



A Multilevel Analysis of the Contribution of Individual, Socioeconomic and Geographical Factors on Kindergarten Children's Developmental Vulnerability: a Saskatchewan Province Wide Study



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Abstract

This study determines the strength of the effect and significance of different predictors of children's developmental vulnerability and multiple challenges using multilevel modeling of nested data measured at levels of child, neighbourhood and regional geographies. Furthermore, delving into greater depth, this study identifies which factors are predictors at each level of the nested hierarchy, which factors present modified effects due to two or more predictors from cross-levels of the nested hierarchy, and the variations of effects across different levels of the hierarchy. This cross-sectional study considered 8655 Saskatchewan children who were ages 4-8 years in the 2008-2009 school year. Multilevel logistic models were used to analyze data compiled from 2009 provincial Early Development Instrument (EDI) data (child level) and 2006 neighbourhood Canada Census data. Child characteristics such as Aboriginal status, an English as Second Language (EAL) learner, and frequent absence from school; neighbourhood income inequality, median income and school type; and regional characteristics such as residence in a large city were identified as having significantly elevated odds for risk of vulnerability.

When children were identified as living in neighborhoods with higher income inequality exacerbated the elevated effects of neighborhood median income on vulnerability; similarly, neighbourhood income inequality exacerbated effects of Aboriginal status on vulnerability. In contrast, residence in a large city mitigated the effects of Aboriginal status on vulnerability and so did neighbourhood median income on the effects of residence in large city on vulnerability. Furthermore, neighbourhood contextual variables contribute to a considerable proportion of the variations of vulnerability and multiple challenges outcomes. The findings of this study add some depth to our understanding of multilevel determinants of early vulnerability, but it also reveals opportunities for targeted interventions-at the level of Aboriginal children, children who speak English as an additional language, and children in neighbourhoods with high income inequality, expectedly all within a coherent, universal provincial-level early years framework.

Keywords : Early development instrument; Developmental health; Income inequality; Vulnerability; multiple challenge index; multilevel logistic model; Compositional and contextual effects

Introduction

Research on kindergarten children's school readiness has gained a strong momentum in recent years. School readiness has been defined as a child's ability to meet the demands of school; such as co-operation, listening to the teacher, and benefiting from the educational activities offered by the school [1,2]. Therefore, school readiness encompasses both the ability to learn within school settings and having the skills and competencies that

best facilitate successful learning [3]. School readiness is of particular importance as it is consistently associated with many social, emotional, and academic outcomes later in life [4-8]. School readiness research has garnered much attention at the provincial, national, and international levels as communities develop and implement new policies and programs aimed to help children reach important developmental outcomes. Within Canada, the Offord Centre for Child Studies (OCCS) in Ontario

has created the Early Development Instrument (EDI) as a measure of school readiness among kindergarten children [9]. The EDI is a checklist completed by the kindergarten teacher for individual children. The results from the measure are interpreted exclusively at the group level (i.e., schools, communities, cities). Children are assessed along five domains indicative of school readiness: Physical health and well-being; Social knowledge and competence; Emotional health and maturity; Language and cognitive development; and Communication skills and general knowledge. The five EDI domains can be further broken down into 16 subdomains. For instance, the Physical health and well-being domain is comprised of three subdomains: physical readiness for school, physical independence, and gross and fine motor skills.

One of the strengths of the EDI is the ability to identify groups of children who may be vulnerable for poor school readiness at school entry and subsequently for poor school achievement as well. Research frequently cites that children from minority groups [10-12] and with low socioeconomic statuses are at an increased risk for low levels of school readiness. More specifically, Aboriginal children are at-risk for many negative developmental outcomes, including being rated as having poor school readiness [13-18]. A recent examination of the EDI in British Columbia revealed that approximately 40% of Aboriginal children received a low score on at least one of the five EDI domains with low scores most often obtained within the Language and cognitive development and Communication skills and general knowledge domains. Indeed, research consistently demonstrates that teachers rate Aboriginal children as having lower levels of school readiness when compared to their non-Aboriginal counterparts, though it is less certain whether this disparity is due to real group differences or validity issues with respect to the EDI measure itself [19,20].

In recent years, researchers have shown that the EDI is an effective tool for assessing children's school readiness through different perspectives, such as studies of individual determinants, and those considering both individual and neighbourhood determinants in the analysis. First, the EDI has shown to be an effective tool in assessing children's school readiness in studies of individual determinants. Muhajarine et al. [20] considered a 1-level logistic model. In this model, multiple challenges status in children has been predicted by individual child's characteristics such as Aboriginal status, female status, possessing fewer special skills, and number of special problems. All of these characteristics were statistically associated with a higher likelihood of being rated as having multiple challenges, with odds ratios of 3.38, 1.91, 2.65, and 2.61, respectively. Secondly, the EDI has shown to be an effective tool in assessing children's school readiness and health status in studies considering both individual and neighbourhood determinants in the analysis. For example, Oliver et al. [12] used the EDI to investigate the relationship between individual and

neighbourhood socioeconomic characteristics on kindergarten students school readiness in a 2-level linear model with two individual child variables and six neighbourhood related variables. The results indicated that a higher family income or speaking English as the maternal language is significantly associated with higher scores majority of 5 EDI domains. In addition, at the neighbourhood level, children in neighbourhoods with higher median income or higher percentage of lone-parent families or higher unemployment rate have lower scores in almost all 5 EDI domains.

The above and other publications in Canadian context generally fall into one of three main categories: first, they include a single level of hierarchy in the study design [21]; second, they have two levels of hierarchy in the study design (neighbourhood/school-child) without discussion of proportion of variation explained at each level of hierarchy [18,22] third, they consider two levels of hierarchy in the study design (neighbourhood-child) and discussion of proportion of variation at each level of hierarchy but lack consideration of within-level and cross-level interaction to present modifying effects of different individual, neighbourhood contextual and geographical variables on the outcome [23-25].

The current study generalizes the design of previous Canadian literature in the field by extending the scale (to the level of geographies in the province) and hierarchy (including three levels) as well as consideration of various within-level and cross-level modifying effects in the model. Its main objectives are to

- (i) Identify significant determinants of child developmental vulnerability at the individual (child), neighbourhood and geographical area level,
- (ii) Identify within-level and cross-level effect modifications of selected key determinants and
- (iii) Specify relative contributions of determinants at each level to the variations of child developmental vulnerability outcomes.

Methods

Setting and procedures

In 2009, Saskatchewan province-wide EDI was implemented led by the Early Childhood Development Unit, Ministry of Education on behalf of the Government of Saskatchewan. Since 2009, and prior to that year as well, EDI has been implemented in Saskatchewan primarily either at local school divisional regions or at the city level. Kindergarten teachers in Saskatchewan's Public and Catholic School Divisions evaluated their students using the EDI. In Saskatchewan, students are able to choose to attend either a Public or Catholic School Division school (or an Aboriginal controlled school or the Francophone School division), as any one of these options are available to all families

with kindergarten children irrespective of their income levels or religious preferences. Most neighbourhoods have a local elementary school within each of the Public and Catholic School Divisions. Prior to implementing the EDI in their classrooms, kindergarten teachers participated in training sessions on the correct implementation of the tool. Most teachers were familiar with the EDI and demonstrated a sound grasp of the proper implementation of the instrument. The EDI was completed approximately mid-way into the kindergarten year (in February) and was typically completed over a two-week period.

This paper included a total of 20 variables comprising 3 hierarchies or nested contextual variables; of these 8 were related to children (child level), 6 related to neighbourhoods (neighbourhood level), and 3 indicator variables related to the city or region (province level). The outcomes were child developmental vulnerability and multiple challenges (both measured via EDI) for 8655 children from 418 schools nested in 185 neighbourhoods in the province of Saskatchewan (Table 1).

Measurement

The early development instrument: The EDI consists of 104 questions and measures five developmental domains: physical health and well-being; social competence; emotional maturity; language and cognitive development; and communication and general knowledge. EDI scores fall along a 10-point standardized scale. Children scoring in the lowest 10% of the distribution of scores are considered not school ready. The EDI is completed by kindergarten teachers for each of their pupils. The EDI also captures basic demographic information such as gender, date of birth, Aboriginal status, mother tongue, and also some school-based designations such as the presence of special skills and special problems. The EDI has been shown to have adequate internal consistency, with Cronbach's alphas from 0.84 to 0.96 for the five domains. Studies examining the psychometric properties of the EDI have demonstrated consistent agreement between parent-teacher ratings, concurrent validity, and convergent validity. Inter-rater reliability on the EDI ranges from 0.53 to 0.80.

Canadian census data: Since EDI data is analyzed and reported at the population level, this allows for EDI data to be linked to other population level databases such as the Census. Statistics Canada conducts a national census every five years (in 2011, there was an alteration to this long-held practice when the Government of Canada instituted the National Household Survey, a voluntary survey of all Canadian households). This allows for analysis to be conducted for areas as small as a neighbourhood and as large as the entire country. For this particular study, the 2006 Census was used to describe the characteristics of urban neighbourhoods and next level of geographical context, the blocks provincial cities or regions.

A common methodological challenge in the neighbourhood effects literature is defining and demarcating neighbourhoods.

Neighbourhood effects studies use a variety of definitions for neighbourhood, many using convenient and contrived boundaries such as census tracts or census dissemination areas [26,27]. However, administratively defined neighbourhoods are often not meaningful for residents and census not reflect the true neighbourhood characteristics at a level that matters to health outcomes [28-30]. This methodological challenge was addressed in this study due to a long history of municipally planned neighbourhoods in the Saskatchewan's major urban centres. Thus, neighbourhood units have well defined geographical boundaries, are meaningful used in this study residents, and have been comprehensively planned to be a unit that is efficient to service (including schools) and maintained over the long term. Neighbourhoods defined in this paper are as close to 'natural neighbourhoods' as one may find.

Vulnerability and multiple challenge index

The EDI data included child's school readiness in five general domains. In each EDI domain the score ranged from 0 to 10 and a child whose EDI score for a particular domain falls below the 10th percentile of the score distribution for a particular site has been deemed "vulnerable" for that particular EDI domain. Based on this basic definition, two further summary measures formed the outcomes for this study: developmental vulnerability and multiple challenges. A child was deemed developmentally vulnerable if he/she scored vulnerable in at least one of the 5 EDI domains. Multiple challenges was defined when a child scored as vulnerable in at least 3 EDI sub domains considered in the Multiple Challenge Index variable [Janus et al. 2007].

Individual-level factors

In addition to the developmental health measures, eight child level variables were also specified in this analysis: age, days absent from school, gender, Aboriginal status, French/English Immersion program attendance, English as an alternate language status, non-parental care status, and language/religion class attendance.

Contextual neighbourhood-level factors

The neighbourhood related data were sourced from Canada census 2006 by linking Saskatchewan neighbourhood based list of postal codes for the cities of Saskatoon, Regina, Prince Albert and Non-urban areas. The neighbourhood level data sourced included school type (public, separate, Francophone), income distribution (Gini index), median income, percent unemployed (for population over 15 years), percent population with a high school diploma, and average value of dwelling. Neighbourhood level variables were derived as follows: the school type variable was measured by finding its corresponding school division at the Saskatchewan Ministry of Education Website, the variable Gini index was calculated based on median household income (before tax) for the population 15+ years of age. The average dwelling value was calculated based on owner-occupied private non-farm, non-reserve dwellings.

Geographical indicator

The Geographical indicator considered in the study comprised of four categories, three urban centers and the remaining non-urban areas (Saskatoon, Regina, Prince Albert, and non-urban areas). In major cities of Saskatoon, Regina and Prince Albert the concept of neighbourhood was operationalized according to the municipalities definition of neighbourhood area within the city. However, in non-urban areas the concept of neighbourhoods is not as easily operationalized. Therefore, in this study, any geographical entity outside of the three large cities such as towns, villages, and resort villages were operationalized as 'neighbourhoods' for non-urban areas [31].

Statistical approach

Chi-squared analysis techniques were utilized for descriptive group comparisons. Such comparisons were conducted for child level (e.g., gender: males vs. females), neighbourhood level and geographical area level variables and results were presented in terms of proportions and 95% confidence intervals. Multilevel logistic regression was used to determine child, neighbourhood, and geographical indicator characteristics associated with being classified as either vulnerable or positive in multiple challenge index. The multilevel logistic regression was considered as following random intercept model:

$$Level1(child): \logit\left(E\left(Y_{ijk}^{(n)}\right)\right) = \beta_{0jk} + \sum_{s=1}^p \beta_{sjk} X_{ijk}^{(s)} + e_{ijk}^{(1)} \quad (n=1,2) \quad (2-1)$$

$$Level2(neighbourhood): \beta_{sjk} = \gamma_{s0k} + \sum_{t=1}^{q_s} \gamma_{stk} X_{jk}^{(t)} + e_{sjk}^{(2)} \quad (0 \leq s \leq p)$$

Level 3 (geographical indicator area):

$$\gamma_{stk} = \delta_{st0} + \sum_{u=1}^{r_{st}} \delta_{stu} X_k^{(u)} + e_{stk}^{(3)} \quad (0 \leq s \leq p, 0 \leq t \leq q_s)$$

where for binary outcome variable of vulnerability status or Multiple Challenge Index $Y_{ijk}^{(n)} \sim \text{Bernoulli}(\pi_{ijk})$

$$\text{with } \pi_{ijk} = \Pr\left(Y_{ijk}^{(n)} = 1\right), (n=1,2).$$

In this study, $p=8, q_0=6, q_s \neq 0$ (for some $s \leq p$), $r_{00}=1$, and $r_{st} \neq 0$ (for some $s \leq p, 1 \leq t \leq q_s$) were found. In addition, with q_s+1 fixed effects for each β_{sjk} , and $r_{st}+1$ fixed effects for each γ_{stk} , the total number of fixed effects in the 3-level model (2-1) was $\sum_{s=0}^p \sum_{t=0}^{q_s+1} (r_{st}+1) = 46$ of which 4 terms were within-level interactions and 23 terms were cross-level interactions. The values $q_s, r_{st} (s, t > 0)$ referred to the cross-level interactions coefficients and

$$\hat{\sigma}_{e(1)}^2 = \text{Var}\left(e_{ijk}^{(1)}\right) = \frac{\pi^2}{3}, \hat{\sigma}_{e(2)}^2 = \text{Var}\left(e_{sjk}^{(2)}\right) < \infty, \text{ and } \hat{\sigma}_{e(3)}^2 = \text{Var}\left(e_{stk}^{(3)}\right) < \infty. \quad (2)$$

The above multilevel logistic regression models applied maximum likelihood method to estimate each level coefficients as well as associated residual variances. In addition, Variance Partition Coefficient (VPC) and Intra Class Coefficient (ICC) statistics at each level of hierarchy were calculated via conventional equations for the three level model [32]. In the equation (2-1) let the two continuous variable "U" and

dichotomous variable "V" with their associated interaction term "U*V" appear in the following form:

$$\logit(E(Y^{(n)})) = \beta_U \cdot U + \beta_V \cdot V + \beta_{U*V} \cdot (U * V) + \dots (n=1,2) \quad (2-2)$$

Then, for each k units increase in the variable "U", the outcome odds ratio of "V=1" versus "V=0" changes by " $(\exp(\beta_{U*V} \cdot k) - 1) \times 100\%$ ". These conclusions were applied in the outcome related results and in their interpretations. All analyses were conducted using STATA version 11 software package.

Results

Descriptive and Inferential Statistics

Data on 8655 children (age range 4.5-8.0 years) collected during the school year 2008-2009 were analyzed for this report. These schools were nested within 185 neighbourhoods, which were further nested in 3 major cities (Saskatoon, 65 neighbourhoods, Regina, 30 neighbourhoods, and Prince Albert, 10 neighbourhoods) and non-urban areas (80 neighbourhoods). Table 1 presents descriptive statistics of the study sample population. As can be seen, the key characteristics included almost equal gender ratio, overwhelming majority of native English speakers (95.86%), majority of public school attendees (69.13%), a moderate mean income inequality (Gini=0.128), and almost equal urban to non-urban ratio. Table 2 summarizes bivariate results of the differences in proportions of vulnerability and multiple challenges outcomes based on characteristics of child, neighbourhood and geographical areas. The most notable findings included significantly higher proportions of vulnerability and multiple challenges among boys, Aboriginal children, children who speak English as an alternate language, and children without Non-parental care; a non-linear association (quadratic trend) between neighbourhood income inequality and proportions of vulnerability and multiple challenges; and a significantly highest proportions of vulnerability and multiple challenges in children in Regina.

Multilevel determinants of vulnerability and multiple challenges

Main effects, Within-level interactions and cross-level interactions: Tables 3a & 3b depict the coefficients (p-value) and odds ratios (95% CI) results for child level, neighbourhood level and geographical area level variables, within-level interactions and cross-level interactions for the two binary outcomes based on multilevel logistic models. In terms of our aim of determining multilevel independent factors associated with developmental vulnerability and multiple challenges, children speaking English as an alternate language had significantly higher odds of being rated as vulnerable and with multiple challenges (2.171, 1.802 respectively); whereas children attending French immersion schools had significantly lower odds of being rated as vulnerable and with multiple challenges (0.887, 0.431 respectively).

In terms of our aim of investigating effects that are modified by other determinants at the same hierarchical level (within-level effect modification), and effects that are modified by other determinants at a different hierarchical level (cross-level effect modification) the results were as follows. Considering within-level interactions, there was a greater positive impact of age on vulnerability and multiple challenges for girls compared for boys. The elevated odds of vulnerability and multiple challenge are attenuated by 55.8% and 84.7%, respectively, for

each year of increase in age for girls, whereas the comparable attenuation were 54.8% and 73.4% for boys. Next, living in neighborhoods with higher income inequality exacerbated the negative impact of higher neighborhood median income on vulnerability and multiple challenges. For neighborhoods with higher income inequality the related odds ratios of vulnerability and multiple challenge for children in neighborhoods where the median income increased by each \$10, 00 at least 19.1%, 7.6% respectively.

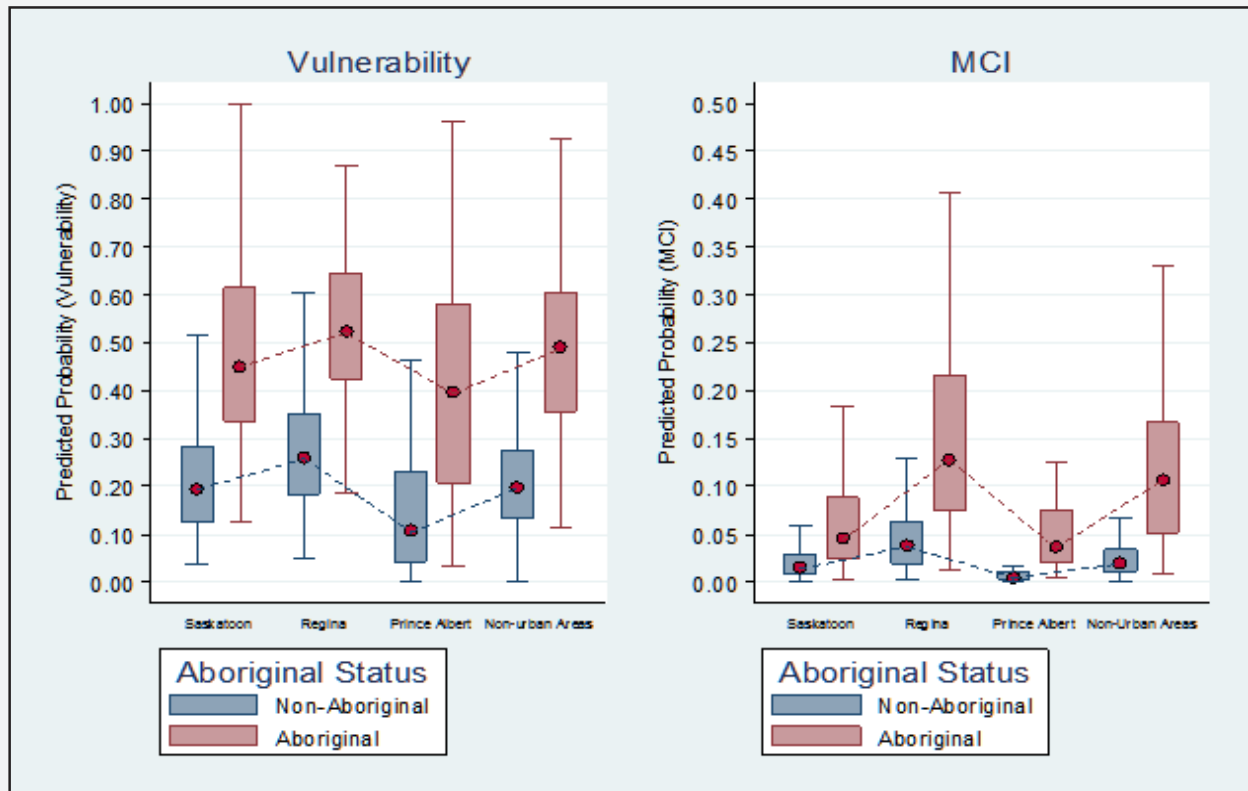


Figure 1 : Predicted Probabilities of Vulnerability and Multiple Challenge Outcomes by Geographical Area and Aboriginal Status.

Considering cross-level interactions, higher neighbourhood income inequality exacerbated negative impact of days absent from school on vulnerability outcome. For each additional week absent from school, odds of being rated as vulnerable increased by 14.2% for children living in neighbourhoods with high income inequality. Depending on the geographical area that the children were from (ie., city), there was either a mitigation of odds or an exacerbation of odds of vulnerability. The controlled for other factor effect of Aboriginal status on vulnerability was significantly lowered (by 31.5%, 33.0%) for children who resided in Regina and Saskatoon, respectively, whereas the odds of multiple challenge was significantly lowered (by 56.9% and 70.8%) for children who resided in Regina and Saskatoon, respectively. Figure 1 displays such differences between different geographical areas in terms of over all non-controlled predicted probabilities.

The effects of neighbourhood median income on vulnerability and multiple challenge were significantly reduced for children residing in all three major provincial cities compared to non-urban areas. For example, odds for vulnerability and multiple challenge were reduced 51.8% and 72.9%, respectively, for each \$10,000 increment of median income for children living in Saskatoon. Such changes were 53.9% and 64.3%; 54.8% and 53.0% for Regina and Prince Albert, respectively. In contrast, however, the odds of vulnerability for children who lived in neighbourhoods with moderate or high income inequality, compared to low, were heightened to 2.80 or 3.17 fold, respectively, for those who resided in Prince Albert. As shown in Figure 2, there is highest variation of over all non-controlled predicted probabilities between different neighborhoods within Prince Albert compared to other geographical areas.

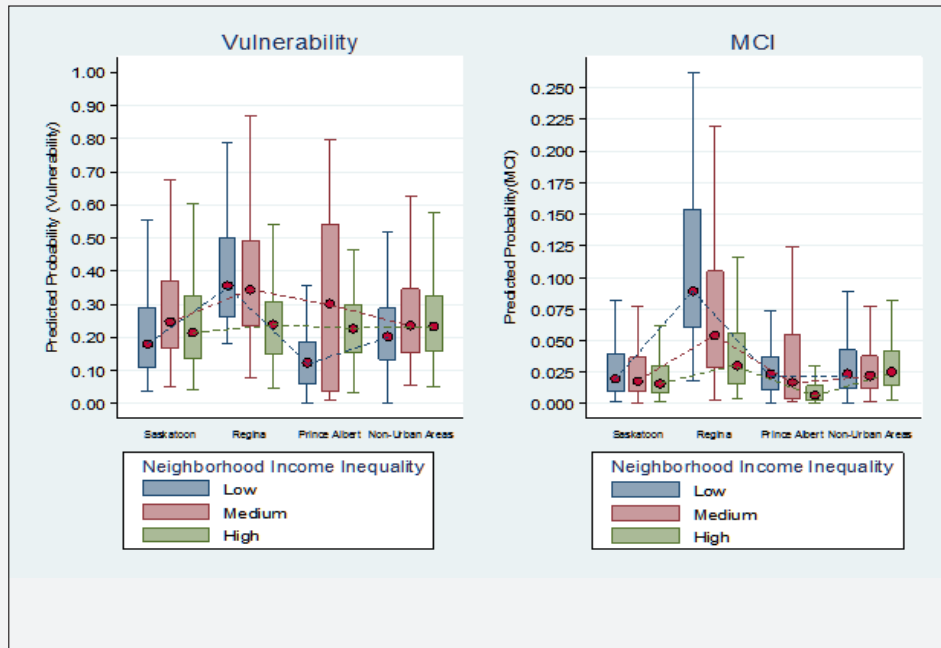


Figure 2 : Predicted Probabilities of Vulnerability and Multiple Challenge Outcomes by Geographical Areas and Neighborhood Income Inequality.

Multilevel contributions to the variances in developmental vulnerability and multiple challenges

Table 4 presents variance, variance partition coefficient and intra-class coefficients at geographical area, neighbourhood, and child levels for vulnerability and multiple challenge outcomes. As seen, as the hierarchy level moved from child to neighbourhood to geographical area, the associated variance at each level contributed to vulnerability and multiple challenge outcomes decreased. Partition of total variance by child, neighbourhood

and geographical area level is shown in Figure 3. Considering the variance partition coefficients, less than 1% of the variance in vulnerability status and multiple challenge outcomes were accounted by geographical areas; however, 11.1% and 18.3% of the variance for each outcome were accounted by variables measured at the neighbourhood level, while the remaining 88.9% and 81.7% of the variance were accounted for variables measured at child level. More than three-quarters of vulnerability and multiple challenge outcomes variations were attributable to the factors related to children themselves.

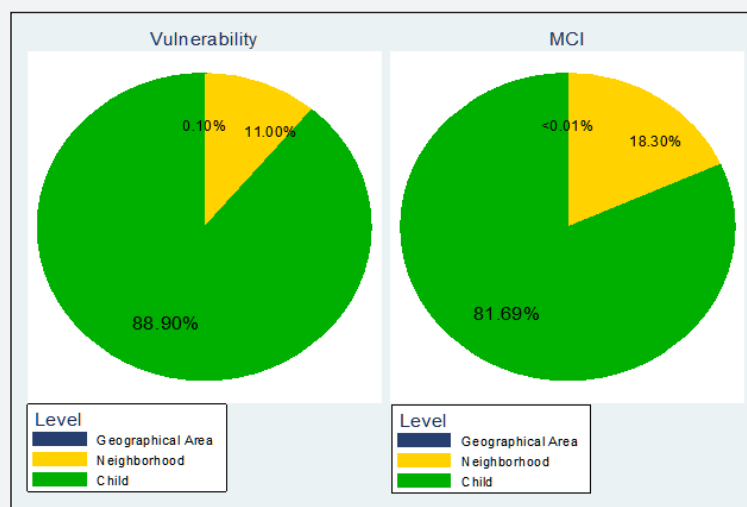


Figure 3 : Relative Contribution to the Variance of Developmental Vulnerability and Multiple Challenges (Variance Partition %) by Child, Neighborhood and Geographical Area Level Determinants.

Finally, observing intra-class coefficients statistics, the correlations between two children living in the same geographical area but different neighbourhoods were negligible for both vulnerability and multiple challenge outcomes, and the correlation between two children living in the same geographical area and in same neighbourhood were 0.111 and 0.183 for vulnerability and multiple challenge outcomes, respectively. Therefore, it is observed that living in the same neighbourhoods rather than adjacent neighbourhoods played a key role in the similarity of different or children's vulnerability and multiple challenge outcomes.

Discussion

Compositional and contextual effects on developmental vulnerability and multiple challenges-what this study adds?

The current study aimed to add two lines of findings to the literature on early childhood developmental vulnerability. First, it identified specific child characteristics, neighbourhood contextual factors, and geographical area indicators associated independently with children's developmental outcomes, vulnerability and multiple challenges. Second, it identified factors at each level of determinants-child, neighbourhood and geographical area-that either mitigates or exacerbates effects on childhood vulnerability outcomes. The characteristics related to children that were associated with the developmental vulnerability included child's gender, Aboriginal status, using English as an alternate language, and days absent from school. As previous studies have founded consistently, male children had higher odds of being rated as vulnerable and having multiple challenges than females. Similarly, compared with non-Aboriginal children, Aboriginal children had significantly higher odds of being rated as vulnerable. Compared to children who speak English as an alternate language, native English speaking children had lower odds of vulnerability and multiple challenge, consistent with past studies [33]. Finally, days absent from school had a negative effect on odds of vulnerability and multiple challenge. This finding lends support to the claim that kindergarten school educational programs are important and may even be critical for children's developmental health.

The main neighbourhood contextual factors that modified the effects of other factors associated with children's developmental vulnerability outcomes included neighbourhood income inequality and median income. High level of neighbourhood income inequality and days absent from school had a compound exacerbating effects on vulnerability. Children who were absent from school on more days had significantly higher odds of vulnerability but this was even more exacerbated if they also resided in neighbourhoods with greater income inequality. The above results give further evidence of the income inequality hypothesis [34,35]. Interestingly, and unexpectedly, children who were absent from school and had elevated odds of vulnerability

and multiple challenges had these odds attenuated if they were attendees of separate schools. While this finding is interesting, without knowing the exact reason for being absent from school (there are varied reasons including sickness but also more positive experiences such as family holidays), it is difficult at this time to conclude with any certainty why attending separate schools, compared to public schools, might accord some mitigation of odds for vulnerability outcomes.

Another intriguing finding relates to the significant interaction effects found between non-parental care and neighbourhood income inequality on vulnerability. While the magnitude of the interaction effects are very small, our findings nonetheless show that non-parental care accords a lower odds of vulnerability especially if the children resided in neighbourhoods with either high or medium level of income inequality. In province of Saskatchewan where non-parental care is often a privately arranged and purchased services, it is likely that only some parents are able to afford these services and not others even if they happen to live in the same neighbourhood [36].

This study also revealed that the geographical area that children resided in had a significant effect on the outcomes of vulnerability and multiple challenges in children. For example, on a less favourable note, children who lived in neighbourhoods with either higher or controlled for other factors medium level of income inequality had especially higher odds of vulnerability if they resided in the city of Prince Albert. On a more positive note, the odds of vulnerability or multiple challenges in Aboriginal controlled for other factors children were significantly attenuated (protected) if they resided in either in the city of Regina or Saskatoon, respectively. What specifically that these two cities (Regina and Saskatoon) offer to Aboriginal children so that their odds for developmental vulnerability are significantly reduced is a question that needs further investigation. Similarly, the odds of vulnerability and multiple challenge for children living in neighborhoods with higher median income were significantly reduced if they resided in the major provincial cities. This gives future evidence of urbanization benefits for financial well off inhabitants [37].

Strength and limitations

The current study has the following strengths. First, this is one of few instances, in Canada, where we have included nearly a full population of kindergarten age children in a province and taken into account data available at three levels of social hierarchy. Previous studies that had utilized province-wide data had been conducted taking into account either two levels of hierarchy or a single level of measurement. Second, as the study sample covered almost all kindergarten aged children attending schools throughout the province of Saskatchewan it is unlikely that this study would have suffered from serious potential selection biases. Third, the EDI and Census data have

been shown to have high reliability and acceptable validity, and, therefore, subject to little information bias. Finally, this study consisted of a large sample size and included a variety of predictors and their interactions yielding a relatively broad spectrum of information regarding individual, neighbourhood and geographical areas impacts on children's developmental vulnerability.

The current study, however, did have some limitations. First, there was a two year time difference between the collection of EDI data in 2008 and the census data in 2006 and this time lag could have affected the findings. Second, fitting the same set of predictor variables and their interactions for vulnerability and multiple challenge caused a loss of model fit for both domains. Third, the definition of 'neighbourhood' (conceptually and operationally) varies across major cities and non-urban areas, even within a single province. In Saskatchewan, municipalities define what a 'neighbourhood' means or entails, and these definitions may not extend easily to the non-urban areas included in this study. The operational definition of a neighbourhood in this study for non-urban areas was developed specifically for this research and we are aware, therefore, that this definition may not be easily transferable [38].

Conclusion

The current study used a combination of 2008-2009 EDI data of Saskatchewan children and 2006 Census data and applied multilevel logistic models in order to provide some insight regarding how individual, neighbourhood contextual and geographical area factors and their within-level and cross-level effects determine children's developmental vulnerabilities. Individual characteristics of Aboriginal status, EAL status, male children and school absenteeism were associated with higher odds of vulnerability and multiple challenge. Also, neighbourhood contextual characteristics such as income inequality and lower median income were associated with higher odds of vulnerability, giving further evidence for the income inequality hypothesis. In terms of factors that mitigates developmental vulnerability, we found that living in neighborhoods with higher median income had lowered the elevated odds of vulnerability in urban children; similarly, those Aboriginal children living in Regina or Saskatoon had lower odds compared to Aboriginal children living in non-urban areas. Intriguingly, we found that children who attended separate schools had lower odds of vulnerability even if they had more days absent from school. In terms of factors that exacerbated odds of vulnerability, we found that children who lived in neighbourhoods with high income inequalities and had more days absent from school had greatly elevated odds for vulnerability. Similarly, children who lived in neighbourhoods with greater income inequality and were from Prince Albert had especially elevated odds for developmental vulnerability.

In terms of child public policy, stakeholders, school policy-makers, and administrators should focus on initiatives for

children who are of Aboriginal status, non-native English speakers, male children, and those with more days absent from school and who are living in neighbourhoods with high income inequality. A recommendation is that the stakeholders design and promote child health programs that increase Aboriginal children's skills and school policy makers and administrators consider policies that minimize days absent from school for children living in neighbourhoods with high income inequality or a high Aboriginal population. Also, on a large scale, there is a need to promote child developmental health supporting programs by authorized institutions in the cities of Regina and Prince Albert. On the basis of these findings, future research should continue to examine and clarify the significance and the strength of association between the above predictors and their compound effects on child developmental health status by considering a longitudinal design and inclusion of more small cities in the hierarchy.

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Appendix

Table 1: Descriptive Statistics: Predictors and Outcome Variables . (n = 8655)

Variable	Category	%	Mean±s.e.
Predictors			
Child Characteristics			
Age			5.70± 0.0036
Days Absent			4.22 ± 0.0773
Gender	Female	49.82	
	Male	50.18	
Aboriginal Status	Aboriginal	16.54	
	Non-aboriginal	83.46	

Attendance at French/English Immersion School	Yes	12.42	
	No	87.56	
English as Second Language(EAL)	Yes	4.13	
	No	95.86	
Non-Parental Care	Yes	45.29	
	No	43.49	
	Unspecified	11.22	
Attendance at Language/Religion Class	Yes	16.09	
	No	68.91	
	Unspecified	14.93	
Neighbourhood Characteristics			
School Type	Public	69.13	
	Separate	30.06	
	Francophone	0.81	
Income Inequality (Gini Index)			0.128± 0.0010
Median Income in \$10,000 increments (per capita)			2.513± 0.0090
Unemployment Rate for People 15+ Years of Age (%)			5.392± 0.0416
Population with at least High School Education (%)			56.630± 0.1071
Average Value of Dwelling in Real \$10,000 increments			12.376± 0.0650
Geographical Area Characteristics			
Geographical Area	Saskatoon	23.44	
	Regina	21.29	
	Prince Albert	2.03	
	Non-urban Areas	53.24	
Outcome variables			
Vulnerability	Yes	28.01	
	No	71.99	
Multiple Challenge Index (MCI)	Yes	5.23	
	No	94.77	

Table 2 : Proportion (95% CI) of Child Level, Neighbourhood Level and Geographical Area Level Variables (%) by Vulnerability Status and Multiple Challenges.

Variable	Vulnerability Status	Multiple Challenges	Variable	Vulnerability Status	Multiple Challenges
Gender			Neighbourhood Income Inequality		
Girls(0)	20.49 (19.29,21.70)	3.11(2.59,3.62)	Low (1st tertile)	24.36 (22.70,26.02)	4.3 (3.52,5.08)
Boys(1)	35.49 (34.07,36.92)	7.32 (6.55,8.10)	Average (2nd tertile)	32.25 (30.51,33.99)	6.45 (5.84,7.36)
Difference (%)	73.2**	135.3**	High(3rd tertile)	27.25 (25.77,28.73)	4.75(4.04,5.45)
Aboriginal Status			Neighbourhood School Type		
Non-Aboriginal(0)	23.78 (22.80,24.76)	3.67(3.24,4.11)	Public	27.65 (26.51,28.78)	4.98(4.43,5.53)
Aboriginal(1)	49.75 (47.14,52.36)	13.16(11.40,14.92)	Separate	29.14 (27.40,30.80)	5.81 (4.91,6.70)
Difference (%)	109.2**	258.6**	Francophone	17.14(8.25,26.04)	4.2(0.00,9.07)
Maternal Language			Geographical Area		
English(0)	27.4(26.43,28.37)	5.13(4.66,5.61)	Saskatoon	27.11(25.20,29.02)	3.45(2.67,4.24)
EAL(1)	41.92(36.77,47.08)	7.37 (4.64,10.09)	Regina	33.4 (31.25,35.56)	7.52(6.31,8.73)

Difference (%)	52.9**	43.6	Prince Albert	24.28(19.74,30.83)	3.43 (0.72,6.13)
Care			Non-urban Areas		
Parental(0)	28.77 (27.15,30.15)	5.69 (4.95,6.43)		26.32 (25.04,27.60)	5.17 (4.53,5.82)
Non-parental(1)	25.08 (23.72,26.44)	3.98 (3.36,4.59)			
Difference	-12.8**	-30.1**			
(%)					

Note: **indicates significant estimates at 5% or lower. Income inequality categories are based on tertiles of Gini Index with i^{th} tertile $T_i = 0.100, 0.169$ respectively.

Table 3a : Regression Coefficients and Odds Ratios (95% Confidence Intervals) for Main Effects, Within-Level Interactions and Cross-Level Interactions Based on Multilevel Logistic Regression Models 3 levels for Developmental Vulnerability. n=7693

Variable	Vulnerability Status		Variable	Vulnerability Status	
	$\hat{\alpha}$ (p-value)	OR (95 %)		$\hat{\alpha}$ (p-value)	OR (95 %)
Child Characteristics					
Age	-0.816**	0.442**	Days Absent	+0.053**(<0.001)	1.053** (1.038,1.071)
Gender(Male)	0.727(0.482)	2.069 (0.273,15.690)	Aboriginal Status	+1.025** (<0.001)	2.787** (2.042,3.804)
French/English Immersion School Attendance	-0.12 -0.203	0.887 (0.737,1.067)	English as Second Language (EAL)	+0.775**(<0.001)	2,171** (1.679,2.804)
Non-Parental Care	+0.008** (0.028)	1.008** (1.000,1.015)	Language/Religion Class Attendance	+0.001 (0.147)	1.001 (1.000,1.003)
Neighbourhood Characteristics					
Separate School	+0.255** -0.002	1.289** (1.100,1.511)	Francophone School	-0.056952	0.405* (0.155,1.081)
Medium Income Inequality	-0.641 (0.370)	0.527 (0.130,2.138)	High Income Inequality	-0.072846	0.278* (0.075,1.138)
Median Income in \$10,000	+0.079 (0.346)	1.081 (0.919,1.274)	Unemployment Rate for People15+ Years of age (%)	0.001 -0.905	1.001 (0.981,1.021)
Population with at least High School Diploma (%)	-0.000 (0.994)	1.000 (0.989,1.010)	Average Value of Dwelling in Real \$10,000	+0.008 (0.572)	1.009 (0.978,1.040)
Geographical Area Characteristics					
Prince Albert	+2.979* -0.07	19.665* (0.782,493.0)	Regina	+2.832** (0.002)	16.979** (2.863,100.7)
Saskatoon		5.749** (1.564,20.803)			
Within-Level Interactions					
Gender*Non-Parental Care	+0.000 (0.799)	1.000(0.997,1.004)	Gender*Age	+0.023 (0.897)	1.023 (0.717,1.462)
Medium Income Inequality*Median Income	0.24 (0.350)	1.271 (0.768, 2.102)	HighIncome Inequality*Median Income	+0.518* -0.052	1.679* (0.995,2.845)
Cross-Level Interactions					
Medium Income Inequality*Days Absent	+0.016 (0.123)	1.119‡ (0.972,1.300)	High Income Inequality*Days Absent	+0.019* -0.097	1.142*‡ (0.979,1.341)
Medium Income Inequality*Aboriginal Status	+0.120 (0.574)	1.127 (0.742,1.716)	High Income Inequality*Aboriginal Status	0.188 -0.388	1.207 (0.308,1.807)

Separate School*Days Absent	-0.033** (<0.001)	0.968** (0.952,0.984)	Francophone School*Days Absent	-0.005 -0.843	0.995 (0.943,1.049)
Medium Income Inequality*Non-parental care	-0.044 (0.154)	0.996 (0.991,1.001)	High Income Inequality*Non-parental care	-0.006** (0.033)	0.994** (0.989,0.999)
Prince Albert*Aboriginal Status	0.3 -0.516	1.35 (0.546,3.333)	Regina*Aboriginal Status	-0.378 (0.079)	0.685* (0.450,1.044)
Saskatoon*Aboriginal Status	-0.0156	0.670** (0.455,0.980)	Prince Albert*Non-parental care	-0.000792	0.991* (0.980,1.001)
Regina*Non-parental care	-0.001 -0.839	2.801 (0.648,12.110)	Saskatoon*Non-parental care	-0.003 (0.235)	0.997 (0.993,1.002)
Prince Albert*Medium Income Inequality	+1.030 (0.168)	2.801 (0.648,12.110)	Regina*Medium Income Inequality	-0.228 -0.584	0.796 (0.352,1.800)
Saskatoon*Medium Income Inequality	0.15 -0.587	1.162 (0.676,1.998)	Prince Albert*High Income Inequality	+1.157 (0.122)	3.177 (0.735,13.740)
Regina*High Income Inequality	-0.794 (0.065)	0.452* (0.194,1.052)	Saskatoon*High Income Inequality	-0.217 (0.449)	0.805 (0.459,1.412)
Prince Albert*Median Income	-1.743** (0.003)	0.175** (0.055,0.555)	Regina*Median Income	-0.773	0.461** (0.249,0.884)
Saskatoon*Median Income	-0.729** (0.001)	0.482** (0.313,0.744)	Constant	+0.660 (0.708)	1.984 (0.061,61.191)
p-value for LR Test	<0.001				
Number of Observations	7693				

Note: *indicates the coefficient estimates significant at 10% level or lower, while **indicates level of significance at 5% or lower. ‡ indicates effect for 7 days.

Table 3b : Regression Coefficients and Odds Ratios (95% Confidence Intervals) for Main Effects, Within-Level Interactions and Cross-Level Interactions Based on Multilevel Logistic Regression Models for Multiple Challenges.

Variable	MCI		Variable	MCI	
	$\hat{\alpha}$ (p-value)	OR (95 %)		$\hat{\alpha}$ (p-value)	OR (95 %)
Child Characteristics					
Age	-0.872** (0.007)+	0.153** (0.040,0.599)	Days Absent	+0.046** (<0.001)	1.047** (1.023,1.071)
Gender(Male)	-2.109 (0.331)	0.121 (0.001,8.525)	Aboriginal Status	+1.164** (<0.001)	3.202** (1.822,5.635)
French/English Immersion School Attendance	-0.841** (0.001)	0.431** (0.265,0.701)	English as Second Language (EAL)	+0.589** (0.019)	1.802** (1.100,2.948)
Non-Parental Care	+0.009 (0.191)	1.009 (0.995,1.023)	Language/Religion Class Attendance	-0.001 (0.633)	0.999 (0.995,1.003)
Neighbourhood Characteristics					
Separate School	+0.522** (0.001)	1.685** (1.248,2.275)	Francophone School	+0.189 (0.335)	1.208 (0.204,7.142)
Medium Income Inequality	-0.845 (0.576)	0.430 (0.022,8.248)	High Income Inequality	-0.386 (0.776)	0.680 (0.048,9.679)

Median Income in \$10,000	+0.433* (0.024)	1.550** (1.060,2.266)	Unemployment Rate for People 15+ Years of age (%)	-0.001 (0.979)	0.999 (0.954,1.047)
Population with at least High School Diploma (%)	-0.012 (0.297)	0.988 (0.965,1.011)	Average Value of Dwelling in Real \$10,000	+0.002 (0.959)	1.002 (0.940,1.067)
Geographical Area Characteristics					
Prince Albert	+0.402 (0.918)	1.495 (0.000,2980)	Regina	+4.277** (0.013)	72.024** (2.499,1096)
Saskatoon	+3.405** (0.007)	30.114** (2.545,365.0)			
		Within-Level Interactions			
Gender*Non-Parental Care	+0.001 (0.827)	1.001 (0.994,1.008)	Gender*Age	+0.552 (0.152)	1.737 (0.816,3.702)
Medium Income Inequality*Median Income	+0.175 (0.747)	1.191 (0.411, 3.449)	High Income Inequality*Median Income	+0.073 (0.892)	1.076 (0.375,3.080)
Cross-Level Interactions					
Medium Income Inequality*Days Absent	-0.008 (0.619)	0.992 (0.960,1.023)	High Income Inequality*Days Absent	+0.006 (0.717)	1.006 (0.975,1.037)
Medium Income Inequality*Aboriginal Status	+0.629* (0.086)	1.876* (0.916,3.845)	High Income Inequality*Aboriginal Status	+0.426 (0.262)	1.531 (0.727,3.225)
Separate School*Days Absent	-0.030** (0.014)	0.970** (0.948,0.994)	Francophone School*Days Absent	-0.044 (0.498)	0.957 (0.840,1.088)
Medium Income Inequality*Non-parental care	-0.007 (0.129)	0.993 (0.985,1.002)	High Income Inequality*Non-parental care	-0.010* (0.051)	0.990* (0.981,1.000)
Prince Albert*Aboriginal	-0.143 (0.905)	0.867 (0.081,9.207)	Regina*Aboriginal Status	-0.841** (0.012)	0.431** (0.223,0.832)
Status					
Saskatoon*Aboriginal Status	-1.229** (0.001)	0.292** (0.142,0.604)	Prince Albert*Non-parental care	-0.006 (0.675)	1.006 (0.977,1.036)
Regina*Non-parental care	0.000 (0.967)	1.000 (0.990,1.011)	Saskatoon*Non-parental care	-0.002 (0.641)	0.998 (0.989,1.007)
Prince Albert*Medium Income Inequality	+0.502 (0.720)	1.652 (0.105,25.920)	Regina*Medium Income Inequality	-0.498 (0.539)	0.608 (0.124,2.974)
Saskatoon*Medium Income Inequality	+0.068 (0.906)	1.070 (0.347,3.297)	Prince Albert*High Income Inequality	+0.169 (0.916)	1.183 (0.052,26.735)
Regina*High Income Inequality	-0.755 (0.377)	0.470 (0.088,2.509)	Saskatoon*High Income Inequality	-0.469 (0.421)	0.625 (0.200,1.958)
Prince Albert*Median Income	-0.981 (0.460)	0.375 (0.028,5.073)	Regina*Median Income	-1.031* (0.098)	0.357* (0.105,1.209)
Saskatoon*Median Income	-1.307** (0.003)	0.271** (0.114,0.640)	Constant	+4.172 (0.292)	64.845 (0.028,14726)
p-value for LR Test	<0.001				
Number of Observations	7693				

Table 4 : The Relative Contribution to the Variation of Vulnerability and Multiple Challenges Based on Multilevel Logistic Model.

	Vulnerability Status	Multiple Challenges
Variance (geographical area), $\sigma_{\epsilon(3)}^2$	0.004	2×10^{-10}
Variance(neighbourhood), $\sigma_{\epsilon(2)}^2$	0.41	0.735
Variance (child), $\sigma_{\epsilon(1)}^2$	3.29	3.29
Variance Partition Coefficient (geographical area)	0.001	5×10^{-11}

Variance Partition Coefficient(neighbourhood) $\sigma_{\epsilon(1)}^2$	0.111	0.183
Variance Partition Coefficient (child)	0.889	0.817
Intra-class Coefficient (geographical area)	0.001	5×10^{-11}
Intra-class Coefficient (neighbourhood)	0.111	0.183



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