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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 and 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.

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 et al., 2014; Shaw et al., 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 and 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

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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 et al., 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 et al., 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 et al., 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 et al., 2013; Nomura et al., 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 (0–12 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 modeling 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 and 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

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.

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 $\alpha = 0.87$), 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 $\alpha = 0.85$), 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 $\alpha = 0.84$), 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 0–10).

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 0–5 and Mean = 0.82; SD = 0.94; 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 et al., 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 $p < 0.05$.

We used a structured modeling 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 modeling approach hypothesized lifecourse models were as follows:

1) 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.
2) Two accumulation of risk models: (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 0–3) 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 social mobility models: (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

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.

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 ($p > 0.05$) 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 and 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 et al., 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 et al., 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

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

			N (%)	Hyperactivity	Physical aggression	Opposition
				Mean ± SE	Mean ± SE	Mean ± SE
Full sample			2120 (100)	1.58 ± 0.078	0.52 ± 0.043	1.11 ± 0.063
Poverty						
P1			680 (32.1)	2.02 ± 0.140	0.80 ± 0.095	1.68 ± 0.119
P2			435 (20.5)	2.01 ± 0.149	0.79 ± 0.084	1.67 ± 0.151
P3			340 (16.0)	2.00 ± 0.169	0.73 ± 0.105	1.75 ± 0.175
Permutations						
P1	P2	P3				
0	0	0	1288 (60.8)	1.34 ± 0.107	0.36 ± 0.061	0.80 ± 0.088
1	0	0	304 (14.3)	1.93 ± 0.271	0.77 ± 0.156	1.55 ± 0.250
0	1	0	48 (2.3)	1.56 ± 0.482	0.63 ± 0.225	0.96 ± 0.324
0	0	1	54 (2.5)	1.74 ± 0.506	0.71 ± 0.313	1.23 ± 0.398
1	1	0	140 (6.6)	2.12 ± 0.289	0.90 ± 0.173	1.55 ± 0.262
1	0	1	39 (1.8)	2.21 ± 0.691	0.63 ± 0.305	1.71 ± 0.504
0	1	1	50 (2.4)	1.91 ± 0.465	0.58 ± 0.290	1.58 ± 0.477
1	1	1	197 (9.3)	2.05 ± 0.230	0.80 ± 0.130	1.94 ± 0.239

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.

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 ($p < 0.001$ 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; $p < 0.001$ 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 ($p > 0.05$ 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 ($p = 0.023$ whereas $B_{P2} = 0.07$, $p = 0.737$; and $B_{P3} = 0.30$, $p = 0.172$).

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 ($p > 0.05$ 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 ($p > 0.07$, 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 ($p = 0.027$).

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 ($p = 0.046$).

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

Poverty	Hyperactivity		Physical aggression		Opposition	
	B	P-value	B	P-value	B	P-value
P1	0.740	0.010	0.371	0.070	0.625	0.085
P2	0.242	0.599	0.212	0.392	0.016	0.962
P3	0.665	0.173	0.391	0.155	0.352	0.352
P1*P2	-0.187	0.720	-0.134	0.621	-0.125	0.772
P1*P3	-0.530	0.593	-0.533	0.214	-0.260	0.739
P2*P3	-0.187	0.773	-0.400	0.254	0.251	0.652
P1*P2*P3	0.108	0.912	0.524	0.286	0.122	0.876
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).

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 (Table 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 and Cassells, 2014; Gerard and Buehler, 2004) as well as the focus on the earliest years of life (Murray et al., 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

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 to 12 years of age.

Lifecourse model	Hyperactivity			Physical aggression			Opposition		
	df	F-statistic	P-value	df	F-statistic	P-value	df	F-statistic	P-value
No effect	7,2110	31.9	<0.001	7,2110	17.2	<0.001	7,2109	10.2	<0.001
Accumulation of risk (strict)	6,2110	2.52	0.020	6,2110	2.70	0.013	6,2109	1.95	**0.070**
Accumulation of risk (relaxed)	6,2110	1.78	**0.129**	6,2110	1.66	**0.158**	6,2109	0.93	**0.444**
Sensitive period									
P1	6,2110	2.33	0.030	6,2110	1.99	**0.064**	6,2109	2.22	0.039
P2	6,2110	6.48	<0.001	6,2110	5.33	<0.001	6,2109	6.05	<0.001
P3	6,2110	6.72	<0.001	6,2110	6.52	<0.001	6,2109	5.36	<0.001
Social mobility									
Mobility P2 to P3	5,2110	10.04	<0.001	5,2110	8.14	<0.001	5,2109	10.36	<0.001
Any mobility	5,2110	2.06	**0.068**	5,2110	1.75	**0.120**	5,2109	2.53	0.027

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 to 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)	0.347	0.181, 0.503	<0.001	0.165	0.076, 0.225	0.001	0.324	0.183, 0.466	<0.001
Accumulation of risk (relaxed)									
P1	0.626	0.110, 1.14	0.023	0.310	-0.117, 0.736	0.125	0.558	0.013, 1.10	0.046
P2	0.073	-0.372, 0.512	0.737	0.086	-0.294, 0.467	0.617	0.026	-0.382, 0.434	0.897
P3	0.303	-0.141, 0.747	0.172	0.070	-0.201, 0.342	0.593	0.385	-0.017, 0.786	0.060
Sensitive period									
P1	0.741	0.301, 1.18	0.004	0.365	0.056, 0.675	0.027	0.658	0.226, 1.09	0.008
P2	0.572	0.186, 0.956	0.007	0.296	0.062, 0.531	0.017	0.493	0.159, 0.828	0.006
P3	0.614	0.261, 0.966	0.001	0.259	0.056, 0.461	0.014	0.601	0.249, 0.954	0.002
Mobility P2 to P3									
Downwards	0.406	-0.185, 0.997	0.161	0.268	-0.083, 0.619	0.121	0.093	-0.335, 0.521	0.661
Upwards	0.519	-0.206, 0.124	0.149	0.206	-0.103, 0.515	0.188	0.211	-0.307, 0.730	0.421
Any mobility									
Downwards	0.544	0.138, 0.949	0.013	0.290	-0.032, 0.613	0.071	0.388	-0.104, 0.879	0.106
Upwards	0.240	-0.486, 0.967	0.470	0.065	-0.309, 0.439	0.705	0.088	-0.365, 0.542	0.691

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).

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 × Environment interactions might precipitate increases in normative aggressive behavior which are in turn likely to persist later in life (Shaw et al., 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 et al., 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 and 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 modeling 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 et al., 2010; Hamad and 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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Competing interest

None.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2017.01.039.

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