



Article

Sex differences in the socioeconomic gradient of children's early development

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A B S T R A C T

Sex differences in early child development (ECD) are well documented, as is the socioeconomic status (SES) gradient in early development outcomes. However, relatively little is known about whether the SES gradient in ECD outcomes varies by sex. This study examines whether the association between neighbourhood SES and developmental health outcomes of Canadian kindergarten children is different for girls than for boys. Individual-level child development data, collected using the Early Development Instrument (EDI), were combined with neighbourhood-level socioeconomic data from Statistics Canada's Census and Tax Filer databases. Using an SES index comprising 10 socioeconomic variables, we show a significant cross-level interaction between neighbourhood SES and sex in relation to children's developmental outcomes: the neighbourhood SES gradient in child outcomes is steeper for males than for females. This finding was consistent across all five developmental domains measured by the EDI, for overall developmental health, and across geographical regions in Canada. Further research using family-level SES data, data from multiple time points and countries, and qualitative studies would help to further contextualize the observed interactions.

1. Introduction

Over the last several decades, the socioeconomic fabric of Canadian society has been shifting. The shift is partly due to changes in education and labour force participation – since the early 1990s, the proportion of women attending post-secondary institutions in Canada has been consistently higher than the proportion of men (Andres & Adamuti-Trache, 2007; Card, Payne, & Sechel, 2011). Coupled with increasing educational requirements in the Canadian labour force (Statistics Canada, 2018), this trend has generated considerable discussion as to how well boys are being prepared for future labour force participation (Failing Boys: Best of Series, 2010). Young men also withdraw from secondary school at a higher rate than young women (Statistics

Canada, 2010), a dynamic that seems to be exacerbated by low socioeconomic status (SES) (Statistics Canada, 2016). There is a growing body of research showing that boys growing up in socioeconomically disadvantaged environments are falling behind girls and non-disadvantaged boys in the education system (Chetty, Hendren, Lin, Majerovitz, & Scuderi, 2016; Entwisle, Alexander, & Olson, 2007). In examining the root causes of this trend, the guiding question of the current study arises: Are developmental deficits for boys in low SES contexts observable even before formal schooling begins?

Two theoretical approaches are commonly used for explaining how sex and gender differences arise during young children's development. In the first, children are thought to experience different exposures to risk characterized by *gender-differentiated socialization processes*. Differences

Abbreviations: PHWB, Physical Health and Well-Being; SC, Social Competence; EM, Emotional Maturity; LC, Language and Cognitive Development; and CSGK, Communication Skills and General Knowledge; OR, Odds Ratio; CI, Confidence Interval.

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in young boys' and girls' academic outcomes have been attributed to gendered interactions with parents, peers, teachers, and others in their communities (Cvencek, Meltzoff, & Greenwald, 2011; Goble, Martin, Hanish, & Fabes, 2012). Families and teachers may engage with children in ways that reflect gendered performance expectations (e.g., math and science as male-dominated domains) (Riegle-Crumb & Humphries, 2012), or wider societal expectations with regards to behaviour (e.g., girls as timid, boys as rambunctious) (Mulvey & Killen, 2015). As a result, children embody knowledge of gender stereotypes, including the choice of toys they play with and activities they engage in as early as their preschool years (Martin et al., 2012). These stereotypes may then influence their subsequent developmental outcomes.

In the second theoretical approach, biological or physiological differences between boys and girls are thought to shape their responses to their environments. For example, in a recent studies of oppositional defiant disorder (ODD) symptoms in young children, it was found that girls and boys not only had different physiological reactions to the same stressful situations (Vidal-Ribas, Pickles, Tibu, Sharp, & Hill, 2017), but also that heightened stress reactivity had opposite associations with academic performance for girls and boys (improved performance for boys and decreased performance for girls), and increased externalising problems for boys only (Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010). Moreover, higher family adversity (financial stress, parenting overload, marital conflict and negative/anger expressiveness), was negatively associated with academic and behaviour problems among boys only (Obradović et al., 2010). It is important to consider that the outcomes in studies that purportedly measure biological responses may have already been influenced by gender-differentiated socialization processes prior to measurement, which then would reflect a combination of both sex and gender. This is dictated mostly by the fact that in many empirical studies, data on gender have not been collected systematically. Historically, many studies have instead used sex-at-birth as a predictor (for example, Vidal-Ribas et al., 2017; Obradović et al., 2010).¹ Therefore, distinguishing lines between theories using sex versus gender as mechanisms to explain observed differences in outcomes may be difficult to draw in practice.

Several empirical studies use population-level data to examine sex and gender differences in developmental outcomes. In early childhood, before schooling begins, these studies consistently show girls to be more advanced over a wide range of measures of cognitive and socioemotional skills compared to boys (Bornstein, Haynes, Painter, & Genevro, 2000; Buchmann, DiPrete, & McDaniel, 2008; Burman, Bitan, & Booth, 2007; Roulstone, Loader, Northstone, & Beveridge, 2002). From kindergarten to grade 5, girls are reported to have better social and behavioural outcomes, along with lower prevalence of antisocial behaviours, attention disorders, speech disorders, and other related problems (Halpern, 1997; Muter, 2003; Rutter et al., 2004). Further, in a study of a nationally representative sample from the U.S. *Early Childhood Longitudinal Study – Kindergarten*, parent and teacher reports suggested that, on average, kindergarten-aged girls demonstrated more persistence in completing tasks and a stronger willingness to learn than their male peers (Buchmann et al., 2008). The largest sex/gender differences are generally observed in verbal and language skills; on average, girls produce words at an earlier age, have a larger vocabulary, and show a higher level of language complexity than boys (Bornstein et al., 2000; Burman et al., 2007; Roulstone, Loader, Northstone, & Beveridge, 2002). These early cognitive, social and behavioural skills are predictive of later cognitive outcomes, educational attainment, and future academic success (DiPrete & Jennings, 2009; Ladd, Birch, & Buhs, 1999; Normandeau & Guay, 1998; Trzesniewski, Moffitt, Caspi, Taylor, & Maughan, 2006).

¹ Note that the present study also uses sex-at-birth as an independent variable of interest. Refer to the discussion section for an evaluation of the implications and limitations of this metric.

Measures of SES and economic disadvantage such as income, parental education, and employment at both the family- and area-level are associated with psychosocial and cognitive difficulties from toddlerhood to early elementary school (e.g., Arnold & Doctoroff, 2003; Brownell et al., 2016; Duncan & Brooks-Gunn, 2000; Duncan & Magnuson, 2005; Minh, Muhajarine, Janus, Brownell, & Guhn, 2017; NICHD Early Child Care Research Network, 2005). Huston and Bentley (2010) suggested that in addition to the traditionally-measured absolute values, the relative socioeconomic position of families and neighbourhoods also matters, as well as the timing of exposure to negative contexts. Gullo (2018) tested a similar model to that proposed by Huston and Bentley to determine whether family income, gender, age and health at birth of low-SES children in the U.S. impacted their readiness for school. He found that better developmental outcomes were associated with higher income, and that girls tended to have better health at birth (using birth weight, Apgar scores and weeks of gestation), which was in turn associated with more developmentally advanced approaches to learning.

Relatively little is known about how the impact of family or neighbourhood SES may be moderated by developmental differences between young boys and girls. Existing evidence suggests that differences between boys' and girls' academic skills are more pronounced amongst socially and economically disadvantaged children (Entwisle et al., 2007; Hinshaw, 1992). The gender gap in adult employment rates was reversed amongst individuals who grew up in poor families: adult males who grew up in families in the bottom of the income distribution were less likely to work than females (Chetty et al., 2016). Therefore, socio-economic conditions during childhood may have profoundly different implications for girls and boys over their lifetimes.

A separate body of literature explores how neighbourhood SES may be associated with sex- and gender-based differences in child development. The *Moving to Opportunities* experiment found that the association between neighbourhood SES and behavioural and health outcomes differed between adolescent boys and girls. Whereas adolescent girls who moved to lower-poverty neighborhoods fared better academically, showed improved mental health, and engaged in fewer risky behaviours compared to those who remained in high-poverty neighborhoods, there were no observed health or social benefits for boys who moved to lower-poverty neighbourhoods. Rather, the study observed higher rates of criminal activity among boys who were relocated. This result was attributed to potential pre-move health vulnerabilities, pre-move exposure to violence, and removal from established social networks (Kling, Liebman, & Katz, 2007; Sanbonmatsu, Kling, Duncan, & Brooks-Gunn, 2006; Schmidt, Glymour, & Osypuk, 2017). Another study found that boys growing up in neighbourhoods with concentrated poverty were less likely to find formal employment at age 30 when compared with two groups: girls in similar neighbourhoods, and boys from wealthy neighbourhoods (Chetty et al., 2016).

To date, most of the evidence of these complex relationships has focused on school-age children or adults. Most existing studies on young children's development have explored sex/gender and SES separately, without directly testing interaction effects. One exception is a recent longitudinal study of children in Florida (Autor, Figlio, Karbownik, Roth, & Wasserman, 2016), which investigated the association between SES and the gap between boys' and girls' academic readiness for kindergarten. Autor et al. found that higher family-level SES was related to a smaller readiness gap between boys and girls. They hypothesized two possible causal mechanisms: first, the development of cognitive and socioemotional skills may be differentially susceptible to stress and stimuli in boys and girls; second, low-SES families (which tend to be disproportionately single-parent and female-headed) may allocate a higher proportion of their resources to girls than high-SES families.

To the best of our knowledge, the interaction between sex and SES gaps in Canadian kindergarten children's development has not yet been tested. Using a large population-level database on children's developmental health linked with neighbourhood-level measures of SES, we tested the cross-level interaction between individual children's sex and

neighbourhood-level SES in early childhood development, within a multilevel framework. Guided by the theory suggesting that either biological differences between sexes or gender-differentiated socialization processes in the early years could be exacerbated by environmental factors, we hypothesize that the neighbourhood SES gradient in early child development would be steeper for boys than for girls across Canada and within all of its regions.

2. Material and methods

2.1. Data sources

The data in our analysis drew from three sources: the Canadian Census, the Canadian Tax Filer, and the Early Development Instrument (described in section 2.2). The Canadian Census is a mandatory socioeconomic and demographic questionnaire sent to the Canadian population by Statistics Canada every 5 years. Tax Filer data are produced by individuals submitting their yearly tax forms, where they must declare income and other tax-related information to Canada Revenue Agency. Statistics Canada holds the Census and Tax Filer databases, and grants access to researchers at varying levels of aggregation. The EDI is a kindergarten teacher-completed measure of children's developmental health at school entry (during the second half of their Senior Kindergarten school year). The EDI data collection is implemented by provincial and territorial governments. During a provincial/territorial collection of the EDI, all Senior Kindergarten teachers in the province/territory fill out the questionnaire for each child in their class. The provinces and territories differ in their EDI collection frequency (described in detail in Section 2.2) and their parental consent strategies, but all are similar in regards to the population-level nature of the data collection. The data for all provinces and territories are securely held at the Offord Centre for Child Studies at McMaster University. EDI data are made available to researchers at varying levels of aggregation (Janus et al., 2018).

2.2. Measures

2.1.1. Child development: Early Development Instrument (EDI)

The EDI includes 103 core items measuring children's development in five domains: Physical Health and Well-Being, Social Competence, Emotional Maturity, Language and Cognitive Development, and Communication Skills and General Knowledge (Janus & Offord, 2007). Teachers rate the child's abilities and behaviour on tasks and skills that are expected of typically developing children at age 5 or 6 (e.g., Does the child know how to handle a book?). All EDI items have 2- or 3-point ordinal response formats, as well as a "don't know" option. The 2 or 3 point scores are rescaled to 0 to 10 and the average is taken across all non-missing items in a domain. Thus, EDI domain scores (varying from 0 to 10) are the mean of all items that contribute to that domain. Each child's domain score is coded as a binary vulnerability score (vulnerable or not vulnerable) depending on whether the score falls below a specific threshold for a domain, which corresponds to the 10th percentile of the baseline Canadian normative distribution (Janus & Duku, 2007). Since the EDI was designed for population monitoring, the 10th percentile threshold was chosen to capture children who may be experiencing difficulties (termed "vulnerabilities"), but not only those who were doing so visibly enough to have already been identified. All years of Canadian EDI data use the same Canadian normative baseline threshold, which makes it possible to compare them over time and between populations. An overall binary score of 'vulnerable on at least one EDI domain' is also created, reflecting vulnerability on at least one of the five domains. This derived measure has shown to be highly predictive of children's future academic and social functioning (e.g., Davies, Janus, Duku, & Gaskin, 2016; Guhn, Gadermann, Almas, Schonert-Reichl, & Hertzman, 2016). The EDI also collects demographic information, such as children's sex-at-birth, age at EDI completion and postal code of

residence. In a study explicitly addressing potential existence of bias in EDI ratings, Guhn, Gaderman & Zumbo (2007) found no evidence of bias in domain scores between girls and boys.

Even though the EDI is completed for individual children, the results are always interpreted for groups aggregated by specific characteristics (e.g., sex, age, community). It is not a diagnostic tool. Postal codes of children's residences allow linkages between the EDI data and administrative databases like the Canadian Census and Tax Filer datasets (<https://www.statcan.gc.ca/eng/concepts/index>).

For our analyses, we used EDI data collected at the closest time point to 2010 in each province/territory, so that the 2005 SES variables approximated the conditions in the period during which the child was born. All provinces/territories had a full provincial EDI data collection within 3 years of 2010 (Table 1). All school boards are included once in the study, but not all school boards collected data at the same time in a given province/territory, resulting in data collection spanning between two to five years in certain provinces (for instance, Alberta's provincial collection spanned 5 years). The dataset includes a single time point for each of the 2052 neighbourhoods across Canada.

2.1.2. Socioeconomic status: Census and Tax Filer data

Individual or family SES data were not available for the comprehensive EDI database and therefore socioeconomic status was derived at an area level. We used a neighbourhood-level SES index based on socioeconomic data from the 2005 Canadian Tax Filer and 2006 Census databases, obtained from Statistics Canada. The SES index was developed for the Canadian Neighbourhoods Early Child Development (CanNECD) Study to examine neighbourhood effects and socioeconomic gradients in early child development (Forer et al., 2019). The CanNECD SES index computed for each neighbourhood is a composite construct of 10 variables, listed below; it is a standardized score with a mean of 0, a standard deviation of 1, and ranges from -3.4 to 3.5 across all neighbourhoods in the study. Each child is assigned the SES value of their neighbourhood in the analysis of individual-level characteristics.

CanNECD SES index - Indicator themes and measures. Indicators from the Canadian Census:

- Education - % with no high school diploma
- Language/Immigration - % not speaking either official language at home
- Marital Status - % separated or divorced
- Residential Stability - % non-migrant movers in the past year

Indicators from the Canadian Tax Filer Data:

Table 1

Provincial data collection years included in the sample. The black vertical line represents the target year (2010) for EDI data collection.

Province	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
Alberta						
British Columbia						
Manitoba						
New Brunswick						
Newfoundland						
Northwest Territories						
Nova Scotia						
Ontario						
Prince Edward Island						
Quebec						
Saskatchewan						
Yukon						

- Poverty - % with low income, lone parent families with children under 6
- Income Inequality - Gini Coefficient, lone female families with children under 6.
- Wealth - % with investment income, families with children under 6
- High Income - % with incomes twice or higher than the provincial median, families with children under 6
- Dues - % with union/association dues, families with children under 6
- Social Capital - % with charitable donations, families with children under 6

2.3. Data aggregation

We defined and created custom neighbourhoods using Census Dissemination Areas (DAs) as the smallest area level, and combined DAs where necessary to ensure each neighbourhood had between 50 and 400 children with EDI data contained within its boundaries. The DA combinations were based on consultation with provincial/territorial governments. For a detailed description of the neighbourhood creation process, see Guhn et al. (2016a). EDI data were then aggregated to these custom geographic neighbourhoods and matched with Statistics Canada’s Census data.

Table 2 shows counts of neighbourhoods and children by province. The number of neighbourhoods and children in a province or territory depended on the jurisdiction’s geographic size and population density. Ontario had the largest population and highest density, and represents 39% of the total neighbourhoods and children. Northwest Territories, while geographically large, represent only 3 neighbourhoods and 0.2% of the total children due to relatively low population density. Among the children in the study, 161,968 (51.3%) were male and age at EDI completion had a mean of 5 years and 9 months, with a range from 3 years and 11 months to 7 years and 6 months.

Table 3 shows the percent of children who were vulnerable based on their EDI domain scores for each of the five EDI domains and the percent of children vulnerable in one or more EDI domain. The counts and vulnerability rates for each EDI domain by province and by sex are listed in Appendix Table A1.

Table 2
Counts of neighbourhoods and children, and percent overall vulnerability by sex and by province/territory.

Province	# Neighbourhoods	# Children	% Vulnerable	
			Female	Male
Alberta	267	35,950	23%	38%
British Columbia	296	46,207	25%	42%
Manitoba	75	12,153	25%	39%
New Brunswick	52	6896	19%	37%
Newfoundland	41	4787	13%	28%
Northwest Territories	3	577	26%	42%
Nova Scotia	57	8309	21%	37%
Ontario	798	123,847	19%	34%
Prince Edward Island	6	1035	12%	25%
Quebec	396	64,983	17%	33%
Saskatchewan	55	10,732	23%	40%
Yukon	6	335	34%	51%
Total	2052	315,811	100%	100%

Table 3

Total number of cases and percent of children developmentally vulnerable across EDI domains.

Variable	N ^a	% Vulnerable
Physical Health and Well-Being	315,462	11.6
Social Competence	315,764	10.7
Emotional Maturity	314,301	12.9
Language and Cognitive Development	314,728	9.1
Communication Skills and General Knowledge	315,718	13.4
One or More Domains	315,811	28.1

^a N column lists all non-missing cases.

3. Analysis

We used multilevel logistic regression to analyze the cross-level interaction between sex and neighbourhood SES in relation to children’s developmental health at school entry.² First, we estimated the probability of a child being vulnerable on one or more domains, controlling for the CanNECD SES index at the neighbourhood-level, child age and sex, as well as year of EDI data collection. The cross-level interaction term, the variable of interest, was a product of the child’s neighbourhood SES and the binary variable for sex (1 = male; 0 = female). We used logistic regression because of the dichotomous nature of the measure of vulnerability. Multilevel modelling accommodated the clustering of children within neighbourhoods in the model and allowed for random intercepts at the neighbourhood level. We controlled for age (in years) because children’s age has consistently been found to be associated with EDI outcomes (Janus & Offord, 2007). As mentioned above, no other child- or family-level demographic variables were available for this sample (such as ethnicity or income).

Second, we examined the relationships between sex, SES and the vulnerability rate separately for each of the five developmental domains of the EDI, using the same modelling strategy for the overall vulnerability score. Regressions using domain scores as outcome variables were also tested (Appendix Table A2), to examine the consistency of results using these instead of vulnerability in each domain. In the domain score regression, we also included a quadratic term on SES to allow for and test the existence of a curvilinear relationship between SES and the EDI.

Third, we analyzed these same relationships, with overall vulnerability as the outcome variable, in five Canadian regions to test whether a sex-SES interaction was specific to certain regions of the country. To ensure an adequate neighbourhood-level sample size for each region, we included the following jurisdictions: British Columbia, the Prairies (Alberta, Saskatchewan and Manitoba), Ontario, Quebec, and the Atlantic Provinces (New Brunswick, Nova Scotia, PEI and Newfoundland and Labrador). Data from the Canadian territories (Yukon, Northwest Territories and Nunavut) were not included in the regional analysis because together they consist of only 10 neighbourhoods, which was insufficient for neighbourhood-level SES to be included in statistical analyses.

All analyses were carried out in STATA version 15.1 (<https://www.stata.com/>). Multilevel logistic regressions were completed using the GLLAMM package with random intercepts for each neighbourhood (Rabe-Hesketh & Skrondal, 2008). Graphical predictions of vulnerability by SES and sex in these models were carried out using the GLLAPRED command (in the GLLAMM package). Simulated confidence intervals were constructed for visualization of confidence bands around each predicted line using the CI_MARG_MU package (Rabe-Hesketh, 2008) with 1000 simulations each. Each graph shown uses the same independent variables for consistency, regardless of their level of

² We use the term cross-level interactions, because our model estimates how associations between the dependent variable and SES at the neighbourhood-level can be moderated by sex, a lower-level variable (Aguinis, Gottfredson, & Culpepper, 2013).

statistical significance in the model.

4. Results

Table 4 shows the results of the analysis for overall developmental vulnerability. The odds ratios demonstrate that children from higher SES neighbourhoods are less likely than children from lower SES neighbourhoods to be developmentally vulnerable at school entry; that boys are significantly more likely than girls to be developmentally vulnerable at school entry; and that older children are less likely than younger children to be developmentally vulnerable at school entry. There was a positive cross-level interaction between neighbourhood SES and male sex. Fig. 1 illustrates the steeper slope of the predicted probabilities of vulnerability for boys compared to girls in relation to neighbourhood SES.

The results from the five multilevel logistic regression models of individual domain vulnerability are shown in Table 5. There was a cross-level interaction between sex and SES for all domains except for Language and Cognitive Development. The results of the regression in Table 5 do not suggest an interaction between sex and SES for the Language and Cognitive Development domain, but visually an interaction is evident (Fig. 2). These results suggest that the SES gradient is steeper for boys than for girls across all domains. SES, age and sex (adjusted in the regressions but not reported in Table 5) are all statistically significant estimators of vulnerability in the domains as well. When domain scores are used as outcomes instead of vulnerability scores (Appendix Table A2), similar results are observed. In all five of the domain score models, the sex-SES interaction terms are observable. These analyses also support the curvilinear functional form of the logistic regressions used, since the curve between SES and the EDI domain scores increases with higher SES at a decreasing rate in three of the domains. The variation observed in the distributions of these domains was not consistent, since the Communication Skills and General Knowledge has the highest vulnerability rate of any domain (Table 3) and the Language and Cognitive Development domain has the lowest vulnerability rate. The lower amount of variation in the Language and Cognitive Development domain most likely also contributes to the lack of a statistically significant sex-SES interaction term in this domain even though it is visually evident.

The results from the five separate geographic regions of Canada are shown in Table 6. Ontario and Quebec were the only two regions with statistically significant interaction terms between sex and SES. Using predicted outcomes, these findings show that the slope of the gradient between SES and vulnerability is steeper for boys than for girls. The interaction term between sex and SES was not statistically significant in any other region we tested, the directionality was the same in British Columbia and the Prairies. In the Atlantic Provinces, the odds ratio was slightly below 1. The Atlantic provinces had relatively fewer neighbourhoods, and observably more variation in the coefficients across all variables.

5. Discussion

Our study confirmed that Canadian kindergarten children living in low-SES neighbourhoods had poorer developmental outcomes than

those living in high-SES neighbourhoods. In support of our hypothesis, we demonstrated that developmental vulnerability in all five domains of the EDI was more strongly associated with neighbourhood socioeconomic disadvantage for boys than for girls. While SES gradients in health outcomes are common, our results showed a consistently steeper SES gradient for kindergarten-aged boys than for girls across Canadian jurisdictions. To put the size of the interaction into perspective, in the regression using probability of overall vulnerability as the dependant variable (Fig. 1), the difference between children in neighbourhoods two standard deviations below the mean SES value compared to two standard deviations above the mean SES value was 23.1 percentage points for boys and 19.4 percentage points for girls (an improvement 1.2 times larger for boys than for girls). Our results therefore support the hypothesis that there is an observable cross-level interaction between individual children's sex and neighbourhood SES in developmental outcomes before children begin grade school.

Two possible mechanisms may be the basis for the results we observed: first, boys may face more severe stresses than girls in worsened socioeconomic environments; second, boys may be less resilient than girls to the stresses of socioeconomic disadvantage. Even though either or both of these mechanisms could have been responsible for the observed patterns, we were unable to determine whether this was the case using the datasets available to us. Our findings, however, can inform the design of an empirical study that isolates these variables at the family-level. Such a study design is necessary to examine the causes of the differential socioeconomic gradients observed for girls and boys study, and would be supported by a literature review of socioeconomic variables that may be subject to the types of mechanisms mentioned above. Nevertheless, our findings clearly establish the differential association between SES and developmental outcomes for boys and girls. Accordingly, a sex/gender lens should be widely applied to socioeconomic-related policies involving children, as boys and girls may react differently to socioeconomic circumstances.

It is important to note that the metric we used for child's sex (sex at birth) did not imply that the interactions observed were between neighbourhoods' SES and biological sex. By kindergarten age, children have already been exposed to gendered socialization processes. The associations found in this analysis capture both sex and gender differences together but could not distinguish between the two. While the distinction between sex and gender is an important topic, we acknowledge the limited ability of our study to address this distinction. We included both terms in our literature search and review of theoretical approaches, but deeper analysis of gender differences is beyond the scope of the present study. Studies that make use of individual-level longitudinal data need access to more contemporary metrics of sex and gender to differentiate these concepts and to test their independent interactions with family and neighbourhood SES.

Many previous studies examining the relationship between sex and SES in childhood have focused on children of grade-school age and academic outcomes (Buchmann et al., 2008; Entwisle et al., 2007). For example, Entwisle et al. (2007) followed a panel of children in schools of diverse SES and ethnicity from grade 1 until age 22. They used data from the schools' meal subsidy program to group the children by SES and track sex differences between grade 1 and grade 5. During this period, sex differences in reading scores increased among children in the meal subsidy program, with girls increasingly outperforming boys, but not among non-subsidized children. However, the authors observed no sex differences among children in families who were not from low-income families. In our analyses, instead of using family low income as a binary variable, we used the entire distribution of the neighbourhood SES and found a slope differential in EDI outcomes for children living in neighbourhoods across the SES spectrum.

To the best of our knowledge, our study is the first to examine the cross-level sex-neighbourhood SES interactions across the whole population of kindergarten-age children in Canada. Although our dataset did not allow us to investigate individual- or family-level mechanisms, it did

Table 4

Odds ratio of developmental vulnerability on one or more of the five domains of the EDI.

	Overall Vulnerability (Odds Ratio)	Confidence Interval
SES (Z-Score)	0.74*	[0.73,0.75]
Male	2.30*	[2.26,2.34]
Age (Years)	0.53*	[0.52,0.55]
SES x Male	1.05*	[1.03,1.07]

* $p < 0.001$.

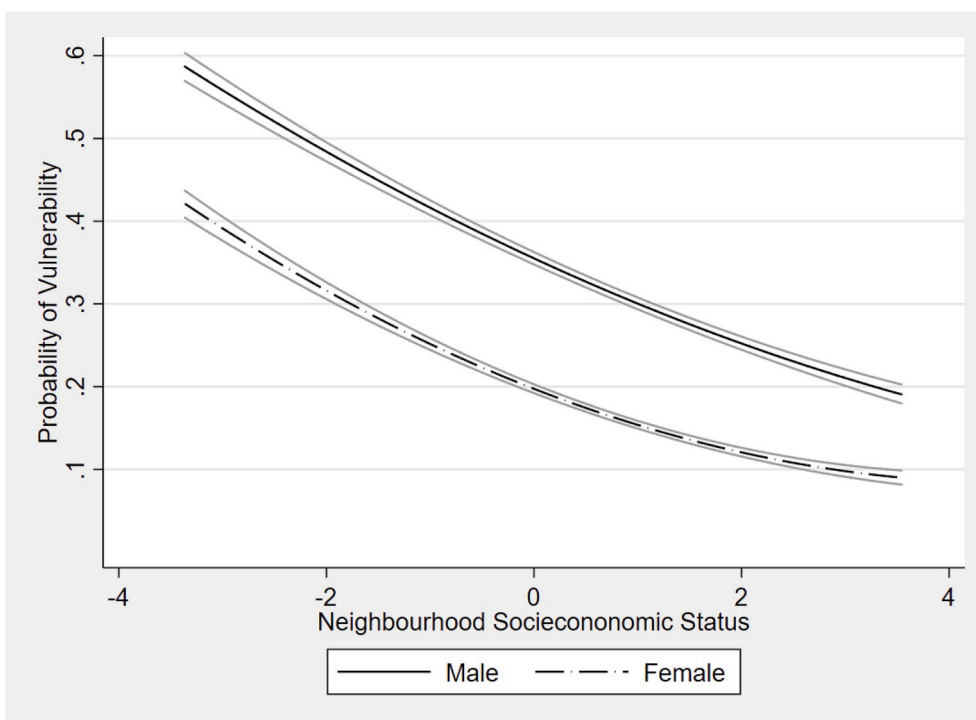


Fig. 1. Fitted relationships between neighbourhood SES (in standardized units) and probability of vulnerability by sex, using logistic regression with 95% simulation-based confidence intervals shown (1000 simulations).

Table 5
Multilevel (individual and neighbourhood) logistic regressions with vulnerability on the five domains of the EDI as the dependent variables.

	Physical Health and Well-Being	Social Competence	Emotional Maturity	Language and Cognitive Development	Communication Skills and General Knowledge
	OR (CI)	OR (CI)	OR (CI)	OR (CI)	OR (CI)
Variables/measures					
SES	0.71* [0.69,0.73]	0.75* [0.73,0.77]	0.79* [0.77,0.81]	0.71* [0.69,0.73]	0.73* [0.71,0.75]
Male	1.86* [1.81,1.90]	2.79* [2.72,2.86]	3.50* [3.41,3.58]	1.88* [1.83,1.93]	1.96* [1.92,2.01]
SES x Male	1.06* [1.03,1.08]	1.07* [1.04,1.09]	1.07* [1.04,1.09]	1.01 [0.98,1.03]	1.04* [1.02,1.07]

95% confidence intervals in brackets.

*p < 0.001.

demonstrate that the cross-level sex-SES interaction was not a localized trend. Rather, the findings suggested the cross-level interaction was observable at a pan-Canadian level, and that it was present to a varying extent in most of the regions of Canada. The evidence of the sex-SES interaction was present for most Canadian regions, but was most apparent for Ontario and Quebec. The only region where the relationship showed signs of being reversed was Atlantic Canada, where the odds ratio was close to 1 and (due to the relatively small number of neighbourhoods) was not significant. The similar directionality and absolute size of the odds ratios for SES, sex and the interaction term suggested that these factors showed a similar trend across Canada.

It is important to consider the implications and limitations of using neighbourhood-level socioeconomic indicators. While most of the literature demonstrates family-level effects, our neighbourhood-level data could be interpreted as the average of these effects in a neighbourhood. A recent literature review highlighted the effects of SES at a neighbourhood level, exploring associations between children’s developmental outcomes and their neighbourhood characteristics (Minh

et al., 2017). Establishing evidence on neighbourhood effects is crucial for understanding contributions of larger social environments beyond the family to children’s developmental trajectories. Both experimental and non-experimental studies have demonstrated that living in a high-income neighbourhood is associated with higher cognitive ability and school achievement compared to living in low-to middle-income neighbourhoods (Leventhal & Brooks-Gunn, 2003). As much as results using only neighbourhood-level variables may be useful for broad policy decisions, they must always be interpreted with caution and acknowledgment that the effects observed are a combination of at least three components: average family-level effects, inter-family relationships in a neighbourhood, and neighbourhood-level policy/infrastructure.

One potential explanation for the existence of different socioeconomic gradients for boys and girls is the existence of a ‘ceiling effect’. A ceiling effect would occur when, in populations with low vulnerability to begin with, there is less room for variation in the level of vulnerability than population which have higher vulnerability. By this explanation, since girls tend to be less vulnerable on average, they have less room to

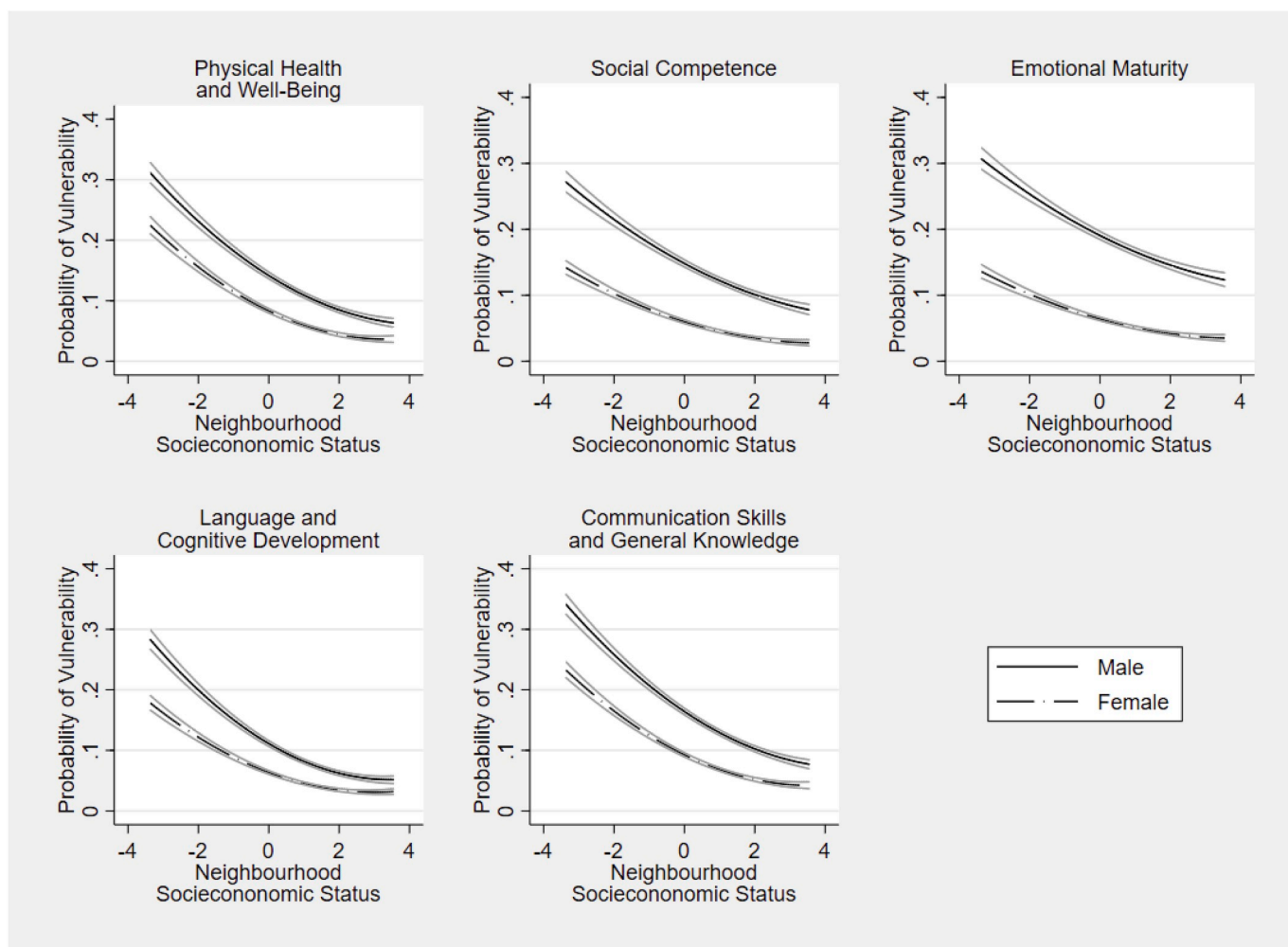


Fig. 2. Fitted relationships between neighbourhood socioeconomic status (standardized scores), sex and the probability of vulnerability on the five domains of the EDI using logistic regression with 95% simulation-based confidence intervals shown (1000 simulations).

Table 6

Multilevel logistic regressions using various regions of Canada as the scope, controlling for age and year of data and using children nested within neighbourhoods. Dependent variable: Overall Vulnerability.

	BC	Prairies	Ontario	Quebec	Atlantic
	OR (CI)	OR (CI)	OR (CI)	OR (CI)	OR (CI)
Variables/measures					
Socioeconomic Status	0.71** [0.67,0.75]	0.73** [0.70,0.76]	0.74** [0.72,0.76]	0.80** [0.77,0.84]	0.76** [0.68,0.85]
Male	2.20** [2.11,2.30]	2.18** [2.10,2.27]	2.31** [2.25,2.37]	2.41** [2.32,2.50]	2.46** [2.27,2.66]
Male x SES	1.03 [0.98,1.08]	1.03 [1.00,1.07]	1.06** [1.03,1.09]	1.05* [1.01,1.09]	0.98 [0.89,1.08]
# Students	46207	58835	123847	64983	21027
# Neighbourhoods	285	397	796	395	156

95% confidence intervals in brackets.

* $p < 0.01$, ** $p < 0.001$.

improve with higher levels of neighbourhood SES. While this is a possible mechanism for the observed interplay between sex and SES, the statistically significant interaction between these variables established in this study still remains an important finding, since it implies that the likelihood of boys achieving developmental expectations by

kindergarten is more prone to influence of the levels of neighbourhood SES than it is for their female peers.

5.1. Future directions

In addition to the need to understand the specific mechanisms behind the cross-level sex-SES interactions observed in early child development, there is a need for further research to contextualize the issue. First, examining family-level SES would strengthen the observed findings and would be useful for deciphering whether and how the relationship between sex and SES changes over children's lives. Further, policy and cultural environments in which children live and the social norms they adopt are constantly changing, so understanding how the interaction is changing over time is important as well. While the current analyses are applicable in a Canadian context, further research involving other developed and developing countries is necessary to determine the generalizability of findings. Another area for future research would be a directed analysis of how gender plays a role in the observed sex-SES relationship, which we were unable to address in the current study given our available data. Finally, while quantitative studies can explore trends in large populations, localized and mixed-method studies would be valuable for understanding how parental and teacher expectations and interactions with a child are differentially affected by the child's sex and socioeconomic status.

6. Conclusion

Across Canada, kindergarten-aged children from lower SES neighbourhoods have poorer developmental outcomes than their counterparts living in higher SES neighbourhoods. Our findings showed that this gradient is steeper for boys than for girls. We observed a cross-level interaction between sex and neighbourhood SES in all five developmental domains of the EDI and for overall vulnerability across multiple regions of Canada. The mechanisms behind this cross-level interaction effect should be further examined to foster a better understanding of how family socioeconomic characteristics differentially influence boys and girls, and to shed light on how we can support equal opportunities for school and lifetime success for all children.

Appendix. Supplementary Material

Table A1

Provincial counts and vulnerability rates (%) across EDI domains by child's sex

	Number of Neighbourhoods	Number of children		Physical Health and Well-Being		Social Competence		Emotional Maturity		Language and Cognitive Development		Communication Skills and General Knowledge		Overall Vulnerability	
		F	M	F	M	F	M	F	M	F	M	F	M	F	M
		Alberta	267	17200	18507	11%	18%	7%	15%	6%	18%	8%	13%	12%	20%
British Columbia	296	22188	23474	12%	20%	8%	18%	9%	22%	8%	13%	13%	21%	25%	42%
Manitoba	75	5965	6072	10%	15%	8%	17%	8%	19%	10%	16%	13%	20%	25%	39%
New Brunswick	52	3361	3446	9%	14%	7%	17%	8%	23%	5%	10%	8%	15%	19%	37%
Newfoundland	41	2347	2411	5%	10%	5%	13%	4%	14%	5%	10%	5%	13%	13%	28%
Northwest Territories	3	274	299	16%	24%	6%	17%	8%	20%	9%	18%	13%	23%	26%	42%
Nova Scotia	57	3954	4290	11%	18%	8%	18%	7%	20%	5%	9%	9%	16%	21%	37%
Ontario	798	59765	62821	8%	13%	6%	15%	6%	17%	5%	10%	9%	17%	19%	34%
Prince Edward Island	6	505	518	4%	8%	5%	9%	4%	13%	5%	8%	4%	8%	12%	25%
Quebec	396	31517	32799	5%	9%	4%	12%	7%	20%	7%	11%	6%	11%	17%	33%
Saskatchewan	55	5159	5511	11%	19%	6%	15%	7%	18%	9%	18%	11%	20%	23%	40%
Yukon	6	167	168	23%	31%	10%	23%	11%	27%	11%	19%	17%	23%	34%	51%

Ethical statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from simrwebb@gmail.com.

Declaration of competing interest

None.

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Table A2

Multilevel (individual and neighbourhood) linear regressions with the five EDI domain scores as the dependent variables (reverse-coded and fitted based on the gamma distribution)

	Physical Health and Well-Being	Social Competence	Emotional Maturity	Language and Cognitive Development	Communication Skills and General Knowledge
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Individual					
SES	-0.18** (0.01)	-0.17** (0.01)	-0.12** (0.01)	-0.17** (0.01)	-0.30** (0.01)
SES Squared	0.03** (0.01)	0.01 (0.01)	0.00 (0.01)	0.03** (0.01)	0.02* (0.01)
Male	0.37** (0.01)	0.84** (0.01)	0.85** (0.01)	0.53** (0.01)	0.81** (0.01)
SES x Male	-0.02** (0.01)	-0.04** (0.01)	-0.02* (0.01)	-0.06** (0.01)	-0.05** (0.01)
Age	-0.36** (0.01)	-0.45** (0.01)	-0.33** (0.01)	-0.61** (0.01)	-0.70** (0.01)
Constant	4.10** (0.04)	4.86** (0.05)	4.57** (0.05)	5.77** (0.04)	6.84** (0.07)
Neighbourhood					
Male	-0.14** (0.006)	-0.16** (0.009)	0.13** (0.008)	-0.21** (0.007)	0.24** (0.01)
Constant	0.27** (0.004)	-0.26** (0.006)	0.26** (0.005)	0.36** (0.005)	0.44** (0.008)
Log-Likelihood	-471882.5	-557649.4	-537521.9	-528049.8	-653849.1

Standard errors in parentheses.

* $p < 0.01$, ** $p < 0.001$.

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