taking advantage of individuals with incomplete data with LMMs as our analytical approach. Fourth, the examination of three subtypes of behavior problems suggesting that poverty is an important and a common risk factor which is age-dependent only to certain behavior problems. However, the present study is not without limitations. Changes in sample demographics over the years may compromise the generalizability of our results. Mothers who did not speak French or English were excluded in the QLSCD and results cannot be inferred to any minority groups who cannot speak French or English. We relied only on maternal ratings of behavior problems. Ideally, children's behavior problems should be assessed by multiple informants (e.g. teacher and parent reports). The use of mother ratings is justified by her being the person who is the most knowledgeable about the child from early-to-middle childhood; teacher's ratings can only be used after age 5 years. Also, because our objective was to model normal variations of changes in behavior problems in a population-based sample, we could not rely on clinical ratings. Finally, although we were careful in controlling for confounders our capacity to make causal inferences is limited due to the correlational design of the study.

Conclusion

The current study supports that poverty is a key factor in differentiating behavior problems among poor and non-poor children from early-to-middle childhood. The difference between poor and non-poor children is stable over time for physical aggression, and it increases as children age for hyperactivity and opposition. Findings highlight that compared to hyperactivity and opposition, the poverty gap in physical aggression does not increase with age. Attrition overtime among the poor and those with higher levels of behavior problems should be addressed in future longitudinal studies when replicating our results

Policies directed at reducing child poverty will help decreasing the poverty gap in behavior problems at least through age 8 years. Such policies may be particularly important in the current economic context given that 2008 crisis and the global recession have harmed children's health, and disproportionately affected the most disadvantaged groups [37]. Policies may be in the form of financial benefits to increase family income or in the form of service delivery including child care and parental interventions [38-40].

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Table 1 Distribution of behavior problems and poverty from baseline to 8 years of age

Age	Hyperactivity	Physical aggression	Opposition	Poverty	
				Poor	Non-Poor
	N (Mean±SD)	N (Mean±SD)	N (Mean±SD)	N (%)	N (%)
0.5	-	-	-	511(24.1)	1571(74.1)
1.5	2045(3.92±2.40)	2045 (1.33±1.53)	2045(3.41±2.14)	416(19.6)	1599(75.4)
2.5	1997(3.91±2.38)	1997 (1.88±1.72)	1997(3.60±2.29)	398(17.4)	1598(75.4)
3.5	1948(4.22±2.15)	1949 (2.29±2.26)	1950(3.88±2.29)	319(15.0)	1594(75.2)
4.5	1942(3.88±2.15)	1942 (1.82±2.08)	1942(3.58±2.15)	-	-
5	1759(3.99±2.09)	1759 (1.77±2.10)	1759(3.50±2.11)	298(14.1)	1438(67.8)
6	1492(3.79±2.20)	1492 (1.63±2.05)	1492(3.47±2.00)	245(11.6)	1235(58.3)
8	1450(3.18±2.25)	1267 (1.53±2.08)	1450(3.03±2.08)	218(10.3)	1220(84.8)

Note. Behavior problems were not available at 0.5 years of age. Poverty status was not available at 4.5 years of age.

Table 2 Frequency of participants according to the number of wave nonresponse in the QLSCD from 1.5 to 8 years of age

Number of times participants missed a wave	N(%)
0	1287 (60.7)
1	280 (13.2)
2	251 (11.8)
3	132 (6.2)
4	42 (2.0)
5	20 (0.9)
6	45 (2.1)
7	63 (3.0)

Table 3 Sequence of models summary

Model	Variables
1 (Time effects)	Age + Age^2
2 (Exposure)	Model 1 + Poverty + Poverty*Age
3 (Baseline confounders)	Model 2 + Immigration status + Maternal antisocial behavior + Child's sex
4(Time-varying confounders)	Model 3 + Maternal education + Family structure
5(Best fit and most parsimonious)	Model 4

Table 4 Longitudinal associations of poverty predicting behavior problems between 1.5 and 8 years of age

	Hyperactivity			Opposition			Physical agression		
	Coef.	P-Value	95% CI	Coef.	P-Value	95% CI	Coef.	P-Value	95% CI
Fixed effects									
Intercept	2.97	<.001	2.77, 3.17	1.47	<.001	1.35, 1.59	1.25	<.001	1.12, 1.38
Age	.316	<.001	.246, .387	.288	<.001	.242, .335	-.055	.025	-.103, -.007
Age^2	-.046	<.001	-.054, -.039	-.038	<.001	-.042, -.033	-.006	.016	-.011, -.001
Poverty	.002	.986	-.236, .241	-.149	.047	-.297, -.002	.212	<.001	.127, .298
Poverty*age	.052	.042	.002, .101	.049	.002	.018, .079	-	-	-
Child' s sex	.638	<.001	.493, .783	.152	<.001	.072, .231	.418	<.001	.333, .502
Immigration status	-.423	.001	-.672, -.175	-.320	<.001	-.459, -.182	-	-	-
Antisocial behavior	.186	<.001	.107, .265	.122	<.001	.080, .166	.087	<.001	.040, .133
Education	.149	.012	.033, .264	-	-	-	.160	<.001	.087, .234
Family structure	.253	.001	.108, .399	.133	.003	.045, .221	.101	.028	.011, .191
Random effects									
Residual variance	2.23	<.001	2.15, 2.31	1.04	<.001	1.01, 1.08	1.15	<.001	1.11, 1.19
Intercept variance	3.87	<.001	3.50, 4.28	.969	<.001	.850, .1.11	1.65	<.001	1.48, 1.83
Covariance(b_{0i}, b_{1i})	-.381	<.001	-.443, -.319	-.090	<.001	-.112, -.069	-.162	<.001	-.189, -.136
Trend variance	.086	<.001	.074, .099	.022	<.001	.018, .027	.024	<.001	.020, .030
-2 log likelihood		41262.45			32754.65			33669.22	

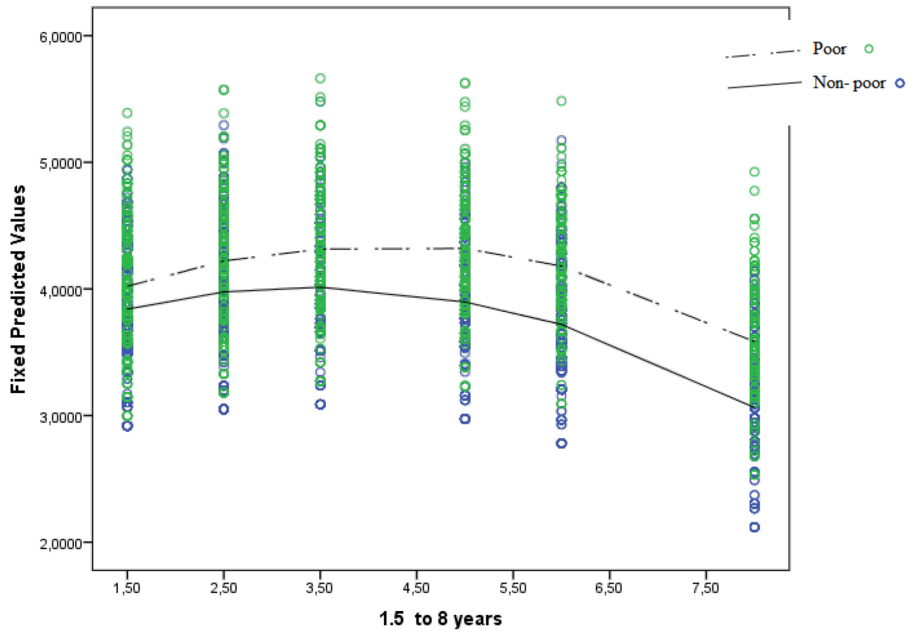
Note. Best fit and most parsimonious model (Model 5 in Table 3); N=2045 participants and N2=14840 observations.

Table 5 Estimating selection bias in longitudinal associations between behavior problems and poverty between 1.5 and 8 years of age

	Model 1		Model 2		Model 3		Model 4	
	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value
Hyperactivity								
Intercept	2.97	<.001	3.01	<.001	3.18	<.001	2.95	<.001
Age	.316	<.001	.314	<.001	.260	<.001	.307	<.001
Age^2	-.046	<.001	-.046	<.001	-.015	<.001	-.045	<.001
Poverty	.002	.986	.016	.894	.015	.900	-.051	.739
Poverty*Age	.052	.042	.049	.050	.052	.054	.052	.085
-2 log likelihood	41262.45		41265.00		-		29832.63	
Opposition								
Intercept	1.47	<.001	1.50	<.001	1.54	<.001	1.50	<.001
Age	.288	<.001	.285	<.001	.260	<.001	.281	<.001
Age^2	-.038	<.001	-.037	<.001	-.032	<.001	-.037	<.001
Poverty	-.149	.047	-.134	.074	-.121	.073	-.223	.019
Poverty*Age	.049	.002	.047	.003	.042	.004	.061	.001
-2 log likelihood	32754.65		32754.94		-	-	23668.75	
Physical agression								
Intercept	1.25	<.001	1.27	<.001	1.44	<.001	1.30	<.001
Age	-.055	.025	-0.57	.021	-.123	<.001	-.065	.021
Age^2	-.006	.016	-.006	.016	.005	.057	-.005	.092
Poverty	.212	<.001	.217	<.001	.194	<.001	.148	.005
-2 log likelihood	33669.22		33673.47		-		24325.69	

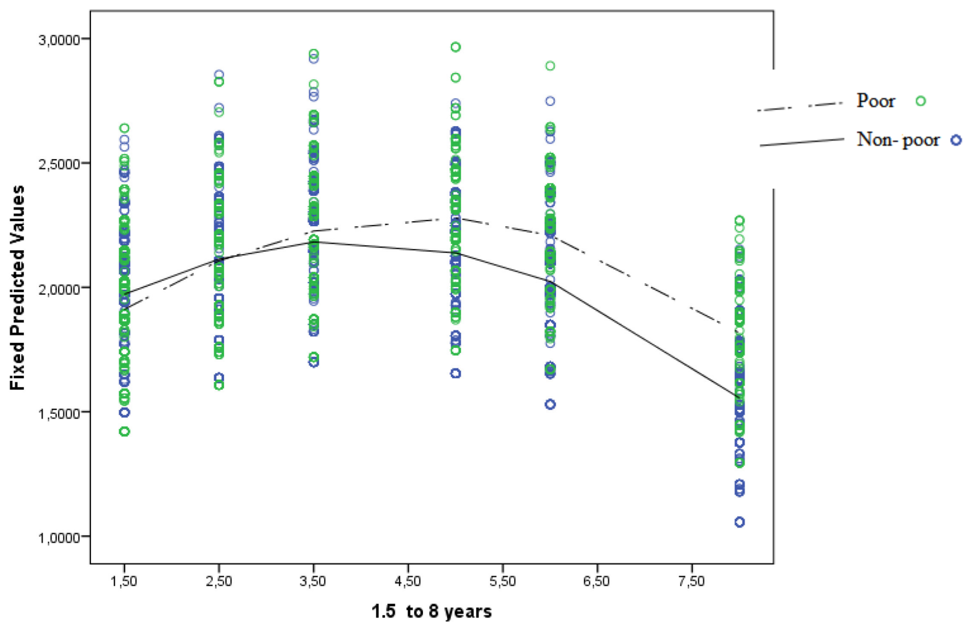
Note. Models are as follow: Model 1: Best fit model as provided in Table 4; Model 2: Model accounting for the number of wave nonresponse; Model 3: Model using imputed data. The -2 log likelihood was not available for MI with SPSS; and Model 4: Model using a sub-sample with complete data (N=1287 and N2=9009 observations).

Fig1. Hyperactivity average trajectories based on random intercept and random trend models for poor and non-poor children between 1.5 and 8 years of age



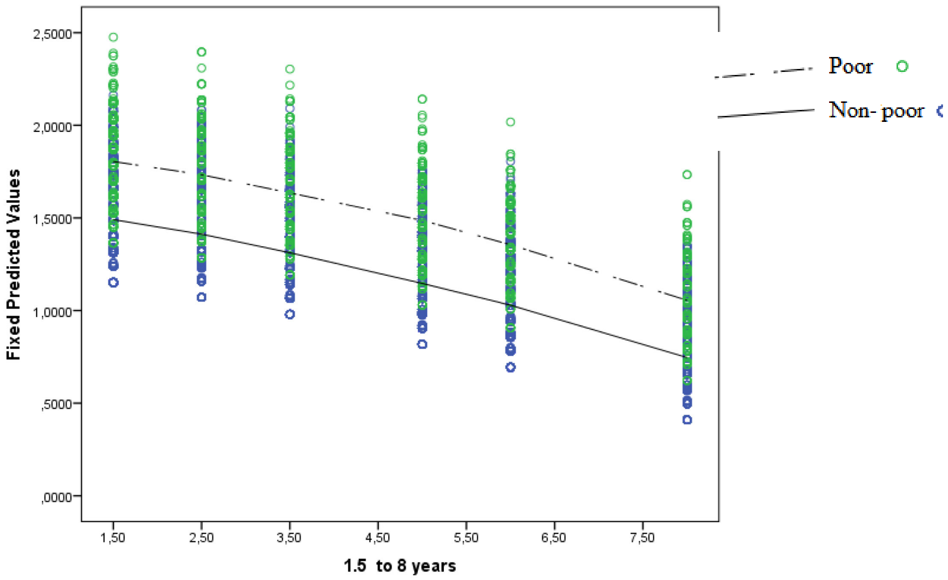
Note. Dots represent individual values.

Fig2. Opposition average trajectories based on random intercept and random trend models for poor and non-poor children between 1.5 and 8 years of age



Note. Dots represent individual values.

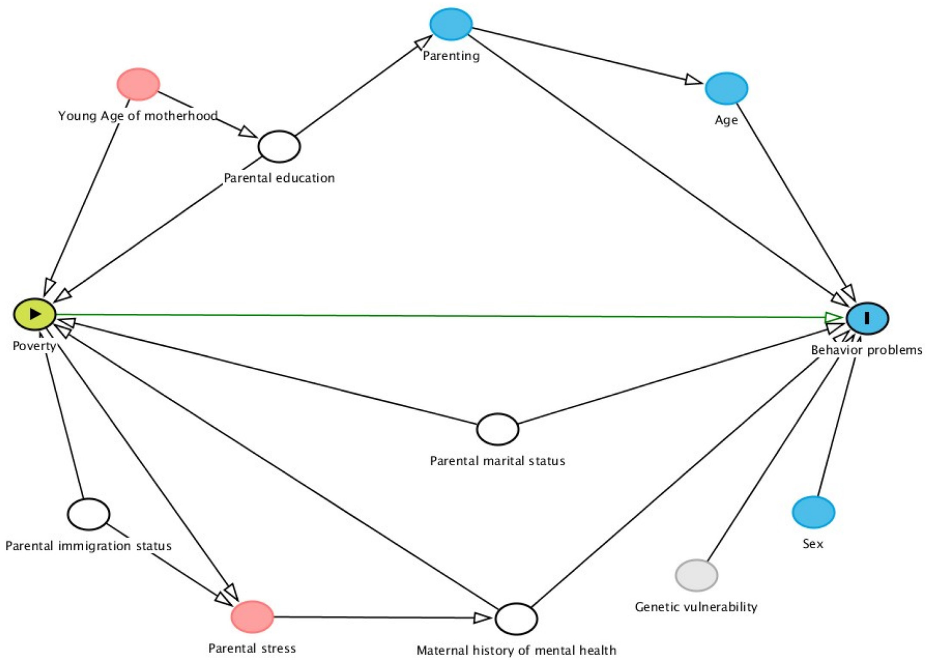
Fig3. Physical aggression average trajectories based on random intercept and random trend models for poor and non-poor children between 1.5 and 8 years of age



Note. Dots represent individual values.

Appendix A: Supplementary materials

Figure S1 DAG illustrating the hypothesized causal structure underlying confounding bias in the association between poverty and behavior problems



Using DAGitty 2.2 [1] , we show that the exposure of interest (i.e. poverty) directly influences the outcome (i.e. behavior problems). Additionally, the outcome is associated with an unmeasured factor, U (i.e. genetic vulnerability). Confounders are represented by factors that influence two or more variables shown in the DAG (i.e. common causes). We represent adjustment in the diagram by the labeling which in turn resulted in closed biasing paths from exposure to the outcome. Otherwise, open biasing paths would be represented by diagram arrows in red. Open causal paths are represented by the diagram arrow in green. See the legend below for a full description of variables and arrows statuses in DAGgitty 2.2:

Variables and arrows	Legend
	Exposure
	Outcome
	Ancestor of exposure
	Ancestor of outcome
	Ancestor of exposure *and* outcome
	Adjusted variable
	Unobserved (latent)
	Other variable
	Causal path
	Biasing path

We considered only minimal adjustments sets to block the biasing paths from poverty to behavior problems. For an introduction to DAGs, we refer readers to Glymour MM, Greenland S. Chapter 12: Causal diagrams. In: Rothman KJ, Greenland S, Lash TL. Modern epidemiology. Lippincott Williams & Wilkins; 2008:183–209.

We do not suggest that this DAG is the only possibility. However, we assume that the DAG reflects a putative causal association between poverty and behavior problems. The DAG shows that poverty directly influences behavior problems.

References

[1] Textor J, Hardt J, Knüppel S (2011) DAGitty: a graphical tool for analyzing causal diagrams. Epidemiology 22(5): 745

4.3. Article 3

Early adolescence behavior problems and timing of poverty during childhood: A comparison of lifecourse models

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Abstract

Context: Poverty is a well-established risk factor for the development of behavior problems, yet little is known about how timing of exposure to childhood poverty relates to behavior problems in early adolescence. **Objective**: To examine the differential effects of the timing of poverty between birth and late childhood on behavior problems in early adolescence by modeling lifecourse models, corresponding to sensitive periods, accumulation of risk and social mobility models. **Methods:** We used the Quebec Longitudinal Study of Child Development (N=2120). Poverty was defined as living below the low-income thresholds defined by Statistics Canada and grouped into three time periods: between ages 0-3 years, 5-7 years, and 8-12 years. Main outcomes were teacher's report of hyperactivity, opposition and physical aggression at age 13 years. Structured linear regression analyses were conducted to estimate the contribution of poverty during the three selected time periods to behavior problems. Partial F-tests were used to compare nested lifecourse models to a full saturated model (all poverty main effects and possible interactions). **Results:** Families who experienced poverty at all time periods were 9.3% of the original sample. Those who were poor at least one time period were 39.2%. The accumulation of risk model was the best fitting model for hyperactivity and opposition. The risk for physical aggression problems was associated only to poverty between 0-3 years supporting the sensitive period. **Conclusion**: Early and prolonged exposure to childhood poverty predicted higher levels of behavior problems in early adolescence. Antipoverty policies targeting the first years of life and long term support to pregnant women living in poverty are likely to reduce behavior problems in early adolescence.

Keywords: Poverty; Hyperactivity; Physical aggression; Opposition; Lifecourse

1. Introduction

Poverty has been associated to behavior problems during childhood and adolescence in many regions of the developed world, including North America and Europe (Russell, Ford, Rosenberg, & Kelly, 2014; Shaw, Lacourse, & Nagin, 2005). However, it remains unclear whether behavior problems in adolescence are more likely because of exposure to poverty during certain periods of childhood, or whether it is a matter of prolonged exposure over the years. This study is grounded in the lifecourse framework (Lynch & Smith, 2005) which describes how exposure to adversity throughout the lifecycle relates to disease risk later in life. Several lifecourse models have been proposed (Kuh et al., 2003; Hallqvist et al., 2004) and correspond to: (1) the sensitive period model describing a time period when exposure has a stronger effect on disease risk than it would at another times; (2) the accumulation of risk model asserting that exposure accumulates overtime increasing disease risk; and (3) the social mobility model proposing that instability in exposure overtime leads to disease occurrence. The current paper examined the timing and duration of childhood poverty in association with three subtypes of behavior problems that are prevalent in adolescence (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015): hyperactivity, opposition, and physical aggression.

1.1 Poverty and behavior problems: A lifecourse approach

Numerous studies have addressed lifecourse poverty in relation to behavior problems across development using a variety of research methods. There is evidence that the adverse prenatal environment and earliest years of life constitute a sensitive period for the development of later-life behavior problems (Côté, Vaillancourt, LeBlanc, Nagin, & Tremblay, 2006; Pingault et al., 2013). Other studies support the accumulation of risk model which states that poverty and low income effects accumulate in childhood and lead to behavior problems in adolescence (McLaughlin et al., 2011; Rekker et al., 2015). However, there is little evidence simultaneously examining different lifecourse models of adversity relative to behavior problems. Of the few studies which have examined these models, the evidence is mixed. An Australian study showed that exposure to maternal depression was more important at age 2 years than exposure later in life or time spent in poverty in explaining aggressive and delinquent problems at age 9.5 years (Giles et al., 2011). Despite the fact that this study did not consider poverty as its measure of adversity (but rather maternal depression), it demonstrated early childhood (i.e. before age 5 years) as a sensitive period of adversity for behavior problems while considering other lifecourse processes such as accumulation of risk and social mobility. This study is particularly interesting as it reported results using a model-building framework to test for several competing lifecourse models (Mishra et al., 2009). One study from the United States showed that low income during middle childhood (6-12 years) was associated with behavior problems beyond the effect of low income during early childhood (0-5 years), thus providing evidence of accumulation of risk for behavior problems which in turn in was better quantified by middle childhood adversity (Tsal, Shalev, & Mevorach, 2005). In this study, timing of exposure to poverty was isolated using accumulation of inputs modeling to test for poverty effects in two distinct points (i.e. early and middle childhood) on behavior problems.

Limitations of these studies should be noted. First, studies yield conflicting results and are limited in terms of comparability due to differences in the analytical strategy used to address lifecourse models. Nor can they be compared in terms of variability in behavioral outcomes and the age distribution of children. Another concern is variation in social policies across high-income countries for which research is available. Second, studies do not rely on annual or biannual measurements of poverty during early and middle childhood years. Repeated and annual measurements allow for the careful control of the timing of exposure to poverty when considering an effect-modification hypothesis, as is required in a lifecourse framework. Finally, few studies have separately examined different subtypes of behavior problems in adolescence (Leis, Heron, Stuart, & Mendelson, 2013; Nomura, Rajendran, Brooks-Gunn, & Newcorn, 2008). It is important to establish whether lifecourse models of poverty holds across different types of behavior problems or if they are specific to certain subtypes because they have different developmental trajectories and require specific corrective interventions (Tremblay, 2010). Thus, it remains unclear whether the association between childhood poverty and behavior problems in adolescence vary in strength across different periods of time.

1.2. Objectives of the present study

Objectives of the present study were: (1) to model lifecourse models of poverty (0 to 12 years) corresponding to sensitive periods, accumulation of risk, and mobility models to predict hyperactivity, physical aggression and opposition at 13 years (2) to identify the lifecourse model that best describes the poverty-behavior problem link. We apply a structured modelling approach (Mishra et al., 2009) as a model-building framework. Based on this approach, nested lifecourse models of poverty in relation to behavior problems are contrasted to a saturated model, an all-inclusive model with as many poverty parameters as there are possible sequences of exposure, to assess which model is most consistent with the data. We hypothesized that prolonged exposure to childhood poverty and possibly exposure during sensitive periods, such as the early childhood (i.e. before age 5 years), would increase behavior problems in early adolescence. We also hypothesized that the identification of lifecourse models would differ across subtypes of behavior problems due to variations of behavior problems trajectories overtime. In addition, the distinct contribution of the study resides in examining the role of timing and duration as well as intermittent exposure to childhood poverty underlying the development of behavior problems in early adolescence.

2. Methodology

2.1. Data

Data originated from the Quebec Longitudinal Study of Child Development (QLSCD) collected between 1998 and 2011. The target population was children born in 1997-1998 and whose mothers resided in Quebec, Canada (Jetté & Groseilliers, 2000). The initial sample comprised of 2120 children aged 3-8 months (mean age 5 months). Data were collected yearly until 2006 when the interview schedule shifted to a biennial design. Interviews were conducted by trained research assistants through home interviews and directed to the person most knowledgeable about the child (mothers in 98% of cases). Written informed consent was obtained from all respondents. We used 12 assessments points at ages: 5 months, 1½, 2½, 3½, 4½, 5, 6, 7, 8, 10, 12, and 13 years. When participants were 13 years of age, 1290 participants from the initial sample remained in the study (i.e. 60.8% retention rate), of which a total of 983 had nonmissing values on at least one of the three subtypes of behavior problems. The characteristics of the QSLCD sample present at 13 years of age and sub-sample with missing data are presented in the Appendix (see **Table S1**).

2.2. Attrition and Non- participation

QLSCD retention rate was high until children aged 4.5 years (92%) with attrition increasing afterwards. By age 13, attrition was nearly 40%. The highest attrition rates were observed for respondents living in poverty, with a high school diploma or less, as well as being in single-parent and immigrant families. Specifically, the proportion of participants exposed to poverty at 5 months of age was 24.1% but only 11.9% using the active or complete case sample at age 13 years, which in turn indicates differential study attrition. **Table 1** presents remaining participants in the QLSCD over sampling period by exposure to poverty.

2.3. Measures

Behavior problems. Teachers rated participants' behavior problems at 13 years of age using the early childhood behavior scale from the Canadian National Longitudinal Study of Children and Youth (Human Resources Development Canada and Statistics Canada, 1996). Teachers rated behavior problems on a frequency scale of whether the participant never (0), sometimes (1), or often (2) exhibited hyperactivity, physical aggression and opposition behavior. For hyperactivity (Cronbach's α =0.87), items used were: 1) "cannot sit still, is restless", 2) "is impulsive, acts without thinking", 3) "has difficulty waiting his/her turn", and 4) "cannot settle down to do anything for more than a few moments". For opposition (Cronbach's α=0.85), items used were: 1) "is defiant or refuses to comply with adults' request or rules?", 2) "does not seem to feel guilty after misbehaving?", and 3) "punishment doesn't change his/her behavior?". For physical aggression (Cronbach's α=0.84), items were as follow: 1) "gets into fights?", 2) "physically attacks others", and 3) "hits, bites, kicks other children". For all behavior measures, higher scores indicated higher levels of behavior problems (range 0 to 10).

Poverty. Poverty was defined according to the Canadian Low Income Cut-Offs (LICOs) calculated by Statistic Canada. The calculation is based on family income, the number of people in the household, and the level of urbanisation of the place of residence in the past 12-months (Giles, 2004). A family was considered to be poor when attributing 20% or more of their household income than the average Canadian family to food, shelter, and clothing. For instance, in 2013 LICOs were \$ 24 934, \$ 28 537, \$ 31 835, \$ 32 236 and \$ 38 117 (CAD) for a family of four living after taxes in rural areas, towns (< 30,000 inhabitants), towns between 30,000 and 99,999 inhabitants, cities between 100,000 and 499,999 inhabitants, and large cities (> 500,000 inhabitants) respectively (Statistics Canada, 2013). In this study, exposure to poverty was grouped into three time periods: a) exposure between ages 0-3 years (P1 and coded 1=yes; 0=otherwise); b) exposure between ages 5-7 years (P2 and coded 1=yes; 0=otherwise); and c) exposure between ages 8-12 years (P3 and coded 1=yes; 0=otherwise).

Child and family confounders. Confounders assessed at baseline included: (a) immigration status (1=immigrant mother and 8.4% of the sample; 0=otherwise); (b) maternal history of antisocial behavior in which higher scores indicate higher levels of antisocial behavior before the end of high school (range 0 to 5 and Mean = .82; SD = .94; e.g. “Before the end of high school, did you more than once get into fights that you had started?”) ; and (c) child’s sex (1=boys and 46.7% of the sample; 0=girls). For confounders measured at multiple time points, we used low maternal education and whether both biological parents were living with the child at ages 0, 3, and 8 years. Low maternal education indicated if mothers did not complete high-school a (1=yes and 44.4% of the sample at age 5 months, 40.2% at age 3, and 24.7% at age 8; 0=no). Children whose biological parents were separated or single were coded as 1 (8.4% at age 5 months, 13.2% at age 3 years, and 19.2% at age 8 years) vs children living with both their biological parents regardless of their marital status coded as

0.Confounders were selected according to their reported association in the literature (Essex et al., 2006; Kim-Cohen, Moffitt, Taylor, Pawlby, & Caspi, 2005; Tremblay et al., 2004) or to their association with behavior problems and poverty in bivariate analyses.

2.4. Analytic Design

We conducted two sets of analyses: (1) Modeling competing lifecourse models of the association between childhood poverty across three time periods (i.e. P1, P2 and P3) and behavior problems at 13 years of age; and (2) Selecting the lifecourse model that best described the association between childhood poverty and behavior problems in early adolescence. Analyses were conducted with SPSS v.22.0 and R software. We used a threshold for significance at $p < .05$.

We used a structured modelling approach (Mishra et al., 2009) to model and compare lifecourse models. Using separate multiple linear regressions, this approach allows for variation around the outcome mean given a binary exposure grouped into three time points (in our case, P1, P2 and P3) as well as all possible permutations. A total of eight possible permutations corresponded to each combination of timing periods P1, P2 and P3. To test for rival lifecourse models given P1, P2 and P3, the structured approach compares a set of nested/reduced models - corresponding to the accumulation of risk, sensitive periods and mobility models - to a saturated/complete model. Specifically, a saturated model included all three main effects, all 2-ways interactions, and a 3-way interaction. With this formulation, β_1, β_2 and β_3 are slope parameters of all three main effects. The second parameterization is the expression of all possible main effects interactions and referred as θ_{12}, θ_{13}, θ_{23} and θ_{123}. Another parameterization is α for the variation around the outcome mean given no exposure to poverty over the three time periods and representing the simplest model (null model or intercept only-model). **Table 2** presents corresponding equations for all nested models within the saturated model given poverty at all three time periods.

Based on the structured modelling approach hypothesized lifecourse models were as follows:

1) Three <u>sensitive period models</u> assuming that the association between poverty and behavior problems is particularly stronger during a certain time period (in our case, P1, P2, or P3) than it would be at other time periods.
2) Two <u>accumulation of risk models</u>: (a) *accumulation of risk strict* assuming that the longer the time spent in poverty, regardless of the time period, the higher the risk for behavior problems. The causal parameter of interested here is represented by the sum of exposure to poverty across three time periods (range 0 to 3) and assumes all three time points contribute equally to the risk for behavior problems. Specifically, for this model no exposure to poverty was compared to those who were poor >=1 time period. And, (b) *accumulation of risk relaxed* assuming that all three time points increase the risk for behavior problems but not necessarily in an equal manner (i.e. no equality constraint).
3) Two <u>social mobility models</u>: (a) *mobility P2 to P3* assuming that behavior problems risk may differ (enhanced or diminished) with later effect-modification. This model suggests that downward changes (i.e. becoming poor) would equally increase behavior problems risk whereas upwards changes (i.e. moving out of poverty) would equally decrease behavior problems risk between P2 and P3, irrespective of early exposure poverty (i.e. P1). Hence, those exposed to poverty in both P2 and P3 would have equal expected means to those who remain non-poor in both P2 and P3 (i.e. testing whether $Y_{00} = Y_{11}$, where Y is the outcome

variable given exposure to P2 and P3). And (b) *any mobility* assuming that upwards changes decreases behavior problems risk and that downwards changes increases behavior problems risk in an equal manner between P1, P2 and P3. Specifically, this model suggests that all upwards changes preceded by downwards changes (Y_{010}, where Y is the outcome variable given exposure to P1, P2 and P3) decreases behavior problems risk as would downwards changes preceded by upwards changes (Y_{101}) increase behavior problems risk.

Next, we used partial F-tests to compare different lifecourse models against the saturated model. Non-significant partial F-tests (p>.05) indicated that lifecourse models (i.e. nested models) did not differ from saturated models in fitting the data. Hence, the corresponding lifecourse model was supported by the data as the added variables in the saturated model would not improve significantly the accuracy of the model. The selection of the best fit and most parsimonious lifecourse model was based on two criteria: a) the largest p-value resulting from a partial F-test given a lifecourse model against the saturated model; and b) only lifecourse models tested against the saturated model with significant poverty estimates. All models were successively adjusted for confounders using the log-likelihood ratio test and employing a backward approach to retain variables below the threshold for significance. Assumptions of linearity, homoscedasticity of the variance, normality, independence among explanatory variables and outliers were examined and met using the studentized deleted residuals, leverage, and Cook's distances.

Because of the high attrition rates in the QLSCD, we conducted multiple imputation to handle missing data (Mostafa & Wiggins, 2015). We imputed values for our initial sample (N=2120) allowing for the inclusion of individuals with missing data in the analyses.

Information on the imputation process is described below on the basis of previous research on the reporting of multiple imputation (Rezvan, Lee & Simpson, 2015). We ran an exploratory analysis to verify patterns of missing values in the data, before imputation, and found that the percentage of incomplete cases was 22.5% (21,478 observations) within these same variables. A nonmonotone missingness was observed indicating that missing patterns were arbitrary .We adopted a MAR mechanism (i.e. Missing at Random) whereby individual missing values are likely to depend on observed data. Explanatory variables used in the imputation process (a total of 5 imputed datasets) to predict missing values were: all behavior problems (13 years), poverty (0-12 years), low maternal education (0-12 years), living with both biological parents (0-12 years) and all baseline confounders. A total of 5 imputed datasets were generated and deemed sufficient in terms of statistical efficiency (as compared to 20 imputations, see Appendix **Table S3**). Pooled F-values were not available in SPSS 22.0 as final estimates do not come directly from a single model. To address this issue, we combined several F- statistics from imputed datasets using an approximation based on χ^2 statistics with R software (Robitzsch, Grund, & Henke, 2016). Results addressing modeling and the selection of lifecourse models were reported using imputed data.

3. Results

3.1. Descriptive analysis

Table 3 presents the distribution of behavior problems at age 13 years by all possible poverty permutations given P1, P2 and P3. Among all poverty permutations, those who remained poor across all time periods were about 9.3% and those who were poor at least during one time period were 39.2% of the participants. Further, the number of observations for some permutations was particularly small (e.g. permutation 101 observed in 39 participants and indicating upwards change followed by downwards change in poverty or exposure in P1 and P3 but not in P2). Those who were never exposed to poverty showed lower levels of behavior problems than those who were exposed to poverty at least during one time period ($p<.001$ for all behavior problems). For all outcomes, children exposed in P1 had significant higher levels of behavior problems than those exposed in P2 and/or P3 permutations (i.e. permutations 100, 110, 101 and 111; $p<.001$ for all behavior problems).

3.2. Modeling and comparing lifecourse models

Table 4 describes saturated models for each subtype of behavior problems. For all outcomes, linear regression models were fitted to the data corresponding to all three main effects and interaction terms of P1, P2 and P3. Saturated models were adjusted for previously defined confounders (see foot of **Table 4**).

Table 5 presents the comparison of the all lifecourse models to the saturated model**.** The majority of the lifecourse models differed significantly in fitting the data from the saturated model. **Table 6** presents adjusted regression coefficients for poverty parameterization in each lifecourse model. Lifecourse models were adjusted for the same set of confounders retained previously in the saturated models with the exception of null models (see foot of **Tables 5** and **6**).

For hyperactivity, results indicated that both the accumulation of risk (relaxed) and any mobility models explained the data as well as the saturated model observed given partial F-tests ($p>.05$ in **Table 5**). The accumulation of risk (relaxed) was the best fitting model given the highest p-value. In this model, the best predictor was the most frequent poverty exposure

P1 (see **Table 6**). Specifically, children exposed between ages 0-3 had significant increased hyperactivity levels of 0.63 units (*p*=.023 whereas B_{P2}=0.07, *p*=.737; and B_{P3}=0.30, *p*=.172).

For physical aggression, three lifecourse models showed a particularly good fit of the data as they did not significantly differ from the saturated model observed given partial F-tests. Lifecourse models were (*p*>.05 in **Table 5**): accumulation of risk (relaxed), sensitive period P1, and any mobility. The accumulation of risk (relaxed) model had the highest p-value followed by the any mobility model, which was almost as large. Further, poverty estimates in both the accumulation of risk (relaxed) and the any mobility model were not significantly associated with physical aggression (*p*>.07, see **Table 6**). So that, physical aggression was best described by the sensitive period P1 model as (1) did not significantly differ from the saturated model and (2) displayed poverty estimates that significantly predicted higher levels of physical aggression. In this model, children exposed between ages 0-3 had significant increased physical aggression levels of 0.37 units (*p*=.027).

For opposition, results indicated that accumulation of risk models performed equally well as the saturated models when fitting the data. The accumulation of risk relaxed showed a particularly better fit (highest p-value, in **Table 5**) and thus was selected as best fitting model. In this model, the best prediction was the most frequent P1 with this group having the greatest disparity in opposition levels (see **Table 6**). This model revealed that children exposed between ages 0-3 had significant increased opposition levels of 0.56 units (*p*=.046).

3.3. Complementary analyses

The following analyses aimed to re-estimate lifecourse models accounting for changes in sample composition overtime. We restricted the analyses to a sub-sample of 1290 participants that remained in the study by age 13 years and to a sub-sample of 983 participants with complete data on at least one of the outcomes variables by age 13 years. Then, we compared the best fitting lifecourse models across this two-staged complete case analysis to those from the initial analysis (as presented in **Table 5**). Variations in the predictive power of lifecourse models were taken into account to analyse magnitude of bias given sample loss and non-response. Analysis given n=983 and our initial findings showed not identical but similar estimates whereas analysis given n=1290 showed mixed results. Restricting samples, without any adjustments to deal with missingness, may produce biased estimates resulting from nonrandom selection (i.e. exclusion of respondents living in poverty). Therefore, unless we retain observations missing from children who had not participated at one or more previous QLSCD assessments, it is not possible to minimize the bias from attrition. For lifecourse models based on restricted samples by age 13 years, see Appendix (**Tables S4-S5**).

4. Discussion

This paper compared different lifecourse models and identified the model that best described poverty from birth to 12 years predicting hyperactivity, opposition and physical aggression at age 13 years. Findings revealed that association between poverty and behavior problems across the lifecourse, spanning from birth to 13 years of age, correspond to both accumulation of risk and sensitive period models. For physical aggression, the sensitive period between ages 0-3 years seemed to be the most appropriate relative to more complex models accounting for more time periods. Findings are consistent with prior research emphasising the importance of the accumulation of economic disadvantaged across the lifespan (Evans & Cassells, 2014; Gerard & Buehler, 2004) as well as the focus on the earliest years of life

(Murray, Irving, Farrington, Colman, & Bloxsom, 2010; Nomura et al., 2008) for behavior problems risk among adolescents and criminal behavior among adults.

These findings are important for several reasons. First, this study highlighted the importance of considering outcome specificity of lifecourse models of poverty predicting behavior problems in early adolescence. While childhood poverty predicted hyperactivity and opposition behavior in a cumulative manner, we found a sensitive period within the early childhood years, between ages 0-3, for physical aggression. Second, we also found a strong association for early life poverty (i.e. 0 and 3 years) derived from the accumulation of risk model for hyperactivity and opposition. One of the reasons for this may be that, when equality constraints are relaxed so that exposure across all time periods predicts behavior problems in an unequal manner it allows for the identification of combined models of sensitive periods and accumulation (Mishra et al., 2009). Hence this notion of accumulation of risk posits that not only poverty does accumulate overtime, but also that early life exposure outperforms subsequent exposures in shaping later-life behavior problems. Emerging evidence suggests physiologic and functional plasticity over the first years of life persists throughout development (Noble et al., 2015). Given the importance of exposure to poverty between ages 0-3 observed in this study, interventions targeting time points during early childhood (i.e., before age 5) may have substantial benefits in reducing behavior problems in early adolescence. Recent findings in low-income populations suggest that family intervention programs initiated during early childhood are vital to reduce children's behavior problems, including opposition and physical aggression (Dishion et al., 2014; Leijten et al., 2015).

Patterns of findings resemble that of previous research examining growth/decline in behavior problems across development. The finding of a sensitive period even as the time spent in poverty increased for physical aggression may indicate that the association between poverty and physical aggression is fairly stable across development. Prior work has suggested that differences in physical aggression trajectories between poor and non-poor children are established as early as age 1.5 years and, rather than increasing with age, remained constant up to age 8 years (Mazza et al., 2016). It is possible that Gene x Environment interactions might precipitate increases in normative aggressive behavior which are in turn likely to persist later in life (Shaw, Bell, & Gilliom, 2000; Tremblay, 2010). Further, several studies suggest that individual differences and growth rate in physical aggression are due to genetic vulnerability which in turn are moderated by prenatal and post-natal environmental risk (Boivin et al., 2013; Lacourse et al., 2014). Nonetheless, our findings supported the accumulation of risk model indicating that differences in hyperactivity and opposition levels increased with time spent in poverty. This confirms results from previous studies suggesting that differences in behavior problems (including hyperactivity and opposition) that were initially small between poor and non-poor children, appeared to increase overtime for children in persistent poverty (Flouri, Midouhas, & Joshi, 2014; Mazza et al., 2016). It may be that both hyperactivity and opposition are more susceptible to change than physical aggression if interventions were to target poverty in any given period from early-to-middle childhood.

Selection bias is an important problem in poverty research given nonrandom exclusion of disadvantaged participants. Complete case analysis for longitudinal data can produce biased results and undertaking data augmentation (in our case 22.5% increase) with imputation techniques is recommended to reduce selection bias (Mostafa & Wiggins, 2015). Excluding participants with incomplete data or those lost to follow-up is inadequate and potentially undermines valid inference.

Finally, most studies on behavior problems- poverty link pertain to children who live in the United States where poverty rates are higher than in most high-income countries (UNICEF, 2012). Our findings suggest that behavior problems risk relates to poverty at different ages during childhood despite lower poverty rates reflecting health care and social policies that are specific to Canada.

4.1. Strengths and limitations

Strengths of this study include the empirical testing of competing lifecourse models of childhood poverty predicting behavior problems in early adolescence using a well-defined model-building framework. A second strength lies in the assessment of behavior problems reported by teachers, rather than by parents. Teacher reports allow for the identification of behavior problems that are not isolated to the home context, but rather informs about psychopathology expressed across school and extracurricular activities (Reyes, 2011). A third strength lies in the use of repeated and robust measures of exposure to poverty using national thresholds (i.e., LICOs). A fourth strength was the examination of three subtypes of behavior problems suggesting lifecourse models that are specific for hyperactivity and opposition as well as for physical aggression. Finally, lifecourse models of poverty predicting behavior problems were robust after carefully controlling for several confounders described in the literature. Several limitations of the study deserve mention. First, the lack of power may be an issue when examining lifecourse models that includes interaction terms. Specific analyses in the structure modelling approach (Mishra et al., 2009) require even larger samples as is the case for the mobility models. This pleads for collaborations with other longitudinal studies. Second, differential attrition could underestimate the observed associations if attrition was dependent on both being poor and having high levels of behavior problems. Reassuringly, this issue was addressed analytically using multiple imputation procedure. Third, it is possible that one or more sensitive periods exist outside of the periods of exposure that were grouped for the analyses and are therefore not detected in analyses. The decision to group exposure to poverty between ages 0-3, 5-7 and 8-12 years was based on assessments approximating different stages of development such as infancy, middle childhood and late childhood. Forth, if missingness depends on explanatory variables, then model misspecification in the multiple imputation procedure could be an alternative explanation worth considering. Lastly, this study is observational and, as such, is limited to make causal inferences of the association between childhood poverty and behavior problems in adolescence.

5. Conclusion

Findings highlight that the length of time spent in poverty across childhood increased the risk for hyperactivity and opposition behavior and that this association may be driven by early poverty. For physical aggression, we found evidence for effects of sensitive period between birth and age 3. Additional research, as with any study, is needed to explore whether these patterns of findings can be replicated in other samples.

This study supports not only the cumulative effect of poverty overtime but also the long-lasting effects of early poverty, and in particular identifies a sensitive period within early childhood years that may compromise mental health in early adolescence. Long term support to pregnant women living in poverty is likely to reduce behavior problems during childhood and adolescence. Also, this paper emphasises the importance of policies to reduce child poverty by boosting income and service delivery to poor families with children and even in a high-income country like Canada. Support programs extending financial benefits to poor families suggest that increasing tax credits is likely to decrease children's and adolescent's behavior problems (Akee, Copeland, Keeler, Angold, & Costello, 2010; Hamad & Rehkopf, 2016). Other support programs, including center-based child care and parent training, are increasingly recognized to benefit children from low-income families in achievement domains as well as to play a protective role in the development of behavior problems (Côté et al., 2007; Dishion et al., 2014; Laurin et al., 2015).

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Table 1 Remaining participants in the QLSCD after 13 years of follow-up by exposure to poverty.

Age (years)	QLSCD sample N (%)	Poverty Poor n (%)	Non-Poor n (%)	Missing n (%)
5 months	2120 (100)	511 (24.1)	1571 (74.1)	38 (1.8)
1.5	2045 (96.5)	416 (20.4)	1599 (78.2)	30 (1.4)
2.5	1997 (94.1)	368 (18.4)	1598 (80.0)	31 (1.6)
3.5	1950 (92.0)	319 (16.4)	1594 (81.7)	37 (1.9)
4.5	1944 (91.7)	-	-	-
5	1759 (83.0)	298 (16.9)	1438 (81.8)	23 (1.3)
6	1492 (70.4)	245 (16.4)	1235 (82.8)	12 (0.8)
7	1528 (72.1)	228 (14.9)	1284 (84.0)	16 (1.0)
8	1451 (68.4)	218 (15.0)	1220 (84.1)	13 (0.9)
10	1334 (62.9)	151 (11.3)	1176 (88.2)	7 (0.5)
12	1396 (65.9)	185 (13.3)	1203 (86.2)	8 (0.6)
13	1290 (60.8)	153 (11.9)	1120 (86.8)	17 (1.3)

Note. N refers to the total participants in the QLSCD at each time point; n refers to the number of participants in the QLSCD depending on the data available. Poverty status was not available at 4.5 years of age.

Table 2 Saturated and lifecourse models specifications given exposure to poverty over three time periods.

Lifecourse model	Equations	Constraints
No effect	$Y=\alpha$	
Accumulation of risk		
Strict	$Y=\alpha + \beta\ (P1+ P2+ P3)$	
Relaxed	$Y=\alpha + \beta_1 P1+ \beta_2 P2+\beta_3 P3$	
Sensitive period		
P1	$Y=\alpha + \beta_1 P1$	
P2	$Y=\alpha + \beta_2 P2$	
P3	$Y=\alpha + \beta_3 P3$	
Social mobility		
Mobility P2 to P3	$Y=\alpha + \beta_2\ P2+ \beta_3\ P3+ \theta_{23}\ P2P3$	$\theta_{23} = -(\beta_2 + \beta_3)$
Any mobility	$Y=\alpha + \beta_1\ P1+ \beta_2\ P2+ \beta_3\ P3+ \theta_{12}\ P1P2+\theta_{23}\ P2P3$	$\theta_{12} = \theta_{23} = -\beta_2$
Saturated model	$Y=\alpha + \beta_1 P1+ \beta_2 P2+ \beta_3 P3+ \theta_{12}\ P1P2+ \theta_{13}\ P1P3+ \theta_{23}\ P2P3+\theta_{123} P1P2P3$	

Note. P1=Poverty between ages 0-3 years; P2=Poverty between ages 5-7 years; P3=Poverty between ages 8-12 year.

Table 3 Distribution of behavior problems at 13 years of age by poverty over three time periods and all possible permutations.

				Hyperactivity	Physical aggression	Opposition
			N (%)	Mean ± SE	Mean ± SE	Mean ± SE
Full sample			2120 (100)	1.58 ± .078	0.52 ± .043	1.11 ± .063
Poverty						
P1			680 (32.1)	2.02 ± .140	0.80 ± .095	1.68 ± .119
P2			435 (20.5)	2.01 ± .149	0.79 ± .084	1.67 ± .151
P3			340 (16.0)	2.00 ± .169	0.73 ± .105	1.75 ± .175
Permutations						
P1	P2	P3				
0	0	0	1288 (60.8)	1.34 ± .107	0.36 ± .061	0.80 ± .088
1	0	0	304 (14.3)	1.93 ± .271	0.77 ± .156	1.55 ± .250
0	1	0	48 (2.3)	1.56 ± .482	0.63 ± .225	0.96 ± .324
0	0	1	54 (2.5)	1.74 ± .506	0.71 ± .313	1.23 ± .398
1	1	0	140 (6.6)	2.12 ± .289	0.90 ± .173	1.55 ± .262
1	0	1	39 (1.8)	2.21 ± .691	0.63 ± .305	1.71 ± .504
0	1	1	50 (2.4)	1.91 ± .465	0.58 ± .290	1.58 ± .477
1	1	1	197 (9.3)	2.05 ± .230	0.80 ± .130	1.94 ± .239

Note. P1=Poverty between ages 0-3 years; P2=Poverty between ages 5-7 years; P3=Poverty between ages 8-12 years. Standard Errors (SE) were reported as opposed to Standard Deviations (SD) because estimates from imputed datasets were combined together producing a single estimate and standard errors for subsequent analyses

Table 4 Estimating saturated models for behavior problems at 13 years of age and poverty from 0-12 years of age.

	Hyperactivity		Physical aggression		Opposition	
	B	P-value	B	P-value	B	P-value
Poverty						
P1	.740	.010	.371	.070	.625	.085
P2	.242	.599	.212	.392	.016	.962
P3	.665	.173	.391	.155	.352	.352
P1*P2	-.187	.720	-.134	.621	-.125	.772
P1*P3	-.530	.593	-.533	.214	-.260	.739
P2*P3	-.187	.773	-.400	.254	.251	.652
P1*P2*P3	.108	.912	.524	.286	.122	.876
Pooled F-statistics	66.4^{***}		44.04^{***}		43.7^{***}	

Note. P1=Poverty between ages 0-3 years; P2=Poverty between ages 5-7 years; P3=Poverty between ages 8-12 years. Models predicting hyperactivity were adjusted for child' sex and maternal immigration status. Models predicting opposition were adjusted for child' sex, maternal history of antisocial behavior and maternal education at age 3.5 years. Model predicting physical aggression was adjusted for child'sex and maternal history of antisocial behavior. Analyses were conducted on our study sample (n=2120).

Table 5 Partial F-tests comparing different lifecourse models against the saturated model for behavior problems at 13 years of age and poverty from 0-12 years of age.

	Hyperactivity			Physical aggression			Opposition		
Lifecourse model	df	F-statistic	P-value	df	F-statistic	P-value	df	F-statistic	P-value
No effect	7,2110	31.9	<.001	7,2110	17.2	<.001	7,2109	10.2	<.001
Accumulation of risk (strict)	6,2110	2.52	.020	6,2110	2.70	.013	6,2109	1.95	**.070**
Accumulation of risk (relaxed)	6,2110	1.78	**.129**	6,2110	1.66	**.158**	6,2109	0.93	**.444**
Sensitive period									
P1	6,2110	2.33	.030	6,2110	1.99	**.064**	6,2109	2.22	.039
P2	6,2110	6.48	<.001	6,2110	5.33	<.001	6,2109	6.05	<.001
P3	6,2110	6.72	<.001	6,2110	6.52	<.001	6,2109	5.36	<.001
Social mobility									
Mobility P2 to P3	5,2110	10.04	<.001	5,2110	8.14	<.001	5,2109	10.36	<.001
Any mobility	5,2110	2.06	**.068**	5,2110	1.75	**.120**	5,2109	2.53	.027

Note. Sensitive period corresponds to ages 0-3, 5-7 and 8-12 years. Models predicting hyperactivity were adjusted for child' sex and maternal immigration status. Models predicting opposition were adjusted for child' sex, maternal history of antisocial behavior and maternal education at age 3 years. Model predicting physical aggression was adjusted for child'sex and maternal history of antisocial behavior. Pooled F-values and corresponding p-values referred to the combination of several F-statistics from imputed datasets and used an approximation based on χ^2 statistics. Bolded: No significant difference of the nested life course model to the saturated model; higher p-value = better model fit. Analyses were conducted on our study sample (n=2120).

Table 6 Adjusted regression estimates for lifecourse models of poverty from 0-12 years of age predicting behavior problems at 13 years of age.

Lifecourse model	Hyperactivity			Physical aggression			Opposition		
	B	95% CI	P-value	B	95% CI	P-value	B	95% CI	P-value
Accumulation of risk (strict)[a]	.347	.181, .503	<.001	.165	.076, .225	.001	.324	.183, .466	<.001
Accumulation of risk (relaxed)[a]									
P1	.626	.110, 1.14	.023	.310	-.117, .736	.125	.558	.013, 1.10	.046
P2	.073	-.372, .512	.737	.086	-.294, .467	.617	.026	-.382, .434	.897
P3	.303	-.141, .747	.172	.070	-.201, .342	.593	.385	-.017, .786	.060
Sensitive period[a]									
P1	.741	.301, 1.18	.004	.365	.056, .675	.027	.658	.226, 1.09	.008
P2	.572	.186, .956	.007	.296	.062, .531	.017	.493	.159, .828	.006
P3	.614	.261, .966	.001	.259	.056, .461	.014	.601	.249, .954	.002
Mobility P2 to P3									
Downwards	.406	-.185, .997	.161	.268	-.083, .619	.121	.093	-.335, .521	.661
Upwards	.519	-.206, .124	.149	.206	-.103, .515	.188	.211	-.307, .730	.421
Any mobility									
Downwards	.544	.138, .949	.013	.290	-.032, .613	.071	.388	-.104, .879	.106
Upwards	.240	-.486, .967	.470	.065	-.309, .439	.705	.088	-.365, .542	.691

Note. Sensitive period corresponds to ages 0-3, 5-7 and 8-12 years. Models adjusted for the following confounders: a) hyperactivity: child' sex and maternal immigration status; b) opposition: child' sex, maternal history of antisocial behavior and maternal education at age 3 years; c) physical aggression: child' sex and maternal history of antisocial behavior. For hyperactivity and opposition, the accumulation model (relaxed) performed as well as the saturated model. For physical aggression, only the sensitive period corresponding to ages 0-3 performed as well as the saturated model. Analyses were conducted on our study sample (n=2120).

Appendix : Supplementary materials

Table S1. Characteristics of QLSCD sample present at 13 years of age and sub-sample with missing data.

Variables	Full sample	Sub-sample with incomplete data
	n (%)	n (%)
Male sex	603(46.7)	159(51.8)
Maternal immigrant status	108(8.4)	39(12.7)
Living with both biological parents	449(34.8)	114(37.1)
High school diploma or less	374(29.0)	101(32.9)
Poverty	153(11.9)	52(16.9)
	Mean ± SD	Mean ± SD
Age of motherhood	26.7 ± 4.91	25.7 ± 5.09
Maternal history of antisocial behavior	0.80 ± 0.91	0.85 ± 0.95
Hyperactivity at 12 years of age	1.35 ± 2.06	1.54 ± 2.11
Physical aggression at 12 years of age	0.79 ± 1.44	0.83 ± 1.44
Opposition at 12 years of age	1.39 ± 2.23	1.76 ± 2.46

Note. Full sample corresponds to a total of 1290 participants present at the 13 years of age assessment and the sub-sample with incomplete data corresponds to a total of 307 participants that had missing values for hyperactivity, opposition and psychical aggression at 13 years of age assessment. Poverty, living with both biological parents and maternal education correspond to the 13 years of age assessment. Age of motherhood ranged 15 to 41 years of age. Maternal history of antisocial behavior coded so that higher scores indicated higher levels of antisocial behavior (range 0 to 5). Behavior problems coded so that higher scores indicated higher levels of behavior problems at 12 years of age (range 0 to 9 for hyperactivity, range 0 to 10 to opposition, and range 0 to 8 to physical aggression).

Table S2 Full sequence of nested models based on all possible poverty permutations over three time periods.

Model	Permutations			Equations
	P1	P2	P3	
Null model	0	0	0	$Y=\alpha$
Model 1	1	0	0	$Y=\alpha + \beta_1 P1$
Model 2	0	1	0	$Y=\alpha + \beta_2 P2$
Model 3	0	0	1	$Y=\alpha + \beta_3 P3$
Model 4	1	1	0	$Y=\alpha + \beta_1 P1+ \beta_2 P2+ \theta_{12} P1P2$
Model 5	1	0	1	$Y=\alpha + \beta_1 P1+ \beta_3 P3+ \theta_{13} P1P3$
Model 6	0	1	1	$Y=\alpha + \beta_2 P2+ \beta_3 P3+ \theta_{23} P2P3$
Model 7 (saturated model)	1	1	1	$Y=\alpha + \beta_1 P1+ \beta_2 P2+ \beta_3 P3+ \theta_{12} P1P2+ \theta_{13} P1P3+ \theta_{23} P2P3+\theta_{123} P1P2P3$

Note. P1=Poverty between ages 0-3 years; P2=Poverty between ages 5-7 years; P3=Poverty between ages 8-12 years.

Computation of the relative efficiencies based on 5 and 20 imputations

A number of imputations were performed to replicate the incomplete QLSCD dataset multiple times. Unknown missing values were replaced with an overall estimate that combined estimated values drawn from replicated datasets in the imputation process. Specifically, a total of 5 imputed datasets (*m*) was generated using 10 sampling iterations from the marginal starting values. The decision to fix $m = 5$ as opposed to $m = 20$ (Graham, Olchowski, & Gilreath, 2007; White, Royston, & Wood, 2011) was based on research indicating that they were reasonably sufficient in terms of statistical efficiency to combine estimates from multiple imputed datasets and obtain stable results (Buuren, Brand, Groothuis-Oudshoorn, & Rubin, 2006; Schafer & Olsen, 1998). In **Table S3**, we computed and compared the relative efficiencies based on 5 and 20 imputations respectively for all ages (1.5 to 13 years old). We can observe that the relative efficiencies varied from 0.993 to 0.927 and from 0.998 to 0.981 with 5 and 20 imputations respectively. The ratios (m=5/m=20) of these relative efficiencies varied from 0.995 to 0.945. So, in the worst case (at 13 years old), our relative efficiency represented 94.5% of the relative efficiency we would have obtained with 20 imputations. This suggests that 5 imputations can be considered as acceptable. Comparing analyses were based on the relative efficiency involving the fraction of missing information (γ) for the parameter being estimated (*m*) given by $(1+ \gamma /m)^{-1}$ (Rubin, 1987).

Table S3 Estimating and comparing relative efficiencies of 5 and 20 imputed datasets based on QSLCD sample composition from ages 1.5 to 13 years.

Age	% of 2120	% of missing (γ)	Relative efficiency m=5 (A)	Relative efficiency m=20 (B)	Relative efficiency of A/B
1.5	0.965	0.035	0.993	0.998	0.995
2.5	0.941	0.059	0.988	0.997	0.991
3.5	0.920	0.080	0.984	0.996	0.988
4.5	0.917	0.083	0.984	0.996	0.988
5	0.830	0.170	0.967	0.992	0.975
6	0.704	0.296	0.944	0.985	0.958
7	0.721	0.279	0.947	0.986	0.960
8	0.684	0.316	0.941	0.984	0.955
10	0.629	0.371	0.931	0.982	0.948
12	0.659	0.341	0.936	0.983	0.952
13	0.608	0.392	0.927	0.981	0.945

Graham, J. W., Olchowski, A. E., & Gilreath, T. D. (2007). How many imputations are really needed? Some practical clarifications of multiple imputation theory. *Prevention Science*, *8*(3), 206-213.

Rezvan, P. H., Lee, K. J., & Simpson, J. A. (2015). The rise of multiple imputation: a review of the reporting and implementation of the method in medical research. *BMC medical research methodology*, *15*(1), 1.

Rubin, D. B. (1987). Multiple imputation for nonresponse in surveys. New York: Wiley.

Schafer, J. L., & Olsen, M. K. (1998). Multiple imputation for multivariate missing-data problems: A data analyst's perspective. *Multivariate behavioral research*, *33*(4), 545-571.

Van Buuren, S., Brand, J. P., Groothuis-Oudshoorn, C. G. M., & Rubin, D. B. (2006). Fully conditional specification in multivariate imputation. *Journal of statistical computation and simulation*, *76*(12), 1049-1064.

White, I. R., Royston, P., & Wood, A. M. (2011). Multiple imputation using chained equations: issues and guidance for practice. *Statistics in medicine*, *30*(4), 377-399.

Complementary analyses

Table S4 presents re-estimated lifecourse models restricting analysis to n=1290. Results indicated that the best fitting lifecourse models were the any mobility model for hyperactivity ($p_{\text{any mobility against the saturated model}}$ =.345), the accumulation of risk strict for opposition and physical aggression ($p_{\text{strict against the saturated model}}$ =.921 for opposition; $p_{\text{strict against the saturated model}}$ =.337 for physical aggression). Results deviated substantially from our initial findings on N=2120 suggesting a less accurate model. Particularly, the accumulation of risk (relaxed) model was no longer the best fit of the data for hyperactivity and opposition nor was the sensitive period P1 model for physical aggression. Results restricting analysis to =1290 were reported using imputed data (i.e. 307 cases were included due to non-response of outcomes and explanatory variables). When restricting analysis to n=983, we found similar results to our initial findings across all outcomes (see **Table S5**). For hyperactivity the accumulation of risk (relaxed) was the best fitting model ($p_{\text{relaxed against the saturated model}}$ =.309) with P1 as the best predictor (B_{P1}=0.66, p=.001). For physical aggression, the sensitive period P1 was the selected model ($p_{\text{P1 against the saturated model}}$ =.060). And finally, for opposition the superior lifecourse model was the accumulation of risk relaxed ($p_{\text{relaxed against the saturated model}}$ =.791). However, the latter differed from our initial findings in terms of the best predictor. Specifically, we found larger effects for P3 (B_{P3}=0.71, p=.004) as opposed to P1 found in our initial findings. Results restricting analysis to n=983 were reported using imputed data (i.e 250 cases included due to non-response of explanatory variables). To keep the manuscript within the word limit, we have added this paragraph in the supplemental material.

In sum, complete case analysis given n=983 and initial analyses of N=2120 showed not identical but similar estimates. However, mixed results between our initial findings and findings from n=1290 imply a loss of information due to attrition that accumulates overtime. Restricting analyses to participant's sub-samples with partially complete or complete data, without any adjustments to deal with missingness (i.e. attrition and non-response) is likely to produce misleading results and possibly biased estimates (Carrigan, Barnett, Dobson, & Mishra, 2007; Mostafa & Wiggins, 2015)

Carrigan, G., Barnett, A. G., Dobson, A. J., & Mishra, G. (2007). Compensating for missing data from longitudinal studies using WinBUGS. *Journal of Statistical Software*, *19*(7), 1-17.

Mostafa, T., & Wiggins, R. (2015). The impact of attrition and non-response in birth cohort studies: a need to incorporate missingness strategies. *Longitudinal and Life Course Studies*, *6*(2), 131–146.

Table S4 Partial F-tests to compare different lifecourse models against the saturated model for behavior problems at 13 years of age and poverty from 0-12 years of age using imputed data (N=1290).

	Hyperactivity			Physical aggression			Opposition		
Lifecourse model	df	F-statistic	P-value	df	F-statistic	P-value	df	F-statistic	P-value
Accumulation of risk	6,1280	1.53	**.165**	6,1280	1.14	**.337**	6,1279	0.33	**.920**
Accumulation of risk (relaxed)	4,1280	1.46	**.210**	4,1280	1.36	**.246**	4,1279	0.27	**.802**
Sensitive period									
P1	6,1280	2.40	.026	6,1280	1.84	**.088**	6,1279	1.37	**.224**
P2	6,1280	3.62	.001	6,1280	2.62	.016	6,1279	1.10	**.358**
P3	6,1280	4.98	<.001	6,1280	3.29	.003	6,1279	1.32	**.247**
Social mobility									
Mobility P2 to P3	5,1280	9.16	<.001	5,1280	6.05	<.001	5,1279	3.46	.004
Any mobility	5,1280	1.13	**.345**	5,1280	1.23	**.294**	5,1279	0.29	**.921**

Note. Sensitive period corresponds to ages 0-3, 5-7 and 8-12 years. Model predicting hyperactivity was adjusted for child' sex and maternal immigration status. Model predicting opposition was adjusted for child' sex, living with both biological parents and maternal education at age 3.5 years. Model predicting physical aggression was adjusted for child'sex and maternal history of antisocial behavior. Pooled F-values and corresponding p-values referred to the combination of several F-statistics from imputed datasets and used an approximation based on χ^2 statistics .Bolded: No significant difference of the nested life course model to the saturated model; higher *p*-value = better model fit.

Table S5 Partial F-tests to compare different lifecourse models against the saturated model for behavior problems at 13 years of age and poverty from 0-12 years of age using imputed data (N=983).

	Hyperactivity			Physical aggression			Opposition		
Lifecourse model	df	F-statistic	P-value	df	F-statistic	P-value	df	F-statistic	P-value
Accumulation of risk	6,909	1.21	**.297**	6,866	2.26	.036	6,923	0.92	**.479**
Accumulation of risk (relaxed)	4,909	1.02	**.309**	4,866	2.76	.027	4,923	0.43	**.791**
Sensitive period									
P1	6,909	2.48	.022	6,866	2.02	**.060**	6,923	2.82	.010
P2	6,909	4.13	<.001	6,866	3.04	.006	6,923	2.61	.016
P3	6,909	3.18	.004	6,866	2.76	.012	6,923	0.65	**.689**
Social mobility									
Mobility P2 to P3	5,909	7.54	<.001	5,866	2.56	.026	5,923	4.92	<.001
Any mobility	5,909	1.62	**.153**	5,866	2.54	.027	5,923	1.04	**.394**

Note. Sensitive period corresponds to ages 0-3, 5-7 and 8-12 years. Models predicting hyperactivity were adjusted for child' sex and maternal immigration status. Models predicting physical aggression were adjusted for child'sex and maternal education at age 3 years. Models predicting opposition were adjusted for child' sex, maternal history of antisocial behavior and maternal education at age 3 years. Pooled F-values and corresponding p-values referred to the combination of several F-statistics from imputed datasets and used an approximation based on χ^2 statistics. Bolded: No significant difference of the nested life course model to the saturated model; higher *p*-value = better model fit. Analyses were conducted on our study sample of n=919 for hyperactivity, n=934 for opposition and n=876 for physical aggression.

CHAPTER 5

Discussion

Chapter 5 is organized into four parts. The first part discusses the major findings corresponding to the three research papers forming the main body of this dissertation. The second part outlines the scientific contribution of our findings. In the third part, strengths and limitations are presented in detail for each research paper. Then, emerging issues and future research into life course determinants of behavior problems are discussed. For specific technical/critical discussion of findings of each paper (e.g., selection of confounders, complementary analyses, and statistical methods) and limitations, please refer to the corresponding chapters.

5.1 Summary of results

5.1.1 Family mediators of the poverty-behavior problems link during early childhood

In *article 1*, our primary aim was to contribute to knowledge about family-mediators of the association between chronic poverty and high levels of physical aggression and hyperactivity during early childhood. We found the following: (1) a 3-trajectory group model for both behavior problems subtypes was identified with 17.54% and 14.15% of the sample in the high-trajectory group, for physical aggression and hyperactivity respectively. (2) A 43% increased odds of being assigned to the high physical aggression trajectory following exposure to poverty and a 76% increased odds of being assigned to the high hyperactivity trajectory. (3) Among several putative family characteristics, only parental overprotection and maternal depression symptoms emerged as significant mediators of the association between chronic poverty and children's high trajectories of physical aggression and hyperactivity between 1.5 and 5 years. (4) Differentiated patterns of mediation were obtained for overprotection whereby higher levels of overprotection were related to higher levels of hyperactivity but unexpectedly, to lower levels of physical aggression. Patterns of associations for overprotection are discussed at length in Chapter 4.

Although we were unable to identify coercion and family dysfunction as mediators of the poverty-behavior problems link (Evans & Cassells, 2014; Shelleby et al., 2014), our findings are consistent with prior research showing that poverty is associated with children's mental health both directly and indirectly through mediators such as maternal depression symptoms and perceived parenting (Conger et al., 2010; Kim-Cohen et al., 2005). Furthermore, estimated indirect effects from poverty to both subtypes of behavior problems through overprotection and maternal depression symptoms were small. Thus, suggesting a need to identify others relevant potential mediators underlying the poverty-behavior problems association during early childhood.

Our findings, nevertheless, add to the literature by identifying overprotection and maternal depression as family processes underlying the association between poverty and behavior problems over the first five years of life. However, they suggest that physical aggression and hyperactivity appear to share a common etiology related to poverty and economic disadvantage, but not shared family processes as mechanisms underlying the association between poverty and behavior problems.

5.1.2 Poverty-behavior problems associations and patterns of change

The major aim of *article 2* was to examine whether poverty predicted changes in hyperactivity, opposition and physical aggression from early-to-middle childhood, and over the first eight years of life. We showed that poverty predicted higher levels of behavior problems over time, and that patterns of poverty-age interactions differed according to subtypes of behavior problems. In addition, the statistical approach employed in this article allowed us to more clearly isolate selection bias given nonrandom exclusion of the most disadvantaged participants, finding similar patterns of results when correcting for attrition over time.

Findings suggest that poor children are more likely to have increasing vulnerability to hyperactivity and opposition over the length of time spent in poverty. Though the estimated differentials were, at least initially, small, children in persistent poverty appeared to develop increasing hyperactivity/opposition as they got older. Specifically, children who remained poor at all seven years exhibited increasing levels of hyperactivity and opposition at a faster rate up to five years and decreasing levels at a slower rate afterwards than their counterparts. In contrast, estimated differentials in physical aggression were observed as early as age 1.5 years. However, contrary to hyperactivity and opposition, physical aggression levels decreased over time at a stable rate for both poor and non-poor children.

It is possible that a biological component occurring *in utero* and/or during the 1.5 years of life accounts for the associations we found. Poverty may lead to permanent physiologic insults early in life, leaving the individual at greater risk of physical aggression. Studies suggest that individual differences in physical aggression may be linked to genetic influence and moderated by pre- and post-natal environmental risk (Boivin et al., 2013; Dionne, Tremblay, Boivin, Laplante, & Pérusse, 2003; Lacourse et al., 2014). This finding may be valuable for exploring the mechanism of fetal programming and epigenetic process underlying patterns of change in behavior problems given exposure to poverty.

Even without proposing a specific mechanism for these patterns of poverty-age interactions, our study make important contributions to the related field of research. First, hyperactivity and opposition disparities in relation to poverty increased as children aged, thus highlighting the need to consider life course exposures or long-term exposures to poverty on behavior problems risk. Second, compared to hyperactivity and opposition, the poverty gap in physical aggression did not increase with age but it may be addressed by reducing or eliminating poverty prior to age 1.5 years or even during the pre-natal period.

5.1.3 Life course model of childhood poverty predicting behavior problems in early adolescence

In *article 3*, the primary interest was to examine life course models of childhood poverty predicting behavior problems in in early adolescence. Among competing life course models, we identified that both accumulation of risk and sensitive period models best described the association between timing of exposure to poverty and behavior problems. Of importance, patterns of findings differed by behavior problems subtype, namely hyperactivity, opposition and physical aggression. While childhood poverty predicted hyperactivity and opposition behavior in a cumulative manner, between ages 0-12; we found a sensitive period within the early childhood years, between ages 0-3, for physical aggression.

Particularly, our findings supported the accumulation of risk model indicating that differences in hyperactivity and opposition levels increased with time spent in poverty. We also found a strong association for early life poverty (i.e. ages 0-3) derived from the accumulation of risk model for hyperactivity and opposition. This confirms results from previous studies suggesting that differences in behavior problems (including hyperactivity and opposition) that were initially small between poor and non-poor children, appeared to increase overtime for children in persistent poverty (Flouri et al., 2014; Rougeaux, Hope, Law, & Pearce, 2017). Further, the finding of a sensitive period even as the time spent in poverty increased for physical aggression may indicate that the association between poverty and physical aggression is fairly stable across development. The latter is consistent with findings from *article 2* whereby differences in physical aggression trajectories between poor and non-poor children were established as early as age 1.5 years and, rather than increasing with age, remained constant up to age 8 years.

Study findings provide a better understanding of behavior problems in early adolescence as a result, to a certain degree, of impairment incurred from exposures earlier in life. Given the importance of exposure to poverty between ages 0-3 observed in this study, interventions targeting time points during early childhood (i.e., before age 5) may have substantial benefits in reducing behavior problems in early adolescence as it is presumed to be a time period with special plasticity.

5.2 Scientific contributions

The current dissertation contributes with a number of substantive findings to the existing literature related to childhood poverty and the development of behavior problems. The current work sought to answer the following questions:

(1) What is the role of different family processes, both directly and indirectly, in explaining the extent to which poverty relates to behavior problems?
(2) How important is poverty and underlying mechanisms to different behavior problems subtypes (hyperactivity, opposition and physical aggression)?
(3) Can we predict behavior problems in relation to poverty exposures at earlier points in a person's life? In other words, do certain periods of time in childhood development "set" the course of later life behavior problems?

Findings from *articles 1* to *3* shed a light on these questions and support that, in a time period spanning from birth to 13 years of age, time and duration of exposure to poverty are predictive of a range of behavior problems in Canadian children and youth. The association between family process and children's behavior problems was also confirmed, and established to be behavior problems-specific than what was previously thought.

Findings from *articles 2* and *3* are a compelling case that hyperactivity and opposition are more susceptible to change than physical aggression given that they were more likely to increase following prolonged exposure to poverty over the years. In turn, differences in physical aggression were likely to be fairly stable over time regardless of time spent in living in poverty. Of importance, differences in physical aggression levels between poor and non-poor children were established as early as age 1.5. This calls for early preventive efforts targeting pregnant women living in poverty and their offspring. Taken together, these findings reinforce the need of age-appropriate interventions tackling child poverty and health during pregnancy as well as a child's early years. The mechanisms explaining the risk of behavior problems in relation to poverty are likely to involve changes in neurodevelopment and in the set point of neuroendocrine systems, and there is evidence that prenatal adversity interacts with genetic and postnatal environmental factors (Schlotz & Phillips, 2009). Of importance, recent findings in low-income populations suggest that family intervention programs initiated during early childhood are vital to reduce children's behavior problems, including opposition and physical aggression (Dishion et al., 2014; Leijten et al., 2015).

As mentioned in Chapter 4, when significant indirect effects of family process were identified linking poverty to behavior problems during early childhood, effect sizes were modest. Although indirect effects were small at least through age 5 years, any observed association is potentially important in understanding how sustained deprivation during a sensitive period of life is associated with behavior problems as markers of emerging psychopathology. But, nevertheless, the finding that mediation by overprotection was behavior problems-specific was an important contribution to the literature. If replicated, they could lead to a clearer understanding of mediators that are specific to behavior problems subtypes and, in turn, would be important in suggesting different strategies for prevention or treatment.

In addition, findings from *article 1* are consistent with prior research showing that poverty is associated with children's mental health both directly and indirectly through mediators such as maternal depression symptoms and perceived parenting (Conger et al., 2010; Shelleby et al., 2014). This adds to the existing behavior problems literature by identifying intervening factors, including poverty and family processes. However, it is possible that focusing initially on understanding and then improving living conditions of poor children may be the most viable option in the early years of life to reduce behavior problems risk than of psychosocial factors such as family processes. Lastly, findings from *article 1* provide additional evidence to poverty research on the role of chronic poverty in the aetiology of behavior problems during early childhood (Najman et al., 2010).

Taken as a whole, our research, and of the others (Dearing et al., 2001; McLaughlin et al., 2012; Pingault et al., 2013; Rekker et al., 2015), inform on the timing and targets for antipoverty policies and interventions aimed at reducing the risk of behavior problems. It is possible that brain plasticity and the ability to change behavior problems decrease over time, so that the developmental period where children are exposed to poverty may represent an opportunity to reframe existing income transfer programs and other interventions. Defining when is the optimal time for those interventions to be implemented is not a simple task. But if well elucidated, it could become a core characteristic for new antipoverty policies and interventions promoting childhood and adolescence mental health.

Taken together, findings from the current dissertation may help to improve recommendations, interventions, and policies relating to poverty and developmental psychopathology among Canadian youth and help define the optimal period of time in childhood development to improve implementation efforts.

5.3 Strengths and limitations

5.3.1 General strengths

The current dissertation has several strengths pertaining to the longitudinal design of the QLSCD and the analytical strategy adopted in each research paper. We discuss these two sets of strengths below.

Strengths of the QLSCD design

A great strength of the QLSCD is the broad range of measures collected prospectively, making it possible to establish temporality and to rule out one or the other causal direction for statistical association as well as to limit recall bias. Also, the QLSCD includes a sufficiently large population-based sample (N = 2120).

A second strength relies on high quality and repeated measures collected at multiple time points over 13 years. Of particular importance are annual measurements of poverty and behavior problems up to age 8 years. This allowed the examination of sensitive period models during early childhood as well as on behavior problems patterns of change from early to middle childhood.

Third, the initial QLSCD sample was representative of the province's general population of singletons with high response rates in the first two waves of data collection (i.e. about 96% and 94% when children aged 1.5 years and 2.5 years, respectively).

A fourth strength is that behavior problems were assessed using indices and existing validated scales, such as the early childhood behavior scale; and starting as early as age 1.5 years.

A fifth strength is that data was assessed by multiple informants including parents and teachers (e.g. behavior problems, family process) as well as trained research assistants (e.g. maternal depression).

A sixth strength is the measurement of poverty based on national thresholds (i.e., LICOs) which have been suggested as the most widely accepted measure of economic deprivation in Canada (Nikiéma et al., 2012).

A seventh strength is that QLSCD data allows to control for several confounders described in the literature and to explore simultaneously different types of parenting constructs (i.e. *article 1*), as opposed to aggregated measures of negative or positive parenting, rarely considered in the literature.

And finally, the detailed measures of behavior problems allowed the examination of three subtypes of behavior problems separately, suggesting that poverty is a common risk factor for all three behavior problems which (a) is age-dependent only to certain behavior problems, (b) exerts different effects on behavior problems subtypes depending on the timing and duration of exposure and (c) with differentiated patterns of mediation for family processes (i.e. higher levels of overprotection were related to higher levels of hyperactivity but unexpectedly, to lower levels of physical aggression.)

Strengths of our analytical strategy

Other strengths of the current work rely on the use of latent and longitudinal statistical techniques in *articles 1* to *3*. First, in *article 1* behavior problems were modeled using a semi-parametric trajectory approach, which allowed to distinguish children into an atypically elevated trajectory-group and as such, reduced measurement error in the classification of children as highly disruptive. This modelling approach addresses group membership uncertainty by computing weighted averages based on high posterior probabilities of group membership (i.e. the likelihood that a person will be assigned to a given trajectory group) (Nagin, 2005). Individuals with higher probabilities are given a higher weight when defining the predicted trajectory groups. This weighted calculation of trajectories groups allows for the use of information provided from those that were well classified which, in turn, decreases measurement errors.

Second, LMMs used in *article 2* dealt with the autocorrelation of repeated measures in so that measurement errors in the former could be accounted for. Because longitudinal data comprise repeated measures on an individual, the observations are likely to be auto correlated, and if this autocorrelation is not taken into account, the standard errors of cross-sectional comparisons will be underestimated (Glymour et al., 2008). Similarly, standard errors of longitudinal effects will be overestimated. Also, given that this multilevel procedure is flexible in dealing with missing data, it allowed us to minimize selection bias in *article 2* by taking advantage of individuals with incomplete data.

Third, the empirical testing of competing life course models of childhood poverty predicting behavior problems in early adolescence in *article 3* using a well-defined model-building framework (Mishra et al., 2009). We distinguished accumulation of risk versus mobility effects rarely found in the literature.

Other advantages of our study include the use of multiply imputed datasets and sensitive analyses in each research paper to address differential attrition and missing data, particularly common in longitudinal studies and poverty research.

5.3.2 General limitations

Despite the considerable strengths of the current work, there are several limitations regarding both internal and external validity of the main findings. Some of these limitations have to do with variation in data quality given the length of the follow-up period, data from multiple sources, and change in data measurements. Other limitations arise from statistical issues in our modeling approaches. Limitations are discussed in detail below.

Of major concern was sample attrition in the QLSCD. Implications were three-fold:

(a) Loss of observations on any variables of interest in *articles 1* to *3* reduced our initial sample size, which in turn, decreased our statistical power. And,

(b) As mentioned in Chapter 3, respondents living in poverty, of low education (i.e., who had a high school diploma or less), as well as in single-parent and immigrant families were more likely to drop out from the QLSCD. So that, attrition was not a random phenomenon given that the probability of discontinued participation or loss to follow-up was depended on a socioeconomic disadvantage (i.e. informative dropout). In addition, attrition was non-random because of losing respondents of a particular type and could possibly underestimate the magnitude of poverty effects in our findings. However, differential attrition over time could only underestimate the observed associations and become a source of selection bias if attrition was dependent on both the exposure of interest (i.e. being poor) as well as the outcomes (i.e. having high levels of behavior problems).

(c) A further limitation of data completeness relates to multiple source data (i.e. parents and teachers) and was identified in *article 3*. The number of participants for whom data were complete on all outcome variables as reported by teachers reduced sample size even further. When participants were 13 years of age, 1290 parents from the initial sample agreed to participate and remained in the study.

Parallel questionnaires were obtained from the teachers of participating children, of which a total of 983 had nonmissing values on at least one of the three subtypes of behavior problems. Hence, retention rates differed between parents and teachers with response rates of 60.8% for parents and 46.5% for teachers. Reassuringly, extensive sensitivity analyses were performed to re-estimate life course models accounting for sample loss and non-response by age 13 years (for details, see Chapter 4).

A second limitation involves examining latent constructs (i.e. behavior problems), that cannot be measured directly and were based on observations from multiple sources. In *articles 1* and *2*, we relied solely on maternal ratings to assess the variables of interest (i.e. exposure, outcomes and mediators) that associations between these measures are likely inflated by shared method variance (Affrunti & Woodruff-Borden, 2015). However, we focused on maternal ratings, as mothers were systematically identified as the person being most knowledgeable about the child throughout the QLSCD. A second reason to focus on maternal ratings was that mothers could provide information from early-to-middle childhood; teacher's ratings can only be used at age 6 years onwards. Ideally, children's behavior problems should be assessed by multiple informants (e.g. parents and teachers). Research suggest that behavior problems should include information about child functioning and cross-setting impairment, which is typically operationalized by combining ratings from both teacher and parent (DuPaul & Stoner, 2014). In *article 3*, behavior problems levels were based on reports provided only by teachers. Although estimates of behavior problems in children and adolescents are generally lower in studies based upon teacher ratings as opposed to parent ratings (Willcutt, 2012), they should be interpreted with caution. It is possible that teacher's level of experience and other characteristics may influence informant's ratings (DuPaul, Reid, Anastopoulos, & Power, 2014). Reassuringly, pooled results suggest that the prevalence of DSM-IV ADHD is similar, whether ADHD is defined by parent ratings, teacher ratings, or a best estimate diagnostic procedure in children and adolescents (5.9– 7.1 %) (Willcutt, 2012). Unfortunately, because we had only two measurement occasions (age 6 and 7 years) with both parental and teacher ratings, we were unable to adequately verify the informant agreement for behavior problems levels.

Third, despite the fact that we used a sample of 2120 children, we had an unbalanced sample of poor and non-poor children with a small number of participants exposed poverty (e.g. 24.1% at baseline, 32.1% between 0-3 years). This issue is particularly important in *article 3*, given that the lack of power may be an issue when examining lifecourse models that includes interaction terms. Specific analyses in the structure modelling approach (Mishra et al., 2009) require even larger samples as is the case for the mobility models. The lack of a significant association in mobility models may therefore reflect this shortcoming. This pleads for collaborations with other longitudinal studies as an attempt to pool together a larger longitudinal sample with more variation in poverty exposures. Nevertheless, this limitation does not jeopardize the conclusion that association between childhood poverty and behavior problems in adolescence correspond to both prolonged exposure to poverty as well as the focus on the earliest years of life.

Another point bear mention regarding the number of participants and issues of unbalanced sample. At the time of writing the research protocol of the current work, we undertook a power simulation study to assess the feasibility in examining the differential effects of the timing of poverty on behavior problems from birth to early adolescence. With the QLSCD collected over 13 years, the sample size was fixed and there was a need to ensure that the proposed analysis would be sufficiently powered to answer the main question. Our results indicated an 80% probability of detecting with the QLSCD fixed sample size to find a significant association between exposure to poverty and behavior problems in the context of LMMs at an alpha level of 5%. Please see **Appendix VII** for detailed description of power simulations and formulas used.

Fourth, although we careful controlled for confounders through statistical adjustment in a regression models in all research papers forming the main body of this dissertation, our capacity to make causal inferences is limited. It is possible that unmeasured and poorly measured confounders or model misspecification might explain the observed associations. The use of DAGs in *articles 2* and *3* was an attempt to illustrate sharing common causes between poverty and behavior and estimated the longitudinal associations within levels of identified confounders as documented in the literature. We do not suggest that those DAGs are the only possibility to represent the putative causal association between poverty and behavior problems as presented in *articles 2* and *3*.

Another shortcoming in approaching confounders by the use of DAGs is the fact that they do not illustrate effect-modification and interaction terms. This issue was specific to *article 3* which did not report each life course model separately due to the fact that poverty exposures within mobility models could not be represented. Also, the equality constraint between P1, P2 and P3 in the accumulation model (strict) would not be represented by DAGs. Further, statistical adjustment and DAGs depend on the assumption that all of the common causes of the exposure and the outcome, or at least some variable along the pathway linking these confounders to either the exposure or the outcome, have been measured (Glymour et al., 2008). They also depend on a second assumption that that all confounding paths have been blocked deemed often implausible by the authors. So that, it is possible that unexamined variables explain part of the observed associations in the present work.

Lastly, another important limitation worth mentioning relates to mediation models in *article 1*. First, associations in main mediation models may be bidirectional due to the lack of temporally ordered data. To address this limitation, complementary analyses were performed to examine concerns about reverse causality bias emerging from partially overlapping data between exposure, mediators and outcomes variables. The analyses presented mediation models with a clear temporal precedence of variables (for details, see Chapter 4). Reassuringly, models respecting temporal ordering of variables replicated patterns of associations found in main mediation models. These convergent patterns of findings indicate the possible direction of the association under investigation, i.e. from poverty to perceived parenting and maternal depression symptoms to behavior problems.

5.4 Emerging issues and future research

The evidence produced in the current dissertation is relevant to the public policy debate on identifying children living in poverty and reducing mental health disparities. Policies directed at reducing or even eliminating child poverty would have the added benefit of reducing the gap in behavior problems levels between children living in poverty and their counterparts. This is important because the 2008 crises and the global recession have harmed children's health, and disproportionately affected the most disadvantaged groups even in high-income countries (Rajmil et al., 2014). Specifically, this study suggested that trends of behavior problems in children have increased following austerity measures from the 2008 crises in certain countries. Thus, it is urgent to support youth living in poverty. Lastly, our definition of relative poverty implies that there will always be families in poverty even if income levels are raised for everyone. However, there is compelling evidence that income gains might matter most to children's development at the bottom of the income distribution.

There are several ways to improve living conditions of poor children such as boosting income and service delivery even in a high-income country like Canada, which should be prioritized during pregnancy and early childhood following findings from *articles 1 to 3*. Prevention efforts could place a greater emphasis on negative life events related to poverty during pregnancy so that additional support could be provided at that time to reduce the impact of such events on maternal mental and physical health, in addition to their offspring. Support programs extending financial benefits to poor families suggest that increasing tax credits is likely to decrease children's and adolescent's behavior problems (Akee et al., 2010; Hamad & Rehkopf, 2016). Other support programs, including center-based child care and parent training, are increasingly recognized to benefit children from low-income families in achievement domains as well as to play a protective role in the development of behavior problems (Côté et al., 2007; Dishion et al., 2014; Laurin et al., 2015).

Moreover, future studies should examine the effects of specific prenatal factors and attempt to disentangle genetic and prenatal environmental effects in the etiology of behavior problems. Also, because mediation models are valuable tools in the practice of preventive medicine and public health, they should be further explored. Targeting poverty seems to be the most promising avenue in reducing the risk of behavior problems. Yet identifying intervening factors at a more micro level, such as the family environment, could also contribute to boost childhood development and well-being. As further studies continue to investigate life course process (e.g. immediate risk, cumulative effects, latency, or mobility) of exposure to poverty associated with the development of behavior problems, differences between behavior problems subtypes requires greater scrutiny.

Also, findings from *articles 1* to *3* add to the ongoing debate of implementing a universal basic income to tackle poverty and social disadvantage. Our results support the feasibility of experimental research on the effectiveness of basic income schemes to insure to income maintenance and combat the risk of behavior problems over the first years of life. This could lead to empirical evidence in favor of a universal unconditional basic income to reduce child poverty and, in turn, promote child health and well-being. Most recently, a large-scale poverty reduction experimental study in the United Stated has been proposed covering the first five years of life (Duncan, Magnuson, & Votruba-Drzal, 2017). Specifically, low-income families with newborns were recruited into a five-year study of early child development and randomly assigned to treatment or control groups whereby control families are provided with monthly payments (i.e. $20) and experimental families much larger monthly payments (i.e. $333 per month, or $4,000 per year). So that, the $3,760 annual difference between the treatment and control groups constitutes a substantial income increase for a family with an income near the poverty line. This knowledge will be invaluable to advance public policies on guaranteed income to improve child health and wellbeing in broader ways. In Canada, a basic income pilot-program has been proposed by the Ontario provincial government for April 2017 to alleviate the burden of poverty (as measured by the LIM) by providing $1,320 a month (i.e. $16,989 annually). Also based on an experimental design, this program does not target the early years of life but rather individuals ages 18-65 years and their children (Government of Ontario, 2016). This can yield new insight from previous intervention efforts in the Canadian context supporting guaranteed annual income to improve overall health (Forget, 2013).

Lastly, it is important to stress once more that our findings should not be singly relied upon for causal inference. Additional research, as with any research, is needed to explore whether these patterns of findings can be replicated in other samples and in other settings with different social and health care policies.

CHAPTER 6

Conclusion

The current dissertation strengthens empirical support for the causal association between poverty and behavior problems outcomes by demonstrating the importance of early childhood as a sensitive period as well as prolonged exposure to poverty over the course of development. In line with the existing literature, poverty was found to be a risk factor for behavior problems among children and adolescents. Patterns of association were found to be behavior problems-specific and indirect effects of family process, including maternal depression and parenting, were identified linking poverty to behavior problems during early childhood.

This research advocates the need to focus on understanding and then improving living conditions of poor children as the most viable option in the early years of life to reduce behavior problems disparities that are likely to persist and grow overtime. Our findings underscore the importance of identifying poor families with children and proving further assistance to relief economic pressure, coupled with other stressful events that are more prevalent among poor families.

Given the importance of exposure to poverty from birth to age 5 years observed in this research, our findings have strengthened the argument for antipoverty policies that prioritize early childhood and the pre-natal period to close the gap in mental health disparities. Also, this research reinforce the direct effect of income-based child poverty on the etiology of behavior problems and the need to use this type of deprivation measurement to monitor trends and the effects on public policies affecting children's health and well-being as suggested by recent research (Wickham, Whitehead, Taylor-Robinson, & Barr, 2017).

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APPENDICES

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Appendix I. QLSCD Ethical approval 1998

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Phase I

Montréal, le 10 mars 1998

Monsieur Richard Tremblay
Université de Montréal - GRIP
350, Édouard-Montpetit
C.P. 6128
Montréal (Québec) H3C 3J7

Objet: Enquête Santé Québec «En 2002 j'aurai 5 ans»

Cher monsieur Tremblay,

Lors de sa dernière réunion tenue le 12 février dernier, le comité d'éthique de Santé Québec a étudié le projet en titre.

Le comité, après discussion, réserve pour le moment sa décision quant à l'approbation du dit projet et désirerait obtenir des précisions supplémentaires. Le comité approuvera le projet dès que les précisions et correctifs seront apportés à sa satisfaction.

Les éléments suivants pourraient être précisés davantage :

- Simplifier la lettre de consentement éclairé dont les termes apparaissent comme hermétiques et peu accessibles au commun des mortels d'y inclure de l'information simplifiée expliquant la nature du projet.
- Présenter une procédure claire et finale de transfert et de garde des données.

Veuillez agréer, Cher Monsieur Tremblay, l'expression de nos sentiments distingués.

Pierre Durand
Président du comité d'éthique

c.c. Daniel Tremblay, directeur de Santé Québec
Mireille Jetté, coordonnateure du projet

Appendix II. QLSCD Ethical approval 2011

CHU Sainte-Justine
Le centre hospitalier universitaire mère-enfant

Pour l'amour des enfants

Université de Montréal

Le 28 mars 2011

Docteur Richard E. Tremblay
GRIP - Université de Montréal
3050 Edouard Montpetit
Montréal (Qc) H3T 1J7

OBJET: Titre du projet: BANQUE DE DONNÉES: ÉLDEQ (EN 2002) Étude longitudinale du développement des enfants au Québec

No. de dossier: 2762

Responsables du projet: Richard E. Tremblay M.D., et Michel Boivin, chercheurs responsables au CHU Sainte-Justine

Cher Docteur,

Ayant reçu les résumés des demandes d'accès aux données GRIP pour analyses exploratoires (DADEX) et pour publication (DADpub) pour les 3 périodes de l'année 2010, nous avons le plaisir de vous annoncer que votre projet cité en rubrique a été réapprouvé par le comité d'éthique de la recherche en date d'aujourd'hui.

Il est de votre responsabilité d'aviser le comité dans les plus brefs délais de toute modification au protocole.

Un résumé des demandes d'accès aux banques doit être acheminé au comité du CHU Sainte-Justine 3 fois par année, soit à la 1ère semaine des mois de mai (pour la période du 1er janvier au 30 avril), septembre (pour la période du 1er mai au 31 août) et janvier (pour la période du 1er septembre au 31 décembre 2010).

Recevez, Cher Docteur, nos salutations distinguées.

[redacted]

Jean-Marie Therrien, Ph.D., éthicien
Président du Comité d'éthique de la recherche

JMT/cp

Appendix III. QLSCD Informed consent form

In 2002... I'll be 5 years old !

2 - 3 8 - ☐ - ☐ - ☐☐ - ☐☐☐☐ - ☐☐☐

1 2 3 4 5 6 7 8 9 10 11 12 13 14

AUTHORIZATION TO DIVULGE INFORMATION
CONTAINED IN FILES ON MOTHER AND BABY

Surname and first name at birth (baby's mother)

Name currently used (baby's mother)

Current addresses of baby's mother

Baby's RAMQ N° — Date of Birth of baby's mother Y M D

Surname and first name of baby's father — Surname and first name of mother (i.e. baby's maternal grandmother)

Surname and first name of baby — Sex: Female or male

Baby's RAMQ N° — Date of birth of baby Y M D

Status of the form

Completed	1
Non completed	2

Admission Date of childbirth :

I, the undersigned, ____________________
Name and current address of baby's mother

in the capacity of ____________________
Beneficiary of authorized individual

do hereby authorize the following establishment: ____________________
Name of the hospital where the delivery took place

to forward to: [redacted]

the following information concerning:

the Mother:
1) Complete summary of obstetrics file
2) Results of anatomopathology exam of placenta
3) Summary Sheet - Hospital (short term stay)

the Baby:
1) Complete summary of newborn medical file
2) Results of umbilical cord blood sample

regarding the care and services received during the period from: ____________ to ____________ as contained in the file of the beneficiaries identified hereinabove.

This authorization shall be valid for a period of ninety (90) days from the date of signing.

____
Signature of beneficiary or authorized individual

Date Y M D

____
Signature of witness (Santé Québec/EIP Interviewer)

Date Y M D

NB: One must ensure that the signatories hereto are authorized to do so under the provisions of applicable legislation.

For consultation only

Appendix IV. Response rates and descriptive statistics of QLSCD

Table 1 Response rates of QLSCD at baseline according to demographics characteristics [a]

Category		Response rates
Maternal age (years)		
	≤19	65.5 %
	20-24	73.9 %
	25-29	77.6 %
	30-34	77.6 %
	> 35	69.4 %
Maternal education		
	No high school diploma	43.3 %
	High school diploma	65.8 %
	Post-secondary degree	74.3 %
	University degree	83.6 %
Language used at home		
	French	79.3 %
	English	68.5 %
	Others	45.9 %
Sanitary region		
	Saguenay S Lac-Saint-Jean	87.4 %
	Québec	84.0%
	Mauricie	86.2 %
	Estrie	82.3 %
	Montreal	63.2 %
	Outaouais	78.0%
	Abitibi-Témiscamingue	79.3 %
	Gaspésie S Îles-de-la-Madaleine	85.2 %
	Laval	75.8 %
	Laurentides Montérégie	79.8 %
	Lanaudière	76.7 %
	Chaudière-Appalaches	63.4 %

[a] « Milieux de vie : la famille, la garde et le quartier » dans Étude longitudinale du développement des enfants du Québec (ÉLDEQ 1998-2002)(Desrosiers, 2000).

Table 2 Characteristics of QLSCD sample present at 13 years of age and sub-sample with missing data according to of primary outcomes.

Variables	Full sample	Sub-sample with incomplete data of primary outcomes
	n (%)	n (%)
Male sex	603(46.7)	159(51.8)
Maternal immigrant status	108(8.4)	39(12.7)
Separated or single parents	449(34.8)	114(37.1)
High school diploma or less	374(29.0)	101(32.9)
Poverty	153(11.9)	52(16.9)
	Mean ± SD	Mean ± SD
Age of motherhood	26.7 ± 4.91	25.7 ± 5.09
Maternal history of antisocial behavior	0.80 ± 0.91	0.85 ± 0.95
Hyperactivity at 12 years of age	1.35 ± 2.06	1.54 ± 2.11
Physical aggression at 12 years of age	0.79 ± 1.44	0.83 ± 1.44
Opposition at 12 years of age	1.39 ± 2.23	1.76 ± 2.46

Note. Full sample corresponds to a total of 1290 participants present at the 13 years of age assessment and the sub-sample with incomplete data corresponds to a total of 307 participants that had missing values for hyperactivity, opposition and psychical aggression at 13 years of age assessment. Poverty, family structure and maternal education correspond to the 13 years of age assessment. Age of motherhood ranged 15 to 41 years of age. Maternal history of antisocial behavior coded so that higher scores indicated higher levels of antisocial behavior (range 0 to 5). Behavior problems coded so that higher scores indicated higher levels of behavior problems at 12 years of age (range 0 to 9 for hyperactivity, range 0 to 10 to opposition, and range 0 to 8 to physical aggression).

Table 3 Remaining participants and corresponding response rates in the QLSCD after 13 years of follow-up.

Year of data collection	Average age of participants (in years)	QLSCD sample size N (%)
1997-1998	0.5	2120 (100)
1999	1.5	2045 (96.5)
2000	2.5	1997 (94.1)
2001	3.5	1950 (92.0)
2002	4.5	1944 (91.7)
2003	5	1759 (83.0)
2004	6	1492 (70.4)
2005	7	1528 (72.1)
2006	8	1451 (68.4)
2008	10	1334 (62.9)
2010	12	1396 (65.9)
2011	13	1290 (60.8)

Note. N refers to the total participants in the QLSCD at each assessment; % refers to corresponding response rates of participants in the QLSCD.

Table 4 Frequency of participants according to the number of wave nonresponse in the QLSCD from 0.5 to 13 years of age.

Number of times participants missed a wave	N(%)
0	984 (46.4)
1	233 (11.0)
2	129 (6.1)
3	121 (5.7)
4	112 (5.3)
5	121 (5.7)
6	161 (7.6)
7	109 (5.1)
8	22 (1.0)
9	20 (0.9)
10	45 (2.1)
11	63 (3.0)

Appendix V. QLSCD variables description

Table 1 Overview of primary outcomes items used in the current work.

Behavior problems, Items	Age (in years)							
	1.5	2.5	3.5	4.5	5	6	8	13
Hyperactivity,								
Could not sit still, was restless and hyperactive;	√	√	√	√	√	√	√	√
Could not stop fidgeting;	√	√	√	√	√	√	√	
Was impulsive, acted without thinking	√	√	√	√	√	√	√	√
Had difficulty waiting for his/her turn in games	√	√	√	√	√	√	√	√
Could not settle down to do anything for more than a very short period of time	√	√	√	√	√	√	√	√
Opposition,								
is defiant or refuses to comply with adults request or rules	√	√	√	√	√	√	√	√
doesn't seem to feel guilty after misbehaving	√	√	√	√	√	√	√	√
punishment doesn't change his/her behaviour	√	√	√	√	√	√	√	√
Physical aggression,								
Gets into fights?	√	√	√	√	√	√	√	√
Hits, bites, kicks other children	√	√	√	√	√	√	√	√
Physically attacks others	√	√	√	√	√	√	√	√

Note. Maternal reported from 1.5, 2.5, 3.5, 4.5, 5, 6, 7 to 8 years and teacher reported at 13 years

Table 2 Distribution of behavior problems from 1.5 to 13 years of age according to informant source (N=2120)

Age	Hyperactivity	Physical aggression	Opposition
	N (Mean±SD)	N (Mean ± SD)	N (Mean±SD)
1.5[1]	2045 (3.92 ± 2.40)	2045 (1.33 ± 1.53)	2045 (3.41 ± 2.14)
2.5[1]	1997 (3.91 ± 2.38)	1997 (1.88 ± 1.72)	1997 (3.60 ± 2.29)
3.5[1]	1948 (4.22 ± 2.15)	1949 (2.29 ± 2.26)	1950 (3.88 ± 2.29)
4.5 [1]	1942 (3.88 ± 2.15)	1942 (1.82 ± 2.08)	1942 (3.58 ± 2.15)
5 [1]	1759 (3.99 ± 2.09)	1759 (1.77 ± 2.10)	1759 (3.50 ± 2.11)
6 [1]	1492 (3.79 ± 2.20)	1492 (1.63 ± 2.05)	1492 (3.47 ± 2.00)
8 [1]	1450 (3.18 ± 2.25)	1267 (1.53 ± 2.08)	1450 (3.03 ± 2.08)
13[2]	938 (1.48 ± 2.39)	893 (0.35 ± 1.27)	952(1.02 ± 2.14)

Note. 1= Maternal reported and 2=Teacher reported; Behavior problems coded so that higher scores indicated higher levels of behavior problems.

Table 3 BIC statistics and intercept estimates for models with 2, 3, and 4 trajectory groups.

	Physical Aggression				
	BIC	Low	Moderate	High	High-rising
Model					
2-trajectory	-13419.05	-1.01	-2.01	-	-
3-trajectory	-13257.30	-1.35	-2.78	-0.26	-
4-trajectory	-13245.14	-8.73	-0.71	-3.00	-0.07

	Hyperactivity				
	BIC	Low	Moderate	High	High-rising
Model					
2-trajectory	-20537.29	2.69	4.75	-	-
3-trajectory	-20216.69	1.98	3.95	5.14	-
4-trajectory	-20133.29	1.28	3.25	4.99	4.38

Note. Analyses were conducted on the 2045 participants with data available for behavior problems.

Table 4 Distribution of poverty from baseline to 13 years of age and changes in sampling composition overtime.

Age (in years)	Poverty		Total
	Poor N (%)	Non-Poor N (%)	
0.5	511(24.1)	1571(74.1)	2082(98.2)
1.5	416(19.6)	1599(75.4)	2015(95.0)
2.5	398(17.4)	1598(75.4)	1996(92.8)
3.5	319(15.0)	1594(75.2)	1913(90.2)
4.5	-	-	-
5	298(14.1)	1438(67.8)	1736(81.9)
6	245(11.6)	1235(58.3)	1480(69.9)
8	218(10.3)	1220(57.5)	1438(67.8)
10	151(7.1)	1176(55.5)	1327(62.6)
12	185(8.7)	1203(56.7)	1388(65.4)
13	153(7.2)	1120(52.8)	1273(60.0)

Note. Poverty status was not available at 4.5 years of age.

Table 5 Items of family functioning, depression symptoms and parenting.

Measurement	Items
Family functioning (7)	Individuals (in the family) are accepted for what they are. We express feelings to each other.(R) There are lots of bad feelings in our family. We feel accepted for what we are. (R) We are able to make decisions about how to solve problems.(R) We don't get along well together. We confide in each other. (R)
Depression symptoms (9)	I felt depressed. I felt that everything I did was an effort. I felt hopeful about the future. My sleep was restless. I was happy.(R) I felt lonely. I enjoyed life. I had crying spells. I felt that people disliked me.
Self-efficacy (7)	I feel that I am very good at keeping my baby amused. I feel that I am very good at calming my baby down when he/she is upset, fussy or crying. I feel that I am very good at keeping my baby busy while I am doing other things. I feel that I am very good at attracting the attention of my baby. I feel that I am very good at feeding my baby, changing his/her diapers, and giving him/her a bath. In general, do you think you are 'a good mother/a good father'?
Perceived impact (5)	My behaviour has little effect on the personal development of my baby.(R) Regardless of what I do, my baby will develop on his/her own.(R) My behaviour has little effect on the intellectual development of my baby.(R) My behaviour has little effect on the development of emotions (for example, happiness, fear, anger) in my baby. (R) My behaviour has little effect on how my baby will interact with others in the future. (R)
Coercive parenting (7)	I have been angry with my baby when he/she was particularly fussy. When my baby cries, he/she gets on my nerves. I have raised my voice with or shouted at my baby when he/she was particularly fussy. I have spanked my baby when he/she was particularly fussy. I have lost my temper when my baby was particularly fussy. I have left my baby alone in his/her bedroom when he/she was particularly fussy. I have shaken my baby when he/she was particularly fussy.
Overprotection (5)	I insist upon keeping my baby close to me at all times, within my eyesight and in the same room as I am. I consider myself a 'real mother hen.' I prefer that my baby sleeps in the same room as me at night. When I leave my baby with a baby-sitter, I miss him/her so much that I cannot enjoy myself. I can never bring myself to leave my baby with a baby-sitter.

(R) Reverse-coded.

Table 6 Distribution of family mediators by exposure to chronic poverty.

Variables, mean ± SD	QLSCD sample	Poverty			Missing (%)
		Not chronic	Chronic	Sig.†	
Maternal depression symptoms	1.43 ± 1.40	1.27 ± 1.29	1.87 ± 1.54	< .001.	41(2.3)
Self-efficacy	8.29 ± 1.19	8.27 ± 1.14	8.35 ± 1.32		47(2.7)
Perceived impact	8.25 ± 1.70	8.50 ± 1.46	7.60 ± 2.12	< .001.	47(2.7)
Coercive parenting	3.81 ± 2.08	3.83 ± 2.08	3.77 ± 2.08		47(2.7)
Overprotection	4.40 ± 2.23	4.06 ± 2.04	5.34 ± 2.45	< .001.	47(2.7)
Family dysfunction	1.31 ± 1.30	1.22 ± 1.25	1.58 ± 1.41	< .001.	123(7.0)

Note. Poverty coded so 1=chronic and 0=otherwise. Maternal depression symptoms coded so that higher scores indicate at risk of depression or in need of treatment. Parenting variables coded so that higher scores indicate higher levels of parenting behavior. Family dysfunction coded so that higher scores indicate higher levels of family conflict.

†P-value determined using analysis of variance F test.

Table 7. Correlation matrix between poverty, behavior problems, and potential mediators.

Variables	1	2	3	4	5	6	7	8	9
1. Physical aggression	1								
2. Hyperactivity	.228**	1							
3.Poverty	.080**	.137**	1						
4. Self-efficacy	-.100**	-.114**	.029	1					
5. Perceived impact	-.051*	-.091**	-.232**	.153**	1				
6. Coercive parenting	.146**	.155**	-.010	-.136**	-.108**	1			
7. Overprotection	-.061*	.113**	.254**	.071**	-.279**	-.068**	1		
8. Maternal depression	.121**	.121**	.193**	-.197**	-.169**	.174**	.182**	1	
9. Family dysfunction	.068**	.067**	.119**	-.251**	-.147**	.071**	.089**	.373**	1

Note. Poverty coded so 1=chronic and 0=otherwise. Trajectories of behavior problems coded so 1=high group and 0=low/moderate groups. Maternal depression symptoms coded so that higher scores indicated at risk of depression or in need of treatment (range 0 to 10). Parenting constructs coded so that higher scores indicated higher levels of perceived parenting (range 0 to 10). Family dysfunction coded so that higher scores indicated higher levels of family conflict (range 0 to 10).

* $p < .01$. ** $p < .001$.

Table 8 Summary of variables used in research article 1 "Poverty and behavior problems during early childhood: The mediating role of maternal depression symptoms and parenting".

Variables	Informant	Age	Scale and coding	Variable type by article
High trajectories of physical aggression and hyperactivity	Mothers	1.5, 2.5, 3.5, 4.5, and 5 years	Dichotomous 1=high, 0=otherwise	O
Chronic Poverty	Mothers	0.5, 1.5, 2.5, and 3.5 years	Dichotomous 1= poor ≥ 2 years, 0=otherwise	E
Family dysfunction	Mothers	1.5 years	Continuous 10-point scale	M
Maternal depression symptoms	Mothers	1.5 years	Continuous 10-point scale	M
Self-efficacy	Mothers	1.5 and 2.5 years	Continuous 10-point scale	M
Parental impact	Mothers	1.5 and 2.5 years	Continuous 10-point scale	M
Coercion	Mothers	1.5 and 2.5 years	Continuous 10-point scale	M
Overprotection	Mothers	1.5 and 2.5 years	Continuous 10-point scale	M
Sex of the child	Mothers	0.5 years	Dichotomous 1= boy, 0=girl	C
Low maternal education	Mothers	0.5, 1.5, 2.5, 3.5, 4.5, and 5 years	Dichotomous 1= no high-school diploma when the child was 5 years of age, 0=otherwise	C
Family structure	Mothers	0.5, 1.5, 2.5, 3.5, 4.5, and 5 years	Dichotomous 1= biological parents were separated or single ≥ 2 years, 0=otherwise	C

Note. O=Outcome variables, E=Exposure variable, M= potential mediators, C=confounders

Table 9 Summary of variables used in research article 2 “Poverty and behavior problems trajectories from 1.5 to 8 years of age: Is the gap widening between poor and non-poor children?”.

Variables	Informant	Age	Scale and coding	Variable type by article
Physical aggression, hyperactivity and opposition	Mothers	0.5, 2.5, 3.5, 4.5, 5, 6, and 8 years	Continuous 6-point scales for Physical aggression and opposition, and 10-point scale for hyperactivity	O
Poverty	Mothers	1.5, 2.5, 3.5, 5, 6, and 8 years	Dichotomous 1= poor, 0=otherwise	E
Sex of the child	Mothers	0.5 years	Dichotomous 1= boy, 0=girl	C
Immigration status	Mothers	0.5 years	Dichotomous 1= was immigrant/not born in Canada, 0=otherwise	C
Maternal history of antisocial behavior	Mothers	0.5 years	Continuous 5-point scale	C
Low maternal education	Mothers	1.5, 2.5, 3.5, 4.5, 5, 6, and 8 years	Dichotomous 1= mothers who did not complete high-school, 0=otherwise	C
Family structure	Mothers	1.5, 2.5, 3.5, 4.5, 5, 6, and 8 years	Dichotomous 1= biological parents were separated or single ≥ 2 years, 0=otherwise	C

Note. O=Outcome variables, E=Exposure variable, M= potential mediators, C=confounders

Table 10 Summary of variables used in research article 3 "Early adolescence behavior problems and timing of exposure to childhood poverty: Comparing lifecourse models".

Variables	Informant	Age	Scale and coding	Variable type by article
Physical aggression, hyperactivity and opposition scores	Teachers	13 years	Continuous 10-point scale	O
Poverty between ages 0-3 years (P1)	Mothers	0.5, 1.5, 2.5 and 3.5 years	Dichotomous 1= poor ≥ 1 year, 0=otherwise	E
Poverty between ages 5-7 years (P2)	Mothers	5, 6 and 7 years	Dichotomous 1= poor ≥ 1 year, 0=otherwise	E
Poverty between ages 8-12 years (P3)	Mothers	8, 10 and 12 years	Dichotomous 1= poor ≥ 1 year, 0=otherwise	E
Sex of the child	Mothers	0.5 years	Dichotomous 1= boy, 0=girl	C
Immigration status	Mothers	0.5 years	Dichotomous 1= was immigrant/not born in Canada, 0=otherwise	C
Maternal history of antisocial behavior	Mothers	0.5 years	Continuous 5-point scale	C
Low maternal education	Mothers	0.5, 3.5 and 8 years	Dichotomous 1= mothers who did not complete high-school, 0=otherwise	C
Family structure	Mothers	0.5, 3.5 and 8 years	Dichotomous 1= biological parents were separated or single ≥ 2 years, 0=otherwise	C

Note. O=Outcome variables, E=Exposure variable, M= potential mediators, C=confounders

Figure 1 DAG illustrating the hypothesized causal structure underlying confounding bias in the association between poverty and behavior problems (Article 2)

Using DAGitty 2.2 [1] , we show that the exposure of interest (i.e. poverty) directly influences the outcome (i.e. behavior problems). Additionally, the outcome is associated with an unmeasured factor, U (i.e. genetic vulnerability). Confounders are represented by factors that influence two or more variables shown in the DAG (i.e. common causes). We represent adjustment in the diagram by the labeling ◯ which in turn resulted in closed biasing paths from exposure to the outcome. Otherwise, open biasing paths would be represented by diagram arrows in red. Open causal paths are represented by the diagram arrow in green. See the legend below for a full description of variables and arrows statuses in DAGgitty 2.2:

Variables and arrows	Legend
	Exposure
	Outcome
	Ancestor of exposure
	Ancestor of outcome
	Ancestor of exposure *and* outcome
	Adjusted variable
	Unobserved (latent)
	Other variable
	Causal path
	Biasing path

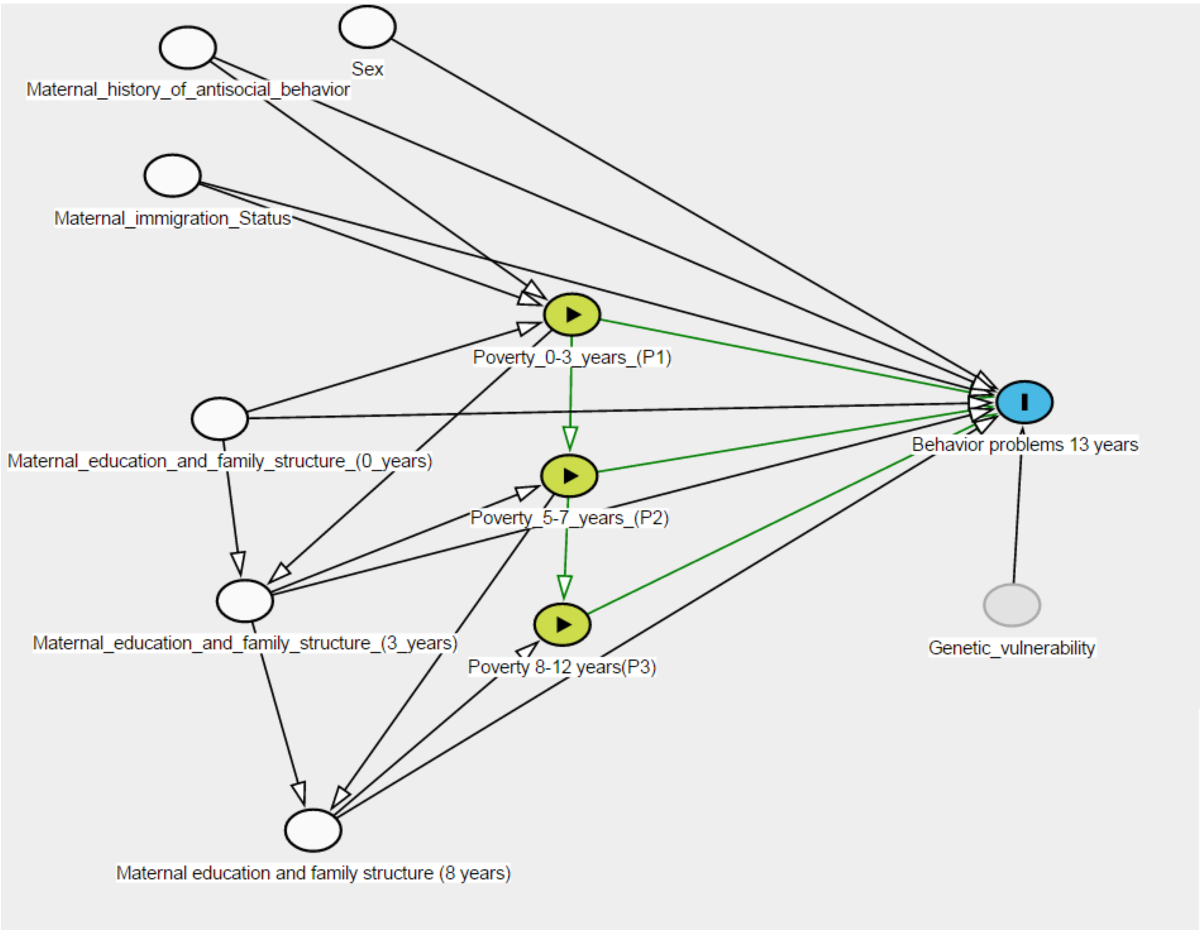
We considered only minimal adjustments sets to block the biasing paths from poverty to behavior problems. For an introduction to DAGs, we refer readers to Glymour MM, Greenland S. Chapter 12: Causal diagrams. In: Rothman KJ, Greenland S, Lash TL. Modern epidemiology. Lippincott Williams & Wilkins; 2008:183–209.

We do not suggest that this DAG is the only possibility. However, we assume that the DAG reflects a putative causal association between poverty and behavior problems. The DAG shows that poverty directly influences behavior problems.

References

[1] Textor J, Hardt J, Knüppel S (2011) DAGitty: a graphical tool for analyzing causal diagrams. Epidemiology 22(5): 745

Figure 2 DAG illustrating the hypothesized causal structure underlying confounding bias in the association between childhood poverty and behavior problems in early adolescence.



Using DAGitty 2.2 [1] , we show that the exposures of interest (i.e. P1, P2 and P3) directly influences behavior problems in early adolescence. Additionally, the outcome is associated with an unmeasured factor, U (i.e. genetic vulnerability). Confounders are represented by factors that influence two or more variables shown in the DAG (i.e. common causes). We represent adjustment in the diagram by the labeling ◯ which in turn resulted in closed biasing paths from exposure to the outcome. Otherwise, open biasing paths would be represented by diagram arrows in red. Open causal paths are represented by the diagram arrow in green and correspond to our main research question of childhood poverty predicting behavior problems in early adolescence. Interaction terms between P1, P2 and P3 within additive regression models were not represented by this DAG given that such diagrams are limited in illustrating effect-modification. See the legend below for a full description of variables and arrows statuses in DAGgitty 2.2:

Variables and arrows	Legend
	Exposure
	Outcome
	Ancestor of exposure
	Ancestor of outcome
	Ancestor of exposure *and* outcome
	Adjusted variable
	Unobserved (latent)
	Other variable

Causal path

Biasing path

We considered only minimal adjustments sets to block the biasing paths from childhood poverty to behavior problems. For an introduction to DAGs, we refer readers to Glymour MM, Greenland S. Chapter 12: Causal diagrams. In: Rothman KJ, Greenland S, Lash TL. Modern epidemiology. Lippincott Williams & Wilkins; 2008:183–209.

We do not suggest that this DAG is the only possibility. However, we assume that the DAG reflects a putative causal association between poverty and behavior problems. The DAG shows that poverty directly influences behavior problems.

References

[1] Textor J, Hardt J, Knüppel S (2011) DAGitty: a graphical tool for analyzing causal diagrams. Epidemiology 22(5): 745

Appendix VI. Structure modeling approach

Table 1 Nested and saturated models based on eight possible trajectories corresponding to each permutation of S1, S2, S3 that may influence the outcome Y

Permutations			Equations
S1	S2	S3	
0	0	0	$Y=\alpha$
1	0	0	$Y=\alpha + \beta_1 S_1$
0	1	0	$Y=\alpha + \beta_2 S_2$
0	0	1	$Y=\alpha + \beta_3 S_3$
1	1	0	$Y=\alpha + \beta_1 S_1 + \beta_2 S_2 + \theta_{12} S_1 S_2$
1	0	1	$Y=\alpha + \beta_1 S_1 + \beta_3 S_3 + \theta_{13} S_1 S_3$
0	1	1	$Y=\alpha + \beta_2 S_2 + \beta_3 S_3 + \theta_{23} S_2 S_3$
1	1	1	$Y=\alpha + \beta_1 S_1 + \beta_2 S_2 + \beta_3 S_3 + \theta_{12} S_1 S_2 + \theta_{13} S_1 S_3 + \theta_{23} S_2 P3 + \theta_{123} S_1 S_2 S_3$

Note. $Permutation_{000}$ is the reference category and $Permutation_{111}$ corresponds to the saturated model

Table 2 Estimating and comparing relative efficiencies of 5 and 20 imputed datasets based on QSLCD sample composition from ages 1.5 to 13 years.

Age	% of 2120	% of missing (γ)	Relative efficiency *m*=5 (A)	Relative efficiency *m*=20 (B)	Relative efficiency of A/B
1.5	0.965	0.035	0.993	0.998	0.995
2.5	0.941	0.059	0.988	0.997	0.991
3.5	0.920	0.080	0.984	0.996	0.988
4.5	0.917	0.083	0.984	0.996	0.988
5	0.830	0.170	0.967	0.992	0.975
6	0.704	0.296	0.944	0.985	0.958
7	0.721	0.279	0.947	0.986	0.960
8	0.684	0.316	0.941	0.984	0.955
10	0.629	0.371	0.931	0.982	0.948
12	0.659	0.341	0.936	0.983	0.952
13	0.608	0.392	0.927	0.981	0.945

Appendix VII. Sample size calculations

Sample size formula for a continuous variable in longitudinal analysis as presented in the research proposal

To examine the differential effects of the timing of poverty on behavior problems from birth to early adolescence., we used a sample size formula as below for (Fitzmaurice, Laird, & Ware, 2012):

$$n = \frac{4\left(z_{\alpha/2} + z_{\beta}\right)^2 \left(\frac{\sigma^2}{V} + \sigma_b^2\right)}{\Delta^2}$$

Where notion are as follow:

$z_{\alpha/2}$ = 1.96 (z value for Type I error in a two-sided test)

z_{β} = 0.842 (z value for Type II error)

$\frac{\sigma^2}{V}$ = Variance within-subject over time for the outcome under investigation

V= Variation of the number of time assessments.

P^1 =Proportion of participants in group 1

Δ^2=Mean difference between slopes of the outcome under investigation between two groups. calculated by P1 (1-P1)Δ^2.

σ_b^2 = Between–subject variance of slopes of the outcome under investigation.

Sample size Implications: Description of simulations for a continuous variable in longitudinal analysis

Because findings from pilot study and of previous research were not available, we conducted exploratory analyses on QLSCD data available from 5 months to 13 years of age to calculate sample size. We used mean levels of hyperactivity as perceived by mothers and teachers (1½ to 13 years of age) as the outcome to model a random intercept that allowed the baseline hyperactivity behavior to randomly vary across individuals and random slopes for age in years, poverty, and the age-poverty interaction. We set an unstructured covariance structure for these random effects. Fixed and random parameters were estimated by using restricted the maximum likelihood (REML) approach. This exploratory model provided a between-subjects slope variance of 0.045 and a residual variance of 3.077. The variation of the number of time assessments was calculated using the sum of squared deviation of the mean of values for the values 0.5, 1½, 2½, 3½, 4½, 5, 6, 7, 8, 10, 12 and 13 in years and it was 165.185.

Significance level was set as 5% and Type II was 20%. The number of observations for the exposed and non-exposed groups was 3106 (17% of all observations) and 15124 (83%) respectively. Sample size returned as 1325 (226 for the exposed group and 1099 for the non-exposed group). This procedure was repeated for the other opposition-defiant behavior. Sample size returned as 694 (118 for the exposed group and 576 for the non-exposed group). The age-poverty interaction term was not significant when modeling the poverty-physical aggression association over time. In other words, we found that with age the poverty gap between slopes in physical aggression was maintained. Thus, we calculated sample size to test for mean difference between parallel slopes. Following the exploratory analyses performed on QLSCD data, we used 0.252 as the mean difference between groups and the standard deviation of 1.022 for a mean score of physical aggression from 1½ to 13 years of age. Sample size returned as 915 participants (156 for the exposed group and 759 for the non-exposed group).

Sample size simulations for each specific outcome

Behavior problems	Sample size simulations in a longitudinal design with two proportions
Hyperactivity	$\alpha \rightarrow z_{\alpha/2}$ ($\alpha = 0.05 \Rightarrow z_{\alpha/2} = 1.96$) $\beta \rightarrow z_{\beta}$ ($\beta = 0.20 \Rightarrow z_{\beta} = 0.84$) , where $(1.96 + 0.84)^2 = 7.8512$ $\frac{\sigma^2}{V} + V(\beta 1) = (3.07653 / 165.185) + 0.044637 = 0.06326$ $P^1 (1-P^1) \Delta^2 = [0.1707 * 0.8296] * (0.051507)^2 = 0.000375$ N= (7.8512 * 0.06326) / 0.000375 =1325 *N = 1325 participants*
Physical aggression	$\alpha \rightarrow z_{\alpha/2}$ ($\alpha = 0.05 \Rightarrow z_{\alpha/2} = 1.96$) $\beta \rightarrow z_{\beta}$ ($\beta = 0.20 \Rightarrow z_{\beta} = 0.84$) $\Delta^2 = 0.252067$ $\sigma = 1.022$ for a mean score from 1½ to 13 years of age $P^1 (1-P^1) = 0.1707 * 0.8296$ N=915 *participants*
Opposition-defiant	$\alpha \rightarrow z_{\alpha/2}$ ($\alpha = 0.05 \Rightarrow z_{\alpha/2} = 1.96$) $\beta \rightarrow z_{\beta}$ ($\beta = 0.20 \Rightarrow z_{\beta} = 0.84$) , where $(1.96 + 0.84)^2 = 7.8512$ $\frac{\sigma^2}{V} + V(\beta 1) = (3.3375 / 165.185) + 0.036611 = 0.05631$ $P^1 (1-P^1) \Delta^2 = [0.1707 * 0.8296] * (0.067157)^2 = 0.0006375$ N= (7.8512 * 0.05631) / 0.0006375= 694 *N=694 participants*

Note: For hyperactivity and opposition-defiant behavior we compare the mean difference between slopes between exposed (i.e. poor) and non-exposed (i.e. not poor) as the interaction term poverty*age was significant. For physical aggression, we test the mean difference between parallel slopes as the as the interaction term poverty*age was not significant.