THE SOCIOECONOMIC GRADIENT IN THE DEVELOPMENTAL HEALTH OF CANADIAN CHILDREN WITH DISABILITIES

By DENA ZERAATKAR, BHSc

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree Master of Science

McMaster University MASTER OF SCIENCE (2017) Hamilton, Ontario (Health Research Methodology)

TITLE: The socioeconomic gradient in the developmental health of Canadian children with disabilities

AUTHOR: Dena Zeraatkar, BHSc (McMaster University)

SUPERVISOR: Dr. Magdalena Janus

NUMBER OF PAGES: xv, 116

Lay Abstract

Children with special needs, compared to typically developing children, experience more problems at school entry, which puts them at risk of poor academic and social outcomes later in life. There is evidence that certain factors can amplify or buffer against these poor outcomes. This thesis explores the association between developmental outcomes of children with special needs at school entry and neighborhood-level socioeconomic status (SES). It uses data from the Early Development Instrument (EDI) as a measure of children's developmental health. To date, the EDI has only been validated for use in typically developing children. Hence, a secondary objective of this thesis was to explore the measurement properties of the EDI in children with special needs. The EDI was found to perform well in this population. Children with special needs from higher SES neighborhoods were found to have better developmental outcomes compared to children from lower SES neighborhoods.

Abstract

Background: Compared with typically developing children, children with special needs often struggle with academic and social aspects of school, though certain factors can improve their academic and social developmental trajectory. The objective of this investigation was to explore the association between the developmental health of children with special needs at school-entry, as measured by the Early Development Instrument (EDI), and neighborhood-level SES. To date, the EDI has only been validated for use in typically developing children. Hence, a secondary objective of this investigation was to explore the psychometric properties of the EDI for children with special needs.

Methods: The data for this investigation were from the Pan-Canadian database of children's developmental health at school entry. The psychometric properties of the EDI, including item and domain characteristics, factor structure, and construct validity, were tested for children with special needs. Hierarchical generalized linear models was used to model the association between EDI domain scores and a custom neighborhood SES index.

Results: A total of 29,841 (69.8% male) and 29,520 (69.7% male) children with special needs were available for the investigation on the psychometric properties of the EDI and the relationship between EDI outcomes and SES, respectively. The psychometric performance of the EDI in children with special needs was similar to its performance in typically developing children. The EDI was subsequently used to explore the association between developmental outcomes and neighborhood socioeconomic status (SES). All EDI domains were positively correlated with SES, indicating that children in high SES neighborhoods have better developmental outcomes at school entry than those in lower SES neighborhoods.

Conclusions: The results of this investigation draw attention to the potential impact of contextual factors on children's health and have implications for policy development and service planning. These

results also indicate that the EDI performs similarly in children with special needs and typically developing children, thus enabling its more extensive use for this population.

Acknowledgements

First and foremost, I would like to thank my parents for giving me the opportunity to pursue my interest in education. Without their support and encouragement, I would not be where I am today.

I would also like to thank my supervisor, Dr. Magdalena Janus, and my committee members, Dr. Eric Duku and Dr. Teresa Bennett, for their patience and valuable direction and advice. Thank you for challenging me and showing me all that I can achieve.

To my friends and colleagues in the Health Research Methodology program, professors, and the administrative team, thank you for making the last two years unforgettable. The opportunity to learn within a collaborative and enriching environment has been phenomenal and I will strive to promote the same qualities within my future endeavors in the program.

Last, but certainly not least, thank you to my partner, Michael, for his unconditional love and support, and without whom this would not have been possible.

Table of Contents

List of tables

List of appendices

List of abbreviations and symbols

ANCOVA = Analysis of Covariance

ANOVA = Analysis of Variance

CanNECD = Canadian Neighborhoods and Early Child Development

CCHICS = Canadian Children's Health in Context Study

CFA = Confirmatory Factor Analysis

CIHR = Canadian Institute of Health Research

EDI = Early Development Instrument

- PHWB = Physical health & wellbeing
- SC = Social competence
- EM = Emotional maturity
- LCD = Language & cognitive development
- CSGK = Communication skills & general knowledge

EFSL = English/French as a second language

FIML = Full Information Maximum Likelihood

GLM = Generalized Linear Model

HGLM = Hierarchical Generalized Linear Model

HiREB = Hamilton Integrated Research Ethics Board

ICC = Intraclass Correlation Coefficient

IEP = Individual Education Plan

MANCOVA = Multivariate Analysis of Covariance

MLR = Robust Maximum Likelihood

PALS = Participation and Activity Limitations Study

R^2 = Coefficient of Determination

REB = Research Ethics Board

SD = Standard deviation

SE = Standard error

SEM = Structural Equation Modeling

SES = Socioeconomic status

SN = Special needs

TD = Typically developing

VIF = Variance Inflation Factor

WLSMV = Mean and Variance Adjusted Weighted Least Squares

Declaration of academic achievement

This thesis is comprised of two different studies. The first investigated the psychometric properties of the Early Development Instrument (EDI) in children with special needs. The second looked at the socioeconomic gradient in the developmental health of children with special needs. This work was completed between September 2015 and May 2017. The data for these two investigations came from two Canadian Institute of Health Research (CIHR)-funded studies by the following investigators:

Canadian Neighbourhoods and Early Child Development (CanNECD) investigators

Martin Guhn, Magdalena Janus, Marni Brownell Eric Duku, Barry Forer, Nazeem Muhajarine

Canadian Children's Health in Context Study (CCHICS) investigators

Magdalena Janus, Marni Brownell, Teresa Bennett, Catherine Birken. Robert Coplan, Eric Duku, Stelios Georgiades, Jan Willem Gorter, Martin Guhn, Barry Forer, Jonathon Maguire, Jacqueline Pei, Rob Santos, Heather Manson

Supported by research staff: Rob Raos, Caroline Reid-Westoby and Sarah Taylor

All work presented herein was reviewed by Dr. Magdalena Janus, Dr. Eric Duku, and Dr. Teresa Bennett who also provided valuable feedback.

1.0 Background

1.1.1 Children with special needs

Definitions of what constitutes special needs in kindergarten vary across provinces and territories. According to the Ontario Ministry of Education and the Education Act, an exceptional child is defined as an individual whose behavioral, communicational, intellectual, physical, or multiple exceptionalities require him or her to be placed in a special education program (1). Generally, most definitions of special needs used across Canada are similar in that they include children who require additional support to succeed in the classroom and do not require children to have a formal diagnosis before being identified as having special needs (1). Additionally, definitions usually include gifted children.

According to the Participation and Activity Limitations (PALS) study, a national survey conducted in 2006 that aimed at collecting information on children and adults with disabilities, 4.2% of children between the ages of 5 to 9 have one or more disabilities (2). There is evidence that approximately half of these children are identified only after entering school, with the prevalence of disabilities increasing by 2.7% upon school-entry (2).

1.1.2 Special education in Canada

Most Canadian provinces and territories have an Education Act which details their special education policy (1, 3). The financing, curriculum development, and delivery of special education programs and services, as well as all other aspects of providing a compulsory education program, come under the control of the provincial or territorial legislative assembly and differ among jurisdictions.

The exact process of registering a child as having special needs depends on the provincial regulations and policies. Usually, a committee determines whether a student is in need of special education programs and services (1). This committee is most often comprised of parent(s), a representative of the board of education that primarily deals with special education, and a representative of the school (usually principal or vice-principal). Other individuals with different roles may be asked to serve as part of the committee, including healthcare professionals. Upon the identification of a child with special needs, individual boards of education can apply to the Department of Education (the term Ministry is used in some provinces in place of Department) for additional funds that may be required to offer special educational services.

Generally, integration is the first choice of classroom placement and any segregated placement must be in accordance with the parent's wishes (1, 4). In fact, some provinces such as New Brunswick have integration as the only option (1). Other provinces have a continuum of placement options, with integration being preferred. An Individual Education Plan (IEP), a common theme in special education across Canada, which may be referred to by different names including Individual Program Plan in Alberta and Individual Support Services Plan in Newfoundland, is created for each child with special needs and outlines the specific abilities of the child, educational objectives for the child, and services and accommodations that would benefit the child in attaining these objectives. It is usually developed by educators, as well as parents and guardians. The role of the IEP is to allow the child with special needs to succeed in the classroom through appropriate accommodations and modifications to curriculum expectations.

Despite the structures in place to provide individualized education to children that meets their special needs, certain challenges still exist. These challenges include the delivery of special education services given the ethnic diversity of Canada, fiscal pressures, and providing qualified teachers, assessment personnel, and services to all rural and remote communities (1). An additional issue that has received less attention is contextual factors, such as the family and socioeconomic environment, which can impact children's learning and development, but is largely outside the control of educators (5). This will largely be the focus of this thesis (Section 1.3).

1.1.3 Academic and socioemotional outcomes and their correlates

Children with special needs have been observed to start school with fewer skills than their typically developing peers and to struggle academically during early childhood (6-8), as well as middle childhood and adolescence (9-11). For example, children with chronic illness between the ages of five and six have been reported to have 20% to 35% increased odds of being classified as developmentally vulnerable at school-entry, meaning that they are more likely to have scores below the 10th percentile on the Early Development Instrument (EDI), a standardized measure of development covering physical, social, emotional, cognitive, and communication domains (7). During middle childhood and adolescence, these children are two to ten times more likely than typically developing children to experience poor school outcomes, such as high absenteeism and low school engagement (9). There is evidence that academic disparities between children with special needs and typically developing children grow larger with increasing age (8).

Children with special needs also disproportionately struggle socially and emotionally compared to typically developing children. Similar to school outcomes, poor social and emotional outcomes have been observed in both early childhood (6, 12, 13), and middle childhood and adolescence (11). McIntyre and colleagues (2006) reported children with intellectual disability between the ages of five and six to have three times higher rates of teacher-reported problem behavior than typically developing children at school entry, as well as significantly fewer social skills and lower self-regulation (12). During adolescence, these children are also less likely to exhibit social engagement, such as working for pay and volunteering (11). Appendix 1A presents an overview of studies on the academic and socioemotional outcomes of children with special needs.

Although children with special needs, on average, have worse outcomes than their typically developing peers, there is also significant heterogeneity in their outcomes (8, 14). Some studies have found that children with special needs can have the same or even better outcomes than typically developing children (15-18), and that modifiable factors unrelated to the child's disability can improve or exacerbate these outcomes (14). These factors can be divided into two categories: (1) community and family social and economic characteristics, and (2) school support and other services.

Higher socioeconomic status (SES), at the community and family levels, has been linked to better outcomes in children with special needs (8, 19-21). In fact, Emerson et al. (2014) show that the increased prevalence of conduct disorders at age three among children with intellectual disability, compared to typically developing children, can mostly be explained by differences in exposure to socioeconomic risk factors (19). Similar to SES, family structure and parenting practices have also been found predictive of outcomes (11, 22). Compared to children in two-parent families, children with special needs living in single-parent families or with step-families have 38% to 164% increased odds of reduced participation in the community (11).

With regard to support structures outside of the family environment, support from school staff, structured hospital-to-school liaison, and mandated case management have been linked to better academic outcomes (10, 14). Studies linking inclusive education with academic and social outcomes have generally been mixed (23), with both positive (24, 25) and negative (26, 27) findings being reported.

Identifying factors that can explain the variation in outcomes of children with special needs is important in planning and implementing interventions that improve the poor developmental trajectory of this already vulnerable population. Existing studies on correlates of outcomes in this population most often address only a few specific diagnoses and are not representative of all disabilities experienced by children. Hence, the role of many modifiable factors in predicting outcomes in this population as a whole is unknown. Appendix 1B presents an overview of studies on factors associated with worse or better outcomes in children with special needs.

1.2 Early Development Instrument (EDI)

The Early Development Instrument (EDI) is a measure of children's developmental health at school entry. It is completed by kindergarten teachers for each child in their classroom in the second half of kindergarten year based on their observation of the child (28). It includes 103 items grouped into five developmental domains: physical health & wellbeing (PHWB), social competence (SC), emotional maturity (EM), language & cognitive development (LCD), communication skills & general knowledge (CSGK). Items are rated either on a 2-point (yes/no) or 3-point (often/very true, sometimes/somewhat true, or never/not true) scale. Domain scores are calculated as a mean of all non-missing responses within the domain and range from 0 (low) to 10 (high). An EDI record from a participant is considered valid if no more than one domain is missing and domain scores are valid if no more than 30% of items within the domain are missing. As per recommendations of the developers, there is no total score on the EDI and only domain scores are interpreted.

In addition to core EDI items, information on key demographic characteristics, such as whether a child has a special needs designation, are also collected alongside the EDI. The EDI definition of special needs includes children who require special assistance in the classroom due to chronic medical, physical, or mental disabling conditions (https://edi.offordcentre.com/wp/wp-content/uploads/2015/07/EDI-Guide-ON-2015-Eng-1.pdf). This definition does not included gifted and talented children, unlike definitions used by some boards of education in Canada.

The EDI has undergone extensive reliability and validity testing to date. Reliability has been established as being more than adequate. The internal consistency of domains ranges from 0.84 to 0.96 (28). Test-retest reliability ranges from 0.84 to 0.94 (28). Tests of convergent and discriminant validity have all yielded results as hypothesized by the investigators (28). These tests include the association of the EDI with age, gender, and English as a second language status.

The predictive validity of the EDI has been established with children's academic and social outcomes at several timepoints throughout early and middle childhood. The EDI, particularly the PHWB and LCD domains, has been shown to explain 36% of the variance in school achievement at first grade (29). At grade 3, LCD and CSGK domains have shown strong correlations with reading, writing, and math scores, and the PHWB, SC, and EM domains have been found to be significantly predictive of achievement scores, with effect sizes larger than demographic variables such as gender and EFSL status (30). At grade 4, SC, EM, and LCD have been shown to predict connectedness to peers, emotional well-being, and literacy and numeracy test results, respectively (31). The Australian version of the EDI has shown to be predictive of literacy and numeracy at ages 8, 10, and 12, with Spearman rho statistics ranging from 0.11 to 0.42 (32).

Other assessments of the psychometric performance of the EDI have also produced favorable, but sometimes conflicting, results. Guhn et al. (2007) report no systematic differences in EDI measurement based on gender and Aboriginal status, apart from one item on which boys are more likely than girls to be rated as physically aggressive by kindergarten teachers (33). In contrast, Rasch analysis of an Irish convenience sample revealed major differential item functioning based on gender for the EM domain, with almost one-third of items being biased in favor of girls (34). With regard to the factor structure of the EDI, Mousavi & Krishnan (2015) found some minor problems (35), which was expected given the theoretical rather than statistical construction of EDI domains (28). Janus et al. (2011) replicated the factor structure of the EDI in Australian and American samples, signifying the factor invariance of the instrument (36).

In summary, evidence indicates the EDI to be a reliable and valid population-level measure of children's developmental health at school entry. Its use also has three associated advantages. First, the instrument covers the relevant developmental areas at a critical age which sets the trajectory for future academic and social outcomes (37). Second, due to its implementation for whole populations of children, databases cover all children in the community, and not only a sample of them. Finally, on account of such wide-scale implementation, it allows aggregation of information for populations of children with specific characteristics who otherwise may only contribute very few scores to community-level data. The problems that have been observed to date, such as potential differential item functioning and heterogeneity within domains, are minor and have not interfered with the adaptation of the EDI across jurisdictions or its use for policy and service development and evaluation.

1.3 Objectives and Thesis Structure

The objectives of this thesis are two-fold. First, the psychometric performance of the EDI was evaluated in Canadian children with special needs. Second, the socioeconomic gradient in the developmental health of Canadian children with special needs was explored. The evaluation of the psychometric performance of the EDI in children with special needs is a qualification to the second part of the thesis, which uses EDI data from children with special needs. The study on the psychometric evaluation of the EDI in Canadian children with special needs is introduced in Section 1.5, methods and results are in Chapter 3, and discussion is presented in Chapter 5 in Section 5.1. The study on the socioeconomic gradient of the developmental health of children with special needs is introduced in Section 1.6, methods and results are presented in Chapter 4, followed by discussion in Chapter 5 in Section 5.2. Chapter 2 describes the data source for these two studies.

1.4 Non-categorical approach to child development

The non-categorical approach to child development emerged in the early 1980's and it refers to categorizing children with disabilities based on their abilities and functional impairments imposed by their conditions rather than diagnostic labels (38). The rationale behind adopting a non-categorical, otherwise referred to as non-diagnostic, approach is threefold (39). First, many diagnoses of childhood disability, such as autism spectrum disorder and cerebral palsy, describe heterogeneous groups of conditions that can impact children's function and development in a variety of different ways, through a variety of biological mechanisms, and are thus imprecise in describing the functional abilities and outcomes of children. Second, treatment strategies are often common across groups of disabilities characterized by similar signs and symptoms. Finally, even when unique treatments are available to target a specific childhood chronic health condition, the connection between receiving treatment and subsequent functional outcomes is weak (40).

In addition to these arguments, there is also empirical evidence supporting a non-categorical approach to childhood disability (38, 41, 42). For example, Stein & Jessop (1989) show that the magnitude of variation between diagnostic categories in measures of social, psychological, and rehabilitative outcomes is less than the magnitude of variation within diagnostic categories (38). Many studies have also identified children without formal medical diagnoses who are in need of additional services and support to succeed in school (8, 43, 44). A diagnostic approach to childhood disabilities draws attention away from these children who may better benefit from early intervention and accommodation compared to those with more severe, diagnosed disabilities.

The non-categorical approach to disability has increasingly gained acceptance in the fields of public health and developmental psychology. It is reflected in the World Health Organization's International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) which focuses on functional abilities (45). The use of the non-categorical approach extends benefits to both research and service delivery. While children in any specific disease category form a very small percentage of all children, collectively, children with disabilities form a sizable segment of the population. Looking collectively at many small clusters of children based on their functional abilities opens the possibility of conducting research on academic and social issues with community and population based samples. Additionally, this approach facilitates the development of service programs that target a range of children with special needs as local communities cannot offer services tailored to every type of condition because of the small number of children within each diagnostic category. Due to these reasons, the objectives outlined in Section 1.3 will be achieved by taking a non-categorical perspective on childhood disability. Specifically, all children with a special needs designation reported on the EDI will be included in the described analyses, regardless of diagnosis or lack thereof.

1.5 Psychometric properties of the Early Development Instrument (EDI) in the Canadian population of children with special needs

High quality, representative data from early childhood can help policymakers and service providers identify factors that impact the developmental health of children with special needs and work towards optimizing the developmental trajectory of this especially vulnerable population (46). The association between early school experiences and later academic and social outcomes has been well demonstrated (10, 14, 30-32, 47, 48). Furthermore, negative academic and social trajectories are more difficult to alter by middle childhood, highlighting early childhood as a critical time for identification and intervention (37, 49). In the United States, federal legislation mandates the collection and reporting of outcome data about the developmental status of children with special needs accessing various programs and services throughout early childhood. There is not a similar federal mandate in place in Canada, however, the EDI is routinely used to collect information on all children's developmental health at school-entry at a population level. The established validity, relevance, and availability of EDI data make it useful for municipal and provincial governments and community-level services. Additionally, the widespread use of the EDI allows comparisons to be made across jurisdictions and time points.

The EDI offers considerable benefit for studying low incidence conditions, such as childhood disability, since outcome data accumulate over time, overcoming the limitations of primary data collection that typically involves small sample sizes across individual schools and time points. To date, EDI data collected from children with special needs have been used to a lesser extent than data collected from typically developing children and only a few research studies have been published that use data from children with special needs (8, 34, 36, 50, 51). There has been some understandable hesitation in the use of EDI data from children with special needs, partly because the EDI has not been formally validated for use in this population (52). Other difficulties in studying this population may be that some parents choose to enroll children in specialized and privatized schools and so this subset of the population, albeit likely very small, would not be accessible in EDI data collections which only target public schools. This may limit the representativeness of EDI data in terms of types and severities of special needs, although the precise impact is difficult to determine due to the unavailability of data comparing children with special needs in private and publicly funded schools.

When an instrument is used in a population other than that which in which it was originally developed and validated, it is important to reassess the reliability and validity of the instrument in the new population (53). In the traditional context of psychological, clinical, and population assessment and measurement, reliability is the ability of an instrument to differentiate between individuals and can be influenced by the magnitude of variability in the construct being measured in a population. Differences between populations can also give rise to floor and ceiling effects where the spectrum of measurement of an instrument is either too high or too low to be able to adequately differentiate between individuals from a new population. Because the magnitude of variability in the construct of measurement is likely to differ between populations, reassessing reliability is important when an instrument is used in a new population. Similarly, the validity of a measure, which is the appropriateness of the inferences that can be made about individuals that produce a set of scores on an instrument, is also closely tied with the population in which it is established. Not only can the interpretation and applicability of items on an instrument differ across populations, but the operation of the construct being measured may also be different such that associations with other constructs are of a different magnitude or direction than that which is usually observed (53-55).

Evaluating the psychometric performance of the EDI in children with special needs is a step towards more extensive monitoring of the developmental health of this population and is important in promoting equitable and inclusive educational opportunities for all children. Although there is no direct evidence addressing the reliability and validity of the EDI in children with special needs, there is evidence that developmental assessments can be valid in both typically developing and special needs populations. For example, the Preschool Development Assessment Scale was tested in typically developing children, in addition to children with special needs (56). There was no evidence of differential item functioning between the typically developing and special needs populations, suggesting that items were relevant to and performed similarly in both groups. Ho & Lo (2013) had a similar experience validating the Gumpel Readiness Inventory (57) in a group of children three to five years old from Hong Kong (58). The only concern identified was the frequency of incomplete data for children with special needs which was higher than for typically developing children.

Chapter 3 presents an evaluation of the psychometric performance of the EDI in the population of Canadian children with special needs. This was done to assess the appropriateness of using EDI data to investigate the socioeconomic gradient in the developmental health of children with special needs at school entry in Chapter 4. The results of this evaluation also have implications for researchers and decision makers in various jurisdictions using or planning to use EDI data from this population for policy and service planning and evaluation.

1.6 The socioeconomic gradient in the developmental health of children with special needs

Gradients in health outcomes according to SES, commonly conceptualized as a combination of economic (finance and wealth), human (education and training) and social (family and community relationships) resources, were first empirically demonstrated by the Whitehall Studies, which looked at the socioeconomic gradient of cardiovascular health and mortality among British civil servants (59, 60). To date, many other health outcomes have also been reported to follow a socioeconomic gradient, including end-stage renal disease, breast cancer, obesity, and cardiometabolic health (61-64). These studies have mainly focused on chronic conditions in adulthood, with studies on the socioeconomic determinants of childhood conditions, including development, only more recently emerging (65-67).

The socioeconomic gradient in typically developing children's developmental health has been reported in various high, middle, and low income countries (68-70). This relationship has been documented in the population of Canadian children using four different published indices of neighborhood-level SES (65). Additionally, Oliver et al. (2007), Lapointe et al. (2007), and Guhn et al. (2010) reported socioeconomic gradients in children's development at school-entry in British Columbia using various social and economic indicators (71-73). Although the existence of the relationship between SES and developmental health has been established in typically developing children, less is known about this relationship in children with special needs.

The prevalence of childhood disabilities has been consistently shown to be negatively associated with SES in many different settings (74). Stabile & Currie (2003) used data from the Canadian National Longitudinal Survey of Children and Youth (NLSCY) for children between 0 and 11 years of age to illustrate an inverse relationship between the prevalence of chronic childhood disabilities and SES (75). However, only evidence on prevalence of disabilities has been reported to date and evidence on the relationship between SES and functional outcomes in this population is limited. The evidence that does exist most often addresses a few specific diagnoses during middle childhood, is not representative of all disabilities or outcomes experienced by children during early childhood, is not conducted in Canada, and does not consider the impact of SES outside of the immediate family environment (i.e., neighborhood SES) which has been shown to be a significant influence on developmental outcomes in typically developing children (65). In a cohort of 6-14 year old children with Down's Syndrome from Manchester, Turner and colleagues (1991) found parental education to be associated with mental age and IQ (76). Social class was also found to be associated with children's improvement in mental age over a two-year time period and mother's assessment of housing adequacy was negatively correlated with child behavioral problems. In the same population, Turner and colleagues (2008) did not find a significant association between parental education attainment and SES and children's academic attainment (77). Rather, parental education attainment and SES were positively correlated with children's enrolment in mainstream schools and children's baseline mental age, which were then positively correlated with children's academic attainment. In a group of 10-13 year old children with learning disabilities from Poland, SES, measured by an index of social and cultural variables, was significantly associated with academic achievement (78). Similar to findings by Turner and colleagues (1991, 2008), this association was mediated by placement in regular and integrative schools, as well as parental engagement.

Understanding determinants of poor developmental health in early childhood can help in identifying groups of children with special needs who are likely to be at risk for worse academic and social outcomes later in life. This information can ultimately inform policy development and service provision to optimize the developmental trajectory of this already vulnerable population. Chapter 4 presents an investigation of the socioeconomic gradient of the developmental health of children with special needs at school entry using Pan-Canadian data. This investigation is different from previous work in that it focuses on early childhood, a time at which experiences are likely to critically impact long-term academic and social outcomes (79), takes a non-categorical approach to child development (section 1.4), and includes a population-based sample (28).

1.7 References

1. Dworet D, Bennett S. A view from the north: Special education in Canada. Teaching Exceptional Children. 2002;34(5):22.
2. Brennan S. Participation and Activity Limitation Survey 2006: Facts on Learning Limitations: Statistics Canada, Social and Aboriginal Statistics Division; 2009.
3. Education A. Partners in education: Principles for a new School Act. Edmonton: Government of Alberta. 1985.
4. Weber KJ, Bennett S, Dworet D. Special education in Ontario schools; 2013.
5. Bronfenbrenner U. Ecological systems theory: Jessica Kingsley Publishers; 1992.
6. Whiteford C, Walker S, Berthelsen D. Australian children with special health care needs: social-emotional and learning competencies in the early years. International Journal of Early Childhood. 2013;45(1):35-50.

7. Bell MF, Bayliss DM, Glauert R, Harrison A, Ohan JL. Chronic Illness and Developmental Vulnerability at School Entry. Pediatrics. 2016;137(5):e20152475.
8. Goldfeld S, O'Connor M, Quach J, Tarasuik J, Kvalsvig A. Learning trajectories of children with special health care needs across the severity spectrum. Academic pediatrics. 2015;15(2):177-84.
9. Reuben CA, Pastor PN. The effect of special health care needs and health status on school functioning. Disability and health journal. 2013;6(4):325-32.
10. Bethell C, Forrest CB, Stumbo S, Gombojav N, Carle A, Irwin CE. Factors promoting or potentially impeding school success: Disparities and state variations for children with special health care needs. Maternal and child health journal. 2012;16(1):35-43.
11. Houtrow A, Jones J, Ghandour R, Strickland B, Newacheck P. Participation of children with special health care needs in school and the community. Academic pediatrics. 2012;12(4):326-34.
12. McIntyre LL, Blacher J, Baker B. The transition to school: Adaptation in young children with and without intellectual disability. Journal of Intellectual Disability Research. 2006;50(5):349-61.
13. Quach J, Barnett T. Impact of chronic illness timing and persistence at school entry on child and parent outcomes: Australian Longitudinal Study. Academic pediatrics. 2015;15(1):89-95.
14. Lum A, Wakefield C, Donnan B, Burns M, Fardell J, Marshall G. Understanding the school experiences of children and adolescents with serious chronic illness: a systematic meta-review. Child: Care, Health and Development. 2017.
15. Gerhardt CA, Dixon M, Miller K, Vannatta K, Valerius KS, Correll J, et al. Educational and occupational outcomes among survivors of childhood cancer during the transition to emerging adulthood. Journal of Developmental & Behavioral Pediatrics. 2007;28(6):448-55.
16. Moonie S, Sterling DA, Figgs LW, Castro M. The relationship between school absence, academic performance, and asthma status. Journal of School Health. 2008;78(3):140-8.
17. Dieluweit U, Debatin KM, Grabow D, Kaatsch P, Peter R, Seitz D, et al. Educational and vocational achievement among long-term survivors of adolescent cancer in Germany. Pediatric blood & cancer. 2011;56(3):432-8.
18. Mackner LM, Bickmeier RM, Crandall WV. Academic achievement, attendance, and school-related quality of life in pediatric inflammatory bowel disease. Journal of Developmental & Behavioral Pediatrics. 2012;33(2):106-11.
19. Emerson E, Blacher J, Einfeld S, Hatton C, Robertson J, Stancliffe RJ. Environmental risk factors associated with the persistence of conduct difficulties in children with intellectual disabilities and autistic spectrum disorders. Research in developmental disabilities. 2014;35(12):3508-17.
20. Emerson E, Hatton C, MacLean J, William E. Contribution of socioeconomic position to health inequalities of British children and adolescents with intellectual disabilities. American Journal on Mental Retardation. 2007;112(2):140-50.
21. Hauser-Cram P, Durand TM, Warfield ME. Early feelings about school and later academic outcomes of children with special needs living in poverty. Early Childhood Research Quarterly. 2007;22(2):161-72.
22. McIntyre LL, Abbeduto L. Parent training for young children with developmental disabilities: Randomized controlled trial. American Journal on Mental Retardation. 2008;113(5):356-68.
23. Freeman SF, Alkin MC. Academic and social attainments of children with mental retardation in general education and special education settings. Remedial and Special Education. 2000;21(1):3-26.
24. Peetsma T, Vergeer M, Roeleveld J, Karsten S. Inclusion in education: Comparing pupils' development in special and regular education. Educational Review. 2001;53(2):125-35.
25. Laws G, Byrne A, Buckley S. Language and memory development in children with Down syndrome at mainstream schools and special schools: a comparison. Educational Psychology. 2000;20(4):447-57.

26. Cole CM, Waldron N, Majd M, Hasazi S. Academic progress of students across inclusive and traditional settings. Mental Retardation. 2004;42(2):136-44.
27. Dessemontet RS, Bless G, Morin D. Effects of inclusion on the academic achievement and adaptive behaviour of children with intellectual disabilities. Journal of Intellectual Disability Research. 2012;56(6):579-87.
28. Janus M, Offord DR. Development and psychometric properties of the Early Development Instrument (EDI): A measure of children's school readiness. Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement. 2007;39(1):1.
29. Forget-Dubois N, Lemelin J-P, Boivin M, Dionne G, Séguin JR, Vitaro F, et al. Predicting early school achievement with the EDI: A longitudinal population-based study. Early Education and Development. 2007;18(3):405-26.
30. Davies S, Janus M, Duku E, Gaskin A. Using the Early Development Instrument to examine cognitive and non-cognitive school readiness and elementary student achievement. Early Childhood Research Quarterly. 2016;35:63-75.
31. Guhn M, Gadermann AM, Almas A, Schonert-Reichl KA, Hertzman C. Associations of teacher-rated social, emotional, and cognitive development in kindergarten to self-reported wellbeing, peer relations, and academic test scores in middle childhood. Early Childhood Research Quarterly. 2016;35:76-84.
32. Brinkman S, Gregory T, Harris J, Hart B, Blackmore S, Janus M. Associations between the early development instrument at age 5, and reading and numeracy skills at ages 8, 10 and 12: a prospective linked data study. Child Indicators Research. 2013;6(4):695-708.
33. Guhn M, Gadermann A, Zumbo BD. Does the EDI measure school readiness in the same way across different groups of children? Early Education and Development. 2007;18(3):453-72.
34. Curtin M, Baker D, Staines A, Perry IJ. Are the special educational needs of children in their first year in primary school in Ireland being identified: a cross-sectional study. BMC pediatrics. 2014;14(1):52.
35. Mousavi A, Krishnan V. Setting the Scope for Early Child Development Instrument (EDI): A Psychometric Re-examination of the Tool with Alberta Data. Social Indicators Research. 2015;122(3):925-44.
36. Janus M, Brinkman SA, Duku EK. Validity and psychometric properties of the early development instrument in Canada, Australia, United States, and Jamaica. Social Indicators Research. 2011;103(2):283-97.
37. Irwin LG, Siddiqi A, Hertzman C. Early child development: A powerful equalizer. Final report to the WHO Commission on social determinants of health, Geneva. 2007.
38. Stein R, Jessop DJ. A noncategorical approach to chronic childhood illness. Public health reports. 1982;97(4):354.
39. Rosenbaum P, Gorter J. The 'F-words' in childhood disability: I swear this is how we should think! Child: care, health and development. 2012;38(4):457-63.
40. Wright F, Rosenbaum P, Fehlings D. How do changes in Impairment, Activity, and Participation relate to each other? Study of children with cerebral palsy (CP) who have received lower extremity Botulinum Toxin Type-A (Bt-A) injections. Developmental Medicine and Child Neurology. 2007;50(4):283-9.
41. Nolan T, Pless I. Emotional correlates and consequences of birth defects. The Journal of pediatrics. 1986;109(1):201-16.
42. Pless IB, Nolan T. Revision, replication and neglect—research on maladjustment in chronic illness. Journal of Child Psychology and Psychiatry. 1991;32(2):347-65.
43. Nelson BB, Dudovitz RN, Coker TR, Barnert ES, Biely C, Li N, et al. Predictors of poor school readiness in children without developmental delay at age 2. Pediatrics. 2016:e20154477.

44. Janus M. Impact of impairment on children with special needs at school entry: comparison of school readiness outcomes in Canada, Australia, and Mexico. Exceptionality Education International. 2011;21(2):29-44.
45. Björck-Åkesson E, Wilder J, Granlund M, Pless M, Simeonsson R, Adolfsson M, et al. The International Classification of Functioning, Disability and Health and the version for children and youth as a tool in child habilitation/early childhood intervention–feasibility and usefulness as a common language and frame of reference for practice. Disability and Rehabilitation. 2010;32(sup1):S125-S38.
46. Guhn M, Janus M, Hertzman C. The Early Development Instrument: Translating school readiness assessment into community actions and policy planning. Early Education and Development. 2007;18(3):369-74.
47. Hertzman C, Boyce T. How experience gets under the skin to create gradients in developmental health. Annual review of public health. 2010;31:329-47.
48. Siegel LS, Ladyman S. A review of special education in British Columbia: British Columbia Ministry of Education; 2000.
49. Belsky J, MacKinnon C. Transition to school: Developmental trajectories and school experiences. Early Education and Development. 1994;5(2):106-19.
50. Janus M, Hughes D, Duku E. Patterns of school readiness among selected subgroups of Canadian children: Children with special needs and children with diverse language backgrounds. The Canadian Council on Learning. 2010.
51. Poon BT, Hertzman C. Development of an integrated child health information system for children who are deaf or hard of hearing. Paediatrics & child health. 2010;15(9):583-9.
52. Goldfeld S, O'Connor M, Sayers M, Moore T, Oberklaid F. Prevalence and correlates of special health care needs in a population cohort of Australian children at school entry. Journal of Developmental & Behavioral Pediatrics. 2012;33(4):319-27.
53. Streiner DL, Norman GR, Cairney J. Health measurement scales: a practical guide to their development and use: Oxford University Press, USA; 2015.
54. Roth DL, Dilworth-Anderson P, Huang J, Gross AL, Gitlin LN. Positive aspects of family caregiving for dementia: Differential item functioning by race. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences. 2015;70(6):813-9.
55. Conrad KJ, Dennis ML, Bezruczko N, Funk RR, Riley BB. Substance use disorder symptoms: Evidence of differential item functioning by age. Journal of Applied Measurement. 2007;8(4):373-87.
56. Leung C, Mak R, Lau V, Cheung J, Lam C. Development of a preschool developmental assessment scale for assessment of developmental disabilities. Research in developmental disabilities. 2010;31(6):1358-65.
57. Gumpel TP. Use of Item Response Theory to develop a measure of first-grade readiness. Psychology in the Schools. 1999;36(4):285-93.
58. Ho DST, Leung C, Lo SK. Validation of the Gumpel Readiness Inventory for preschool children in Hong Kong. Research in developmental disabilities. 2013;34(10):3066-76.
59. Marmot MG, Rose G, Shipley M, Hamilton PJ. Employment grade and coronary heart disease in British civil servants. Journal of epidemiology and community health. 1978;32(4):244-9.
60. Marmot MG, Stansfeld S, Patel C, North F, Head J, White I, et al. Health inequalities among British civil servants: the Whitehall II study. The Lancet. 1991;337(8754):1387-93.
61. Hill KE, Gleadle JM, Pulvirenti M, McNaughton DA. The social determinants of health for people with type 1 diabetes that progress to end-stage renal disease. Health Expectations. 2015;18(6):2513-21.
62. Shariff-Marco S, Yang J, John EM, Kurian AW, Cheng I, Leung R, et al. Intersection of race/ethnicity and socioeconomic status in mortality after breast cancer. Journal of community health. 2015;40(6):1287-99.

63. Tomayko E, Flood T, Tandias A, Hanrahan L. Linking electronic health records with community-level data to understand childhood obesity risk. Pediatric obesity. 2015;10(6):436-41.
64. Puckrein GA, Egan BM, Howard G. Social and Medical Determinants of Cardiometabolic Health: The Big Picture. Ethnicity & disease. 2015;25(4):521.
65. Webb S, Janus M, Duku E, Raos R, Brownell M, Forer B, et al. Neighbourhood socioeconomic status indices and early childhood development. SSM-Population Health. 2017;3:48-56.
66. Frederick CB, Snellman K, Putnam RD. Increasing socioeconomic disparities in adolescent obesity. Proceedings of the National Academy of Sciences. 2014;111(4):1338-42.
67. Cabieses B, Pickett KE, Wilkinson RG. the Impact of Socioeconomic Inequality on Children's Health and Well-being. The Oxford Handbook of Economics and Human Biology: Oxford University Press; 2016. p. 244.
68. Letourneau NL, Duffett-Leger L, Levac L, Watson B, Young-Morris C. Socioeconomic status and child development: A meta-analysis. Journal of Emotional and Behavioral Disorders. 2013;21(3):211-24.
69. Kershaw P, Forer B, Irwin LG, Hertzman C, Lapointe V. Toward a social care program of research: A population-level study of neighborhood effects on child development. Early Education and Development. 2007;18(3):535-60.
70. Carpiano RM, Lloyd JE, Hertzman C. Concentrated affluence, concentrated disadvantage, and children's readiness for school: A population-based, multi-level investigation. Social Science & Medicine. 2009;69(3):420-32.
71. Oliver LN, Dunn JR, Kohen DE, Hertzman C. Do neighbourhoods influence the readiness to learn of kindergarten children in Vancouver? A multilevel analysis of neighbourhood effects. Environment and Planning A. 2007;39(4):848-68.
72. Guhn M, Gadermann AM, Hertzman C, Zumbo BD. Children's development in kindergarten: A multilevel, population-based analysis of ESL and gender effects on socioeconomic gradients. Child Indicators Research. 2010;3(2):183-203.
73. Lapointe VR, Ford L, Zumbo BD. Examining the relationship between neighborhood environment and school readiness for kindergarten children. Early Education and Development. 2007;18(3):473-95.
74. Spencer NJ, Blackburn CM, Read JM. Disabling chronic conditions in childhood and socioeconomic disadvantage: a systematic review and meta-analyses of observational studies. BMJ open. 2015;5(9):e007062.
75. Stabile M, Currie J. Socioeconomic Status and Child Health: Why Is the Relationship Stronger for Older Children? American Economic Review. 2003;93(5):1813-23.
76. Turner S, Sloper P, Knussen C, Cunningham CC. Socio-economic factors: their relationship with child and family functioning for children with Down's syndrome. Journal of Applied Research in Intellectual Disabilities. 1991;4(1):80-100.
77. Turner S, Alborz A, Gayle V. Predictors of academic attainments of young people with Down's syndrome. Journal of Intellectual Disability Research. 2008;52(5):380-92.
78. Szumski G, Karwowski M. School achievement of children with intellectual disability: The role of socioeconomic status, placement, and parents' engagement. Research in developmental disabilities. 2012;33(5):1615-25.
79. Duncan GJ, Magnuson K, Kalil A, Ziol-Guest K. The importance of early childhood poverty. Social Indicators Research. 2012;108(1):87-98.

Appendix 1A: An overview of studies reporting on academic and social outcomes in children with special needs

Study	Population	Outcomes	Results
Bell et al., 2016	Australian children between 4-6 years old n=22,890 (2,897 children with chronic illness)	Early Development Instrument (EDI) (Janus & Offord, 2007)	Children with chronic illness had 20%–35% increase in odds of being classified as developmentally vulnerable.
Bethell et al., 2016	American children between 6-17 years old n=63,843 (14,989 Children with Special Health Care Needs)	Parent-reported engagement, participation, and safety at school	Children with Special Health Care Needs were 11.5% less likely to experience school engagement, participation in activities, and to feel safe at school. They were also more likely to miss more than 11 days of school, repeat a grade, and to receive more than three calls home from the school.
Goldfeld et al., 2015	Australian followed up longitudinally from 4 to 9 years old n=720 (28 with Special Health Care Needs)	Who Am I? (De Lemos & Doig, 1999) Longitudinal Study of Australian Children Questionnaire Academic Rating Scale (ARS) (Rock & Pollack, 2002) National Assessment Program—Literacy and Numeracy assessments (NAPLAN)	Children with Special Health Care Needs were 3.06 (95% CI 1.03-9.10) more likely to fall into weaker performing learning pathways.
Houtrow et al., 2012	American children 6 to 7 years old n=64,076 (49,027 with Special Health Care Needs)	Parent-reported school attendance, participation in organized activities, working for pay, and	Children with Special Health Care Needs were 1.85 times more likely to miss more than five days of school. Children with Special Health Care Needs with functional limitations were 1.18 to

		volunteering	1.48 times more likely to experience all four types of participation restrictions.
McIntyre et al., 2006	American children 5 years old n=67 (24 with intellectual disability)	Delay of gratification task (Vaughn et al., 1984) Social Skills Rating System (Gresham & Elliott, 1990) Teacher's Report Form (Auchenbach, 1991) The Student–Teacher Relationship Scale (Pianta, 2001)	Children with intellectual disability were three times as likely to have teacher-reported problem behavior. Teachers rated their relationship with children with intellectual disability as less positive overall. Parents and teachers reported children with intellectual disability to have fewer social skills.
Quach et al., 2015	Australian followed up longitudinally from 6 to 11 years old n=4464 (1108 with chronic illness at any timepoint throughout followup)	Academic Rating Scale (ARS) (Rock & Pollack, 2002) Social Rating Scale (Rock & Pollack, 2002) Wechsler Intelligence Scale for Children IV (Wechsler, 2003) Teacher–Child Relationship Scale–Short Form (Pianta, 2001) Strengths and Difficulties Questionnaire (Goodman, 2001) Pediatric Quality of Life	Children with chronic illnesses had worse learning, cognition, child-teacher relationship, behavioral and emotional problems, and health-related quality of life, with the worse outcomes generally being experienced by children with persistent chronic illness.

		Inventory 4.0 (Varni et al., 2003)	
Reuben et al., 2003	American children 6 to 17 years old n=59,440 (13,746 Children with Special Health Care Needs)	Parent-reported use of special education services, number of days missed from school, problem reports from the school, and lack of school engagement	Children with complex Special Health Care Needs had an increased risk of all negative outcomes compared to children without Special Health Care Needs, while children using medications were only at higher risk for absenteeism.
Whiteford et al., 2013	Australian children followed up from 4-5 years of age to 6-7 years of age n=1300 (650 Children with Special Health Care Needs)	The Outcome Index (Sanson et al., 2015)	Children with Special Health Care Needs scored significantly lower on social emotional and learning competencies than children without Special Health Care Needs.

Appendix 1B: An overview of studies reporting on correlates of academic and social outcomes in children with special needs

Study	Population	Outcomes	Correlates	Results
Cole et al., 2004	American students in grades 2 to 5 with mild disability n=429 students with mild disability	Basic Academic Skills Sample (BASS)	Inclusive education	Students with disabilities educated in inclusive schools did not differ in math or reading outcomes, compared to their peers educated in classic pull-out programs.
Dessemont et al., 2012	Children between 7 and 8 years old from Switzerland n=68 (34 in inclusive education and 34 matched controls)	LEst 4–7 (Moser et al., 2004) and the LEst 6–9 (Moser & Bayer 2007) Adaptive Behavior Assessment System – Second edition, 5 to 20 years (ABAS-II) (Harrison & Oakland 2002)	Inclusive education	Included children made slightly more progress in literacy skills than children attending special schools. No differences were found between the progress of the two groups in mathematics and adaptive behaviour.
Emerson et al., 2007	Children from the United Kingdom between 5 and 15 n=10,483 (264 children with intellectual disability)	Parent- or child-reported health status Development and Well Being Assessment (Goodman, Ford, & Richards, 2000)	Socioeconomic position (equivalized household income, occupational prestige, and maternal education)	Variables associated with socioeconomic position and household composition decreased the strength of the association between intellectual disability and child health by 24%.
Emerson et al., 2014	Children from the United Kingdom followed up from age 3 to 7 n=11,776 (449 children with intellectual disability excluding autism spectrum disorder; 224 children with autism spectrum disorder)	Strengths and Difficulties Questionnaire (Goodman, 1999)	Household Poverty and Neighborhood Deprivation Scale, the Maternal Health and Wellbeing Scale, and Parental Resources and Parenting Behaviors (Emerson, 2014)	Adjusting for the likely effects of increased exposure to risk among children with intellectual disability and ASD eliminated the elevated prevalence of conduct difficulties among children with intellectual disability and reduced the elevated

				prevalence of conduct difficulty among children with ASD.
Freeman et al., 2000	Systematic review School-aged (elementary, middle, and high school) with mental retardation 9 studies (N=623) on academic outcomes 14 studies (N=642) on social outcomes	Academic and social outcomes	Integrative schools	Overall, children in integrated classrooms performed better academically than children in special education classrooms. The results on social outcomes were more inconsistent.
Goldfeld et al., 2015	Australian followed up longitudinally from 4 to 9 years old n=720 (28 with Special Health Care Needs)	Who Am I? (De Lemos & Doig, 1999) Longitudinal Study of Australian Children Questionnaire Academic Rating Scale (ARS) (Rock & Pollack, 2002) National Assessment Program—Literacy and Numeracy assessments (NAPLAN)	Family socioeconomic position comprised of parents' educational attainment, income, occupational prestige	Proportion of children with Special Health Care Needs in lower learning trajectory coming from disadvantaged families was 1.44 times than proportion of children with Special Health Care Needs in lower learning trajectory coming from advantaged families.
Hauser-Cram et al., 2001	American children followed up from the age of 5 to fifth grade receiving special education services n=103	Feelings About School (FAS) measure (Valeski & Stipek, 2001) Teacher-reported academic outcomes in fifth grade	Parent-reported family income	Greater family income related positively to children's perceived competence in academic skills but not to other feelings about school or to their academic outcomes in fifth grade.

Houtrow et al., 2012	American children 6 to 7 years old n=64,076 (49,027 with Special Health Care Needs)	Parent-reported school attendance, participation in organized activities, working for pay, and volunteering	Federal Poverty Level (FPL) Family structure	Poverty status was associated with restrictions in all types of participation such that children living in or near poverty had increased odds of participation restrictions. Compared with having two biological/adoptive parents, children living with single mothers had increased odds for restrictions in organized activities (1.38) and volunteering (1.47). Similarly, children living in step-families had participation restrictions in organized activities (1.89) and volunteering (2.64).
Laws et al., 2000	Children from the United Kingdom between 7 and 14 years of age with Down's Syndrome n=44	British Picture Vocabulary Scale (Dunn & Dunn, 2009) Test for the Reception of Grammar (Bishop, 1983) Sentence repetition Memory Auditory Digit Span (Kaufman & Kaufman, 1983) Visual Digit Span	Inclusive education	Children in inclusive education achieved significantly higher scores for vocabulary, grammar, sentence repetition, and digit span measures, but not for the remaining measures, which are mainly non-language based memory measures.

		Hand movements Face recognition British Ability Scales: Basic Reading (Elliott et al., 1978)		
McIntyre et al., 2008	American children 2 to 5 years old with developmental delays n=49 children (24 assigned to intervention and 25 as control)	Family Impact Questionnaire (Donenberg & Baker, 1993) Child Behavior Checklist (Achenbach, 2000) Behavior Index Child-Directed Praise	Incredible Years Parent Training (IYPT) intervention (Webster-Stratton et al., 1984)	The IYPT intervention was effective in reducing negative parent-child interactions and child behavior problems.
Peetsma et al., 2001	Dutch children 7 or 8 years old with learning and behavioral difficulties and mild mental retardation n=504 children at baseline and 216 at four year follow up	Standardized achievement tests on language and mathematics Teacher-reported psychosocial functioning	Inclusive education	Children with learning and behavioral difficulties in inclusive education made more progress in language, mathematics, and motivation than matched controls in special education. Children with mild mental retardation in inclusive education made more progress in language and mathematics but had worse motivation.

2.0 Pan-Canadian population-based monitoring system for early childhood development

The data for the two investigations presented in Chapters 3 and 4 come from the Pan-Canadian database on children's developmental health at school entry. The database includes data from all provincial implementations of the EDI, as well as a large set of socioeconomic variables from the 2006 Canadian Census and Taxfiler data, aggregated according to custom neighborhoods. Creation of this database was supported by two grants by the Canadian Institute of Health Research (CIHR) and the full protocol for creation of the database is reported in Guhn et al. 2016 (1). Below, the description of the database is provided as it is relevant to this thesis.

2.1 Data coverage

In Canada, data on early childhood development at school entry have been collected with the EDI at the population level since 2003/2004 in 12 out of the 13 Canadian provinces and territories (excluding Nunavut). For each province, the EDI has been implemented at least once and up to five times. Provincial EDI data collections have either been done in 'waves', where a subset of the population is sampled each year until all communities within the province have been included, or all at once, where data on the full province are collected in one year. During provincial implementations, all publicly funded schools participate and only passive consent is required from parents - except in Alberta where participation is voluntary and active consent is required. Data from all provincial implementations of the EDI from 2003/2004 to 2013/2014 have been cleaned and harmonized and used to construct the Pan-Canadian database, with the objective of monitoring children's development and exploring variability between jurisdictions and trends over time. The resulting database includes 798,298 children of kindergarten age. A summary of provincial implementations is presented in Table 2.1 and a list of variables available within the database used for the analyses in Chapters 3 and 4 is provided in Table 2.2.

Table 2.1: Provincial implementations of the EDI

Province	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013

	/ 2002	/ 2003	/ 2004	/ 2005	/ 2006	/ 2007	/ 2008	/ 2009	/ 2010	/ 2011	/ 2012	/ 2013	/ 2014
AB								*2 waves					
BC													
MB													
NB													
NL													
NT													
NS													
ON													
PE													
QC													
SK													
YT													

Merged cells represent single implementations. AB=Alberta; BC=British Columbia; MB=Manitoba; NB=New Brunswick; NL=Newfoundland and Labrador; NT=Northwest Territories; NS=Nova Scotia; ON=Ontario; PE=Prince Edward Island; QC=Quebec; SK=Saskatchewan; YT=Yukon

Table 2.2: Variables of the Pan-Canadian database used for analyses presented in Chapters 3 and 4

- EDI outcomes
  - Physical health & wellbeing
  - Social competence
  - Emotional maturity
  - Language & cognitive development
  - Communication skills & general knowledge
- Age at EDI completion
- Gender
- Unique custom created neighborhood code
- Province
- Year of data collection

EDI=Early Development instrument

2.2 Development of geographic neighborhood boundaries

To explore the association between early childhood developmental health at school entry and neighborhood socioeconomic characteristics, custom neighborhood units were created across Canada. These neighborhoods were created with the objective of optimally portraying variability in developmental health and socioeconomic characteristics across regions. In constructing neighborhood boundaries, maintaining meaningful neighborhoods based on existing social structures and administrative and geographic divisions was a priority. All neighborhoods were constructed so that they were made of the smallest viable geographic unit that allowed for linking with Canadian Census and Taxfiler data and so that they contain a minimum of 50 and a maximum of 400-600 EDI records. Census Subdivisions, Consolidated Subdivisions, and Census Divisions with 50 or more EDI records were defined as neighborhood units. Units with less than 50 records were dissolved with surrounding units. If a Census Subdivision had more than 400 to 600 EDI records, other geographic or administrative boundaries were used to subdivide into smaller neighborhood units. When possible, neighborhood boundaries were confirmed with local education and government contacts. This process produced a total of 2,058 neighborhoods. Guhn et al. (2016) provide a complete description of the neighborhood definition process (2).

2.3 Development of neighborhood socioeconomic status (SES) index

A neighborhood SES index was used as a measure of neighborhood SES in the investigation presented in chapter 4. The index offered the ability to use a single measure to define a multi-dimensional concept, to average out measurement error over more than one variable, and to reduce the likelihood of multicollinearity. To create this index, Canadian Census and Taxfiler variables from 2006, aggregated by custom neighborhoods (Section 2.2), were linked to EDI data. The Canadian Census contains approximately 2,200 variables covering population, demographics, income, employment, immigration, language, education, mobility, and housing. Taxfiler data include approximately 400 variables related to income, poverty, and wealth.

First, variables from the Census and Taxfiler variables were categorized into 19 theoretically relevant themes (Table 2.3). A total of 250 variables were categorized into these themes and variables not related to any one of these themes were excluded. Exploratory Factor Analysis (EFA) was subsequently conducted for each of the 19 themes, and 44 were subthemes derived based on the results of the EFA. From each of the subthemes, the variable with the strongest association with EDI vulnerability rates (proportion of children scoring below the 10^{th} percentile on one or more EDI domains in a neighborhood) was selected and all other variables from the themes or subthemes were excluded.

Table 2.3: Theoretically relevant themes used to categorize Census and Taxfiler variables

- Age
- Distribution
- Occupation
- Residential Stability
- Dwelling age
- Dwelling type
- Poverty
- Wealth
- Education
- Cost of living
- Employment/unemployment
- Family and child policy
- Ethnicity
- Immigration
- Family structure
- Income
- Income inequality
- Gender division of earnings
- Language diversity
- Marital status

A series of multiple "forward" and "backward" regression analyses were then conducted with EDI domain scores and vulnerability rates across neighborhoods specified as dependent variables and candidate Census and Taxfiler variables as predictors. Variables that were not statistically significant ($p < 0.05$) in either of the regression analyses were excluded. A second set of regression analyses were conducted and variables that explained less than 5% of variance in EDI domain scores and vulnerability rates across neighborhoods were excluded. From the remaining variables, ten variables, presented in Table 2.4, were selected using Pratt score methodology based on the amount of variance they each explained in EDI outcomes (3). The index is calculated as the mean of these standardized variables coded such that higher scores indicate higher SES.

Table 2.4: Final variables included in the neighborhood socioeconomic status (SES) index

Education	% with no high school diploma
Language/Immigration	% not speaking either official language at home
Marital Status	% separated or divorced
Wealth	% with investment income, families with children under 6
High Income	% with incomes $\geq$ twice than 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
Poverty	% with low income, lone parent families with children under 6
Residential Stability	% non-migrant movers in the past year
Income Inequality	Gini Coefficient, lone female families with children under 6

2.4 Ethics

EDI data collection was approved by the McMaster University Research Ethics Board (REB), now Hamilton Integrated Research Ethics Board (HiREB). The two CIHR-funded projects on which this research is based, the Canadian Neighborhoods and Early Child Development (CanNECD) study and the Canadian Children's Health in Context Study (CCHICS), were approved by both the Behavioral REB at the University of British Columbia and HiREB. To maintain confidentiality, the Pan-Canadian database is de-identified and all Census and Taxfiler data are only available at the aggregated neighborhood level.

2.5 References

1. Guhn M, Janus M, Enns J, Brownell M, Forer B, Duku E, et al. Examining the social determinants of children's developmental health: protocol for building a pan-Canadian population-based monitoring system for early childhood development. BMJ open. 2016;6(4):e012020.
2. Guhn M, Gadermann AM, Almas A, Schonert-Reichl KA, Hertzman C. Associations of teacher-rated social, emotional, and cognitive development in kindergarten to self-reported wellbeing, peer relations, and academic test scores in middle childhood. Early Childhood Research Quarterly. 2016;35:76-84.
3. Thomas DR, Hughes E, Zumbo BD. On variable importance in linear regression. Social Indicators Research. 1998;45(1):253-75.

3.0 The psychometric properties of the Early Development Instrument (EDI) in the Canadian population children with special needs

3.1 Introduction

This chapter presents an investigation of the psychometric properties of the EDI in the Canadian population of children with special needs. The psychometric properties investigated were item and domain characteristics, factor structure, and construct validity. This chapter sets the stage for the use of the EDI in Chapter 4 to investigate the socioeconomic gradient in the developmental health of children with special needs at school entry. An introduction to this investigation is presented in chapter 1 (Section 1.5) and interpretation of results and a discussion of the implications of findings are presented in chapter 5 (Section 5.1).

3.1.1 Hypotheses

Generally, children with special needs start school with fewer skills than typically developing children, reflecting their disabilities (4, 5). Therefore, we hypothesized that children with special needs would on average have lower scores on the EDI than typically developing children and that this difference would be similar in magnitude to those reported by Janus (2011) using an international sample (6). We also hypothesized that the performance of the EDI in children with special needs would be similar to its performance in typically developing children, based on lack of prior evidence suggesting otherwise.

3.2 Analytic methods

The Pan-Canadian database on children's developmental health was used for this analysis (1). IBM SPSS Statistics Version 23 and the psychometric and lavaan packages (Version 2.2; Fletcher, 2012) written for the statistical software R (Version 3.3.0 2016) were used for all analyses (7-9).

3.2.1 Item and domain characteristics

Given that EDI items use dichotomous and ordinal scales, all alpha and correlation statistics were calculated as polychoric coefficients. For each item, adjusted item-total domain score correlation coefficients and item-deleted alpha statistics were calculated. Item-total correlation coefficients quantify the correlation between an item and the respective total domain score, excluding the item of interest, and are an indication of the extent to which the item is related to other items in that domain. The coefficient is adjusted by omitting the item of interest from the total domain score to avoid artificially inflated correlation estimates. As recommended by Streiner et al. (2015), item-total correlation coefficients should generally be between 0.20 and 0.80 (10). Lower coefficients indicate that the item is unrelated to other items within the domain and higher coefficients indicate possible item redundancy. Item-deleted alpha statistics measure the homogeneity of a scale excluding an item of interest. Because alpha statistics tend to increase with the length of a scale, if an item-deleted alpha statistic is lower than the total domain alpha statistic, the item may not be related to other items within that domain and hence may contribute to inconsistency. The frequency of endorsement of each response option for all items was also examined for end-aversion bias and inadequate spread, which may limit the ability of a scale to discriminate between children of varying developmental health.

For each domain, alpha statistics were calculated. As per Streiner et al. (2015), alpha statistics for a scale should range between 0.70 and 0.90 (10). Lower values indicate possible inconsistency among items in the domain and higher values indicate item-redundancy. Domain scores were also examined for adequate variability and for ceiling and floor effects. Variability in total domain scores is a necessary precondition for domains to be able to discriminate between children of varying developmental health. Finally, the frequency of missingness of data for each domain, as well as items within each domain, were investigated.

3.2.2 Confirmatory factor analysis (CFA)

Confirmatory Factor Analysis (CFA) is an extension of structural equation modelling (SEM) that tests the extent to which measures of a construct are consistent with a priori defined models of that construct. CFA can also provide an indication of the comparability of the performance of a measure across different populations, through assessment of the similarity in factor loadings and goodness-of-fit indices. For this analysis, goodness-of-fit indices reported from typically developing populations were compared to those obtained from the population of Canadian children with special needs.

The reporting of the results of the CFA was done in accordance with recommendations made by Jackson et al. (2009) (11). First, the fit of each domain was individually evaluated, and second, the fit of all five EDI domains were simultaneously tested. This two-step approach was used to reflect the conceptual development of the EDI as five separate domains, with the second step allowing estimation of overall EDI fit indices.

Typical maximum likelihood estimation methods in CFA do not perform well for data that deviate from normality, such as EDI data that are positively skewed. Hence, the Mean and Variance Adjusted Weighted Least Squares (WLSMV) estimation technique was used which can accommodate the binary and ordinal nature of EDI items (12-14). The use of the WLSMV estimator also allowed for comparisons to be made with the original investigation of the EDI factor structure in typically-developing Canadian children, which also used the WLSMV estimator (6). Listwise deletion was used to handle missing data. As a sensitivity analysis, the robust maximum likelihood (MLR) estimator was used to allow better handling of missing data with Full Information Maximum Likelihood (FIML), even though there is evidence that robust MLR can only accommodate continuous data and does not work well for ordinal measures with fewer than five response options, such as EDI items (12).

A mix of absolute and comparative goodness-of-fit indices were used to assess model fit. Absolute fit indices indicate how well a model fits or reproduces the data whereas relative fit indices compare the fit of the model to a null model. Absolute fit indices used were the chi-square test of model fit and the root mean square error of approximation (RMSEA). Relative fit indices used were the comparative fit index (CFI) and the Tucker-Lewis index (TLI). These fit indices were selected as they have been found to perform well with respect to detecting model misspecification and, apart from the chi-square test of model fit, are generally independent of sample size (11, 15, 16). Although subject to some debate, a non-significant chi-square test, a CFI and TLI greater than or equal to 0.95, and an RMSEA value between 0 to 0.06 have generally been used in the literature to indicate good model fit (17). In this paper, these guidelines are pragmatically used, with the caveat that maintaining strict cut-offs is not recommended (18).

3.2.3 Construct validation

A multivariate analysis of covariance (MANCOVA) was used to test the association between EDI domain scores and gender and age. Dependent variables were the five domains of the EDI with gender specified as a fixed factor and age as a covariate. MANCOVA is an extension of analysis of covariance (ANCOVA) for cases with multiple dependent variables. In this case, each of the five EDI domains was specified as a dependent variable. ANCOVA is a variant of analysis of variance (ANOVA). Similar to ANOVA, ANCOVA tests for differences in means across two or more groups but, unlike ANOVA, also adjusts for the effects of one or more continuous covariates.

3.2.4 Sample size calculation

A sample size calculation was done to ensure that the analyses presented would be adequately powered (≥ 80%). The sample size calculation for this analysis was based on the CFA, as it was expected to be the analysis with the greatest sample size requirement. Various rules of thumb have been proposed to describe the sample size requirements of CFA and SEM. These include (a) 100-200 observations in total, (b) 5-10 observations per parameter, and (c) 10 observations per variable (19). Wolf et al. (2013) found that a minimum sample size of 160 observations is required for a three-factor model with eight indicators, factor loadings of 0.50, and interfactor correlations of 0.30 (19). Sample size requirements were generally lower for models with only one factor or more than three factors and models with more indicators. Because only models with one factor and five factors and models with eight to 28 indicators were tested for this investigation, sample size requirements are likely lower than 160. It is important to acknowledge that this is a rough estimation of the sample size requirements for the CFA analysis presented in this chapter because it is not specific to the models tested. Sample size requirements are likely to be affected by the number and nature of indicators, the correlation between latent variables, the magnitude of factor loadings, and the estimator used. More accurate sample size estimations can be obtained using Monte Carlo simulation methods (20), however, given the availability of population-level data, Monte Carlo simulations were deemed not necessary.

3.2.5 Missing data

A total of 31,487 children with special needs designation were identified in the database. 1,646 (5.23%) were excluded for having been in the kindergarten classroom for less than one month prior to data collection or for missing more than one EDI domain. In the analytic sample, 69 (0.23%), 86 (0.29%), 241 (0.81%), 175 (0.59%), 45 (0.15%) were missing PHWB, SC, EM, LCD, and CSGK scores, respectively. An additional 29 (0.10%) and 108 (0.36%) children were missing information on gender and age variables, respectively. Demographic characteristics of the sample ineligible for analysis (n=1,646) are presented in Appendix 3A. Demographic characteristics of the analytic sample missing specific EDI domain scores are presented in Appendix 3B through 3F.

3.3 Results

3.3.1 Population characteristics

The population demographic characteristics and breakdown by province are presented in Table 3.1. The mean age was 5.79 years (SD 0.42), and there were significantly more boys (69.8%) than girls (30.2%). Children excluded from analysis did not differ from those that were included on gender or age (Appendix 3A). The EDI domain scores for this population were lower than those for typically developing children in the EDI normative dataset, with large effect sizes, as previously demonstrated (Table 3.2).

Table 3.1: Characteristics of the valid sample[a] (29,841)

Gender		
Male *n (%)*	20,809 (69.8)	
Female *n (%)*	9,003 (30.2)	
Missing *n (%)*	29 (0.097)	
Age		
Mean age (SD)	5.79 (0.42)	
Missing age *n (%)*	108 (0.36)	
Province		
	N	**%**
Ontario	13276	44.5
British Columbia	5124	17.2
Quebec	3174	10.6
Manitoba	2468	8.3
Alberta	2099	7.0
Saskatchewan	1447	4.8
Nova Scotia	1088	3.6
Newfoundland	641	2.1
New Brunswick	327	1.1
Yukon	103	0.3
Northwest Territories	65	0.2
Prince Edward Island	29	0.1

[a]Valid EDI cases (i.e., no more than 1 missing domain) only

Table 3.2: Early Development Instrument (EDI) score distributions for children with special needs and typically developing children (normative data)

		PHWB		**SC**		**EM**		**LCD**		**CSGK**	
		SN	**TD**	**SN**	**TD**	**SN**	**TD**	**SN**	**TD**	**SN**	**TD**
Mean (SD)		6.86 (2.10)	8.80 (1.30)	5.46 (2.55)	8.32 (1.79)	5.95 (1.94)	8.04 (1.49)	5.95 (3.01)	8.45 (1.78)	4.05 (3.15)	7.65 (2.55)
Effect size (Cohen's d)		0.81		1.30		1.21		1.01		1.26	
Min		0	0.38	0	0.00	0	0.33	0	0.00	0	0.00
Max		10	10.00	10	10.00	10	10.00	10	10.00	10	10.00
Percentiles	**10**	3.85	7.08	2.00	5.58	3.45	6.00	1.54	5.77	0.00	4.38
	25	5.38	8.07	3.65	7.31	4.50	7.17	3.46	7.69	1.25	5.63
	50	7.08	9.23	5.38	9.00	5.89	8.33	6.54	9.20	3.75	8.75
	75	8.46	10.00	7.50	9.81	7.33	9.17	8.80	9.62	6.25	10.00

PHWB=Physical health & wellbeing; SC=Social competence; EM=Emotional maturity; LC=Language & cognitive abilities; CSGK=Communication skills & general knowledge; SN=special needs; TD=typically developing

3.3.2 Item and domain characteristics

To evaluate item and domain characteristics, corrected item-total score correlation coefficients and item-deleted alpha statistics were computed (Appendix 3G). A total of 29 items had corrected item-total score correlation coefficients outside of the acceptable range. Of these 29, 11 were from in the SC domain, one in the EM domain, 15 in the LCD domain, and two in the CSGK domain. The item in the EM domain ("is shy") had a weak negative correlation with the total EM score. All other items were positively correlated with domain scores. Additionally, four items in the PHWB domain had item-deleted alpha statistics higher than the domain alpha coefficients, suggesting possible domain multidimensionality. The endorsement frequency of response options for EDI items are presented in Appendix 3H. There was adequate spread in endorsement of response options, with only five items having a particular option endorsed for more than 80% of the population. All items were missing for less than 10% of the population.

Descriptive characteristics of EDI domains are presented in Table 3.3. Mean (SD) domain scores ranged from 4.05 (3.15) to 6.86 (2.10) for the CSGK and PHWB domains, respectively. No ceiling or floor effects were detected, as indicated by the mean and median domain scores which were approximately within two points of the center of the scale. Full ranges of scores were observed for all domains, indicating good discriminative ability. SDs for children with special needs were slightly greater than SDs for typically developing children, suggesting greater variation in scores. Alpha statistics ranged from 0.88 for the PHWB domain to 0.98 for the SC and LCD domains. All domain alpha statistics, except for the PHWB domain, were greater than the recommended cut-off (10). From the analytic sample, no more than 1% were missing data on any one domain of the EDI.

Table 3.3: Domain characteristics

Domain	Mean (SD)	Median	Min	Max	Ordinal alpha	Missing (%)
PHWB	6.86 (2.10)	7.08	0	10	0.88	69 (0.2)
SC	5.46 (2.55)	5.38	0	10	0.98	86 (0.3)

EM	5.95 (1.94)	5.89	0	10	0.95	241 (0.8)
LCD	5.95 (3.01)	6.54	0	10	0.98	175 (0.6)
CSGK	4.05 (3.15)	3.75	0	10	0.96	45 (0.2)

PHWB=Physical health & wellbeing; SC=Social competence; EM=Emotional maturity; LCD=Language & cognitive development; CSGK=Communication skills & general knowledge

3.3.3 Confirmatory factor analysis (CFA)

A total of 18,431 children were available for the CFA using the WLSMV indicator, as 11,410 were excluded due to missing EDI items, which was deemed more than sufficient for the analysis based on the a priori sample size estimation. No significant differences in age or gender were observed between the sample available for the CFA and sample excluded from the analysis (Appendix 3I). Results of the tests of goodness-of-fit for the CFA using the WLSMV estimator are presented in Table 3.4.

Table 3.4: Domain goodness-of-fit indices (WLSMV estimator with listwise deletion)

Domains	Chi-square (df); p value	CFI	TLI	RMSEA (90% CI)
Physical health & wellbeing	942003.52 (78); p < 0.001	0.977	0.973	0.112 (0.110-0.113)
Social competence	194049.31 (299); p < 0.001	0.978	0.976	0.156 (0.156-0.157)
Emotional Maturity	512206.87 (405); p < 0.001	0.901	0.893	0.229 (0.229-0.230)
Language & cognitive development	51353.04 (299); p < 0.001	0.988	0.987	0.083 (0.082-0.083)
Communication skills & general knowledge	4820.21 (20); p < 0.001	0.997	0.996	0.091 (0.089-0.093)
Five Factor Model	1178237.60 (5140); p < 0.001	0.953	0.952	0.111 (0.111-0.111)

WLSMV=Mean and Variance Adjusted Weighted Least Squares; CFA=Comparative fit index; TLI=Tucker-Lewis index; RMSEA= Root mean square error of approximation

All chi-square statistics were significant ($p < 0.001$), most likely due to sample size. The CFIs ranged between 0.901 (EM) and 0.996 (CSGK). The TLIs ranged between 0.893 (EM) and 0.997 (CSGK). All RMSEA values were greater than the recommended 0.06 cutoff, ranging between 0.083 (LCD) and 0.229 (EM). The EM domain had the worst fit based on all four fit indices and the CSGK domain had the best fit. CFA goodness-of-fit indices using the MLR estimator are presented in Appendix 3J. Generally, goodness-of-fit indices using the MLR estimator were worse than those from the WLSMV estimator.

3.3.4 Construct validation

Results of the MANCOVA of EDI domain scores and gender and age demonstrated that girls had significantly higher scores than boys on all domains (Table 3.5). Effect sizes were moderate for SC (0.32) and EM (0.46), and small (0.03 to 0.14) for the remaining three domains. Results of the MANCOVA for age are presented in Table 3.6. Only the EM domain scores were significantly associated with age (F(1,29111)=9.434, p = 0.02). A closer examination of EDI domain scores across age-bands suggests a positive association between age and EDI domain scores among younger children, but a negative one for the oldest group (older than 6.3 years), resulting in a non-linear relationship (Figure 3.1).

Table 3.5: Mean domain scores of the Early Development Instrument (EDI) for girls and boys

Domain	Gender	Mean (SD)	Effect size (Cohen's d)	F-Statistic
Physical health & wellbeing	Boys	6.83 (2.05)	0.048	$F(1, 29{,}111) = 18.23^{a}$
	Girls	6.93 (2.21)		
Social competence	Boys	5.21 (2.46)	0.32	$F(1, 29{,}111) = 660.83^{a}$
	Girls	6.03 (2.67)		
Emotional maturity	Boys	5.68 (1.88)	0.46	$F(1, 29{,}111) = 1386.05^{a}$
	Girls	6.58 (1.92)		
Language & cognitive abilities	Boys	5.92 (2.97)	0.033	$F(1, 29{,}111) = 8.21^{b}$
	Girls	6.02 (3.12)		
Communication skills & general knowledge	Boys	3.92 (3.07)	0.14	$F(1, 29{,}111) = 130.66^{a}$
	Girls	4.36 (3.31)		

$^{a}p<0.001$
$^{b}p<0.005$

Table 3.6: Results of Multivariate Analysis of Covariance (MANCOVA) for age

Domain	F-Statistic	P-value
Physical health & wellbeing	F(1, 29,111) = 0.001	0.978
Social competence	F(1, 29,111) = 1.688	0.194
Emotional maturity	F(1, 29,111) = 9.434	0.002
Language & cognitive abilities	F(1, 29,111) = 0.051	0.821
Communication skills & general knowledge	F(1, 29,111) = 0.984	0.321

Figure 3.1: Bar graphs showing mean Early Development Instrument (EDI) domain scores across age bands

3.4 References

1. Guhn M, Janus M, Enns J, Brownell M, Forer B, Duku E, et al. Examining the social determinants of children's developmental health: protocol for building a pan-Canadian population-based monitoring system for early childhood development. BMJ open. 2016;6(4):e012020.
2. Guhn M, Gadermann AM, Almas A, Schonert-Reichl KA, Hertzman C. Associations of teacher-rated social, emotional, and cognitive development in kindergarten to self-reported wellbeing, peer relations, and academic test scores in middle childhood. Early Childhood Research Quarterly. 2016;35:76-84.
3. Thomas DR, Hughes E, Zumbo BD. On variable importance in linear regression. Social Indicators Research. 1998;45(1):253-75.
4. Goldfeld S, O'Connor M, Sayers M, Moore T, Oberklaid F. Prevalence and correlates of special health care needs in a population cohort of Australian children at school entry. Journal of Developmental & Behavioral Pediatrics. 2012;33(4):319-27.
5. Janus M, Hughes D, Duku E. Patterns of school readiness among selected subgroups of Canadian children: Children with special needs and children with diverse language backgrounds. The Canadian Council on Learning. 2010.
6. Janus M. Impact of impairment on children with special needs at school entry: comparison of school readiness outcomes in Canada, Australia, and Mexico. Exceptionality Education International. 2011;21(2):29-44.

7. Fletcher TD. Psychometric: applied psychometric theory. R package version. 2010;2(2).
8. RCore T. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Online: http://wwwR-projectorg. 3.3.0 ed2013.
9. IBM SPSS Statistics for Windows. 23.0 ed. Armonk, NY: IBM Corp.; 2015.
10. Streiner DL, Norman GR, Cairney J. Health measurement scales: a practical guide to their development and use: Oxford University Press, USA; 2015.
11. Jackson DL, Gillaspy Jr JA, Purc-Stephenson R. Reporting practices in confirmatory factor analysis: an overview and some recommendations. Psychological methods. 2009;14(1):6.
12. Li C-H. Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares. Behavior research methods. 2015:1-14.
13. Muthén B. A general structural equation model with dichotomous, ordered categorical, and continuous latent variable indicators. Psychometrika. 1984;49(1):115-32.
14. Muthen B, du Toit S, Spisic D. Robust inference using weighted least squares and quadratic estimating equations in latent variable modeling with categorical and continuous outcomes. 1987. Retrieved 2007/01/08/, from http://www.gseis.ucla.edu/faculty/muthen/articles/Article_075.pdf; 2010.
15. Fan X, Sivo SA. Sensitivity of fit indexes to misspecified structural or measurement model components: Rationale of two-index strategy revisited. Structural Equation Modeling. 2005;12(3):343-67.
16. Fan X, Thompson B, Wang L. Effects of sample size, estimation methods, and model specification on structural equation modeling fit indexes. Structural Equation Modeling: A Multidisciplinary Journal. 1999;6(1):56-83.
17. Hooper D, Coughlan J, Mullen M. Structural equation modelling: Guidelines for determining model fit. Articles. 2008:2.
18. Marsh HW, Hau K-T, Wen Z. In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. Structural equation modeling. 2004;11(3):320-41.
19. Wolf EJ, Harrington KM, Clark SL, Miller MW. Sample size requirements for structural equation models an evaluation of power, bias, and solution propriety. Educational and Psychological Measurement. 2013;73(6):913-34.
20. Muthén LK, Muthén BO. How to use a Monte Carlo study to decide on sample size and determine power. Structural equation modeling. 2002;9(4):599-620.

Appendix 3A: Descriptive characteristics of children excluded from analysis (n=1,646)

Gender	
Male *n (%)*	1133 (68.8)
Female *n (%)*	508 (30.9)
Missing *n (%)*	5 (0.3)
Age	
Mean age (SD)	5.73 (0.65)
Age missing *n (%)*	19 (1.2)

Appendix 3B: Descriptive characteristics of children with missing physical health & wellbeing scores (69)

Gender	
Male *n (%)*	51 (73.9)
Female *n (%)*	17 (24.6)
Missing *n (%)*	1 (1.4)
Age	
Mean age (SD)	5.84 (0.40)
Age missing *n (%)*	1 (1.4)

Appendix 3C: Descriptive characteristics of children with missing social competence scores (86)

Gender	
Male *n (%)*	55 (64.0)
Female *n (%)*	31 (36.0)
Missing *n (%)*	0 (0)
Age	
Mean age (SD)	5.63 (1.64)
Age missing *n (%)*	0 (0)

Appendix 3D: Descriptive characteristics of children with missing emotional maturity scores (241)

Gender	
Male *n (%)*	173 (71.8)
Female *n (%)*	67 (27.8)
Missing *n (%)*	1 (0.4)
Age	
Mean age (SD)	5.79 (0.41)
Age missing *n (%)*	2 (0.8)

Appendix 3E: Descriptive characteristics of children with missing language & cognitive development scores (175)

Gender	
Male *n (%)*	128 (73.1)
Female *n (%)*	47 (26.9)
Missing *n (%)*	0 (0)
Age	
Mean age (SD)	5.77 (1.73)
Age missing *n (%)*	0 (0)

Appendix 3F: Descriptive characteristics of children with missing communication skills & general knowledge (45)

Gender	
Male *n (%)*	27 (60.0)
Female *n (%)*	18 (40.0)
Missing *n (%)*	0 (0)
Age	
Mean age (SD)	5.69 (1.60)
Age missing *n (%)*	1 (2.22)

Appendix 3G: Item-total correlation and item-deleted alpha statistics for items of the Early Development Instrument (EDI)

Domain (ordinal alpha)	Subdomain	Item	Domain	
			Item-total correlation	**Item-deleted alpha[a]**
Physical health & wellbeing (0.88)	**Physical readiness for the school day**	Dressed inappropriately	0.35	<u>0.89</u>
		Too tired	0.56	0.88
		Late	0.25	<u>0.89</u>
		Hungry	0.36	<u>0.89</u>
	Physical independence	Washroom	0.59	0.87
		Hand preference	0.60	0.87
		Well coordinated	0.71	0.87
		Sucks thumb	0.33	<u>0.89</u>
	Gross and fine motor skills	Level of energy	0.68	0.87
		Proficient at holding pen	0.73	0.87
		Manipulates objects	0.76	0.87
		Climbs stairs	0.73	0.87
		Overall physical	0.80	0.86
Social competence (0.98)	**Overall social competence**	Overall social/emotional	0.80	0.98
		Gets along with peers	0.79	0.98
		Cooperative	<u>0.85</u>	0.98
		Plays with various children	0.80	0.98
		Self-confidence	0.69	0.98
	Responsibility and respect	Respects property	<u>0.83</u>	0.98
		Follows rules	<u>0.87</u>	0.98
		Self-control	<u>0.83</u>	0.98
		Respect for adults	<u>0.82</u>	0.98
		Respect for children	<u>0.81</u>	0.98
		Accept responsibility	<u>0.84</u>	0.98
		Takes care of materials	<u>0.83</u>	0.98
		Tolerance for mistake	0.73	0.98

	Approaches to learning	Listens	0.81	0.98
		Follows directions	0.85	0.98
		Completes work on time	0.76	0.98
		Independent	0.77	0.98
		Works nearly	0.74	0.98
		Independently solves problems	0.81	0.98
		Follows simple instructions	0.78	0.98
	Readiness to explore new things	Curious	0.65	0.98
		Eager to play with new toy	0.61	0.98
		Eager to play a new game	0.67	0.98
		Eager to read a new book	0.63	0.98
Emotional maturity (0.95)	**Prosocial and helping behaviour**	Helps hurt	0.61	0.94
		Clears up mess	0.65	0.94
		Stops quarrel	0.64	0.94
		Offers help	0.63	0.94
		Comforts upset	0.56	0.94
		Spontaneously helps	0.63	0.94
		Invites bystanders to join game	0.59	0.94
		Helps sick	0.62	0.94
	Anxious and fearful behaviour	Upset when left	0.29	0.95
		Seems unhappy	0.54	0.94
		Fearful	0.48	0.95
		Worried	0.39	0.95
		Cries a lot	0.55	0.94
		Nervous	0.55	0.94

		Indecisive	0.58	0.94
		Shy	-0.05	0.95
	Aggressive behaviour	Gets into fights	0.55	0.94
		Bullies or mean	0.54	0.94
		Kicks, etc.	0.69	0.94
		Takes things	0.62	0.94
		Laughs at others	0.47	0.95
		Disobedient	0.76	0.94
		Temper tantrums	0.74	0.94
	Hyperactivity and inattentive behaviour	Restless	0.71	0.94
		Distractible	0.72	0.94
		Fidgets	0.70	0.94
		Impulsive	0.77	0.94
		Difficulty awaiting turns	0.75	0.94
		Can't settle	0.74	0.94
		Inattentive	0.72	0.94
Language & cognitive development (0.98)	**Basic literacy**	Handles a book	0.81	0.98
		Identifies letters	0.85	0.98
		Sounds to letters	0.87	0.98
		Rhyming awareness	0.86	0.98
		Group reading	0.79	0.98
		Experiments writing	0.65	0.98
		Writing direction	0.87	0.98
		Writes own name	0.84	0.98
	Interest in literacy/numeracy and memory	Interested in books	0.63	0.98
		Interested in reading	0.79	0.98
		Remembers things easily	0.77	0.98
		Interested in maths	0.87	0.98

		Interested in number games	0.80	0.98
	Advanced literacy	Reads simple words	0.88	0.98
		Reads complex words	0.77	0.98
		Reads sentences	0.84	0.98
		Writes simple words	0.84	0.98
		Write simple sentences	0.78	0.98
		Writing voluntarily	0.69	0.98
	Basic numeracy	Sorts and classifies	0.80	0.98
		1 to 1 correspondence	0.87	0.98
		Counts to 20	0.83	0.98
		Recognizes 1-10	0.84	0.98
		Compares numbers	0.88	0.98
		Recognizes shapes	0.85	0.98
		Time concepts	0.78	0.98
Communication skills & general knowledge (0.96)	**No subdomains**	Listens – English	0.80	0.96
		Tells a story	0.93	0.95
		Imaginative play	0.76	0.96
		Communicates needs	0.89	0.95
		Understands	0.85	0.95
		Articulates clearly	0.80	0.96
		Effective use – English	0.91	0.95
		Knowledge about world	0.80	0.96

Underline indicates statistics outside of the acceptable range.

Appendix 3H: Endorsement frequencies of Early Development Instrument (EDI) items

Domain	Items		Response options			
		Yes *n (%)*	No *n (%)*	Don't know *n (%)*	Missing *n (%)*	
Physical health & wellbeing	Dressed inappropriately	4266 (14.3)	25515 (85.5)	14 (0.0)	46 (0.0)	
	Too tired	8106 (27.2)	21578 (72.3)	83 (0.3)	74 (0.2)	
	Late	8233 (27.6)	21514 (72.1)	21 (0.1)	73 (0.2)	
	Hungry	3137 (10.5)	25989 (87.1)	637 (2.1)	78 (0.3)	
	Washroom	23196 (77.7)	6465 (21.7)	122 (0.4)	58 (0.2)	
	Hand preference	25243 (84.6)	4293 (14.4)	228 (0.8)	77 (0.3)	
	Well coordinated	17586 (58.9)	12094 (40.5)	79 (0.3)	82 (0.3)	
	Items	**Often/ very true** *n (%)*	**Sometimes/ Somewhat** *n (%)*	**Never/ not true** *n (%)*	**Don't know** *n (%)*	**Missing** *n (%)*
	Sucks thumb	1559 (5.2)	1957 (6.6)	25672 (86.0)	611 (2.0)	42 (0.1)
	Items	**Poor/ very poor** *n (%)*	**Average** *n (%)*	**Very good/ good** *n (%)*	**Don't know** *n (%)*	**Missing** *n (%)*
	Level of energy	4598 (15.4)	15029 (50.4)	10134 (34.0)	25 (0.1)	55 (0.2)
	Proficient at holding pen	11983 (40.2)	11089 (37.2)	6712 (22.5)	8 (0.0)	49 (0.1)
	Manipulates objects	8229 (27.6)	13639 (45.7)	7900 (26.5)	11 (0.0)	62 (0.2)
	Climbs stairs	5796 (19.4)	13201 (44.2)	8950 (30.0)	1803 (6.0)	91 (0.3)
	Overall physical	6596 (22.1)	14842 (49.7)	8229 (27.6)	103 (0.3)	71 (0.2)
Social competence	Overall social/emotional	14183 (47.5)	11188 (37.5)	4286 (14.4)	116 (0.4)	68 (0.2)
	Gets along with peers	10844 (36.3)	13034 (43.7)	5781 (19.4)	129 (0.4)	33 (0.2)
	Items	**Never/ not true** *n (%)*	**Sometimes/ somewhat true** *n (%)*	**Often/ very true** *n (%)*	**Don't know** *n (%)*	**Missing** *n (%)*
	Cooperative	8009 (26.8)	14609 (49.0)	7185 (24.1)	25 (0.1)	13 (0.0)
	Plays with various children	7616 (25.5)	14502 (48.6)	7685 (25.8)	20 (0.1)	18 (0.0)

	Self-confidence	6486 (21.7)	15735 (52.7)	7041 (23.6)	556 (1.9)	23 (0.0)
	Respects property	4348 (14.6)	11576 (38.8)	13722 (46.0)	171 (0.6)	23 (0.0)
	Follows rules	5104 (17.1)	15877 (53.2)	8804 (29.5)	29 (0.1)	27 (0.1)
	Self-control	7232 (24.2)	14110 (47.3)	8417 (28.2)	60 (0.2)	22 (0.1)
	Respect for adults	2828 (9.5)	12014 (40.3)	14813 (49.6)	170 (0.6)	16 (0.0)
	Respect for children	3589 (12.0)	13829 (46.3)	12208 (40.9)	197 (0.7)	18 (0.0)
	Accept responsibility	7923 (26.6)	11933 (40.0)	9414 (31.5)	558 (1.9)	13 (0.0)
	Takes care of materials	4445 (14.9)	12287 (41.2)	12986 (43.5)	104 (0.3)	19 (0.0)
	Tolerance for mistake	6271 (21.0)	10708 (35.9)	11046 (37.0)	1729 (5.8)	87 (0.3)
	Listens	8010 (26.8)	15639 (52.4)	6052 (20.3)	127 (0.4)	13 (0.0)
	Follows directions	5662 (19.0)	16976 (56.9)	7155 (24.0)	33 (0.1)	15 (0.0)
	Completes work on time	8661 (29.0)	13075 (43.8)	7843 (26.3)	234 (0.8)	28 (0.1)
	Independent	13312 (44.6)	10096 (33.8)	6374 (21.4)	32 (0.1)	27 (0.1)
	Works neatly	10661 (35.7)	12079 (40.5)	6960 (23.3)	113 (0.4)	28 (0.1)
	Independently solves problems	13703 (45.9)	11868 (39.8)	4124 (13.8)	94 (0.3)	52 (0.2)
	Follows simple instructions	3397 (11.4)	14634 (49.0)	11761 (39.4)	14 (0.0)	35 (0.1)
	Curious	3491 (11.7)	11320 (37.9)	14407 (48.3)	603 (2.0)	20 (0.0)
	Eager to play with new toy	1917 (6.4)	8890 (29.8)	18839 (63.1)	170 (0.6)	24 (0.1)
	Eager to play a new game	3507 (11.8)	9616 (32.2)	16495 (55.3)	207 (0.7)	16 (0.0)
	Eager to read a new book	4992 (16.7)	10598 (35.5)	14046 (47.1)	189 (0.6)	16 (0.0)
Emotional maturity	Helps hurt	10036 (33.6)	11392 (38.2)	7081 (23.7)	1287 (4.3)	45 (0.1)
	Clears up mess	15332 (51.4)	9204 (30.8)	4750 (15.9)	515 (1.7)	40 (0.1)
	Stops quarrel	19078 (63.9)	6943 (23.3)	2135 (7.2)	1640 (5.5)	45 (0.1)
	Offers help	18156 (60.8)	7971 (26.7)	2962 (9.9)	704 (2.4)	48 (0.1)
	Comforts upset	13504 (45.3)	10447 (35.0)	4474 (15.0)	1376 (4.6)	40 (0.1)

	Spontaneously helps	15229 (51.0)	9882 (33.1)	4079 (13.7)	604 (2.0)	47 (0.1)
	Invites bystanders to join game	17561 (58.8)	8684 (29.1)	2404 (8.1)	1151 (3.9)	41 (0.1)
	Helps sick	15862 (53.2)	8438 (28.3)	3183 (10.7)	2301 (7.7)	47 (0.1)
	Upset when left	19262 (64.5)	8542 (28.6)	1792 (6.0)	215 (0.7)	30 (0.1)
	Seems unhappy	19381 (64.9)	8173 (27.4)	2060 (6.9)	193 (0.6)	34 (0.1)
	Fearful	19419 (65.1)	8443 (28.3)	19419 (65.1)	259 (0.9)	25 (0.1)
	Worried	20939 (70.2)	7027 (23.5)	1695 (5.7)	44 (0.1)	25 (0.1)
	Cries a lot	20488 (68.7)	6724 (22.5)	2369 (7.9)	219 (0.7)	41 (0.1)
	Nervous	19262 (64.5)	8542 (28.6)	1792 (6.0)	215 (0.7)	30 (0.1)
	Indecisive	13363 (44.8)	11323 (37.9)	4808 (16.1)	302 (1.0)	45 (0.1)
	Shy	18108 (60.7)	8748 (29.3)	2704 (9.1)	251 (0.8)	30 (0.1)
	Gets into fights	22128 (74.2)	5641 (18.9)	1924 (6.4)	92 (0.3)	56 (0.1)
	Bullies or mean	21920 (73.5)	5818 (19.5)	1969 (6.6)	76 (0.3)	58 (0.1)
	Kicks, etc.	19686 (66.0)	7358 (24.7)	2682 (9.0)	71 (0.2)	44 (0.1)
	Takes things	20274 (67.9)	7143 (23.9)	2185 (7.3)	199 (0.7)	40 (0.1)
	Laughs at others	23953 (80.3)	4628 (15.5)	963 (3.2)	241 (0.8)	56 (0.2)
	Disobedient	15171 (50.8)	10425 (34.9)	4092 (13.7)	109 (0.4)	44 (0.1)
	Temper tantrums	17220 (57.7)	8541 (28.6)	3907 (13.1)	138 (0.5)	35 (0.1)
	Restless	10337 (34.6)	10115 (33.9)	9313 (31.2)	21 (0.1)	55 (0.1)
	Distractible	8406 (28.2)	10124 (33.9)	11253 (37.7)	19 (0.1)	39 (0.1)
	Fidgets	9742 (32.6)	10019 (33.6)	100010 (33.5)	24 (0.1)	46 (0.1)
	Impulsive	10995 (36.8)	10386 (34.8)	8235 (27.6)	178 (0.6)	47 (0.1)
	Difficulty awaiting turns	10939 (36.7)	10267 (34.4)	8404 (28.2)	195 (0.7)	36 (0.1)
	Can't settle	12266 (41.1)	10575 (35.4)	6915 (23.2)	53 (0.2)	42 (0.1)
	Inattentive	7060 (23.7)	13234 (44.3)	9465 (31.7)	55 (0.2)	27 (0.1)
Language & cognitive development	**Items**	**Yes** ***n (%)***	**No** ***n (%)***	**Don't know** ***n (%)***	**Missing** ***n (%)***	
	Handles a book	27718 (92.9)	2055 (6.9)	49 (0.2)	19 (0.0)	

	Identifies letters	20386 (68.3)	9175 (30.7)	235 (0.8)	45 (0.2)	
	Sounds to letters	16331 (54.7)	13069 (43.8)	392 (1.3)	49 (0.2)	
	Rhyming awareness	13390 (44.9)	15441 (51.7)	980 (0.3)	30 (0.1)	
	Group reading	17905 (60.0)	11766 (39.4)	152 (0.5)	18 (0.0)	
	Experiments writing	21530 (72.1)	8228 (27.6)	62 (0.2)	21 (0.1)	
	Writing direction	19557 (65.5)	9740 (32.6)	513 (1.7)	31 (0.1)	
	Writes own name	22472 (75.3)	7346 (24.6)	10 (0.0)	13 (0.0)	
	Interested in books	25323 (84.9)	4421 (14.8)	88 (0.3)	9 (0.0)	
	Interested in reading	18982 (63.6)	10509 (35.2)	323 (1.1)	27 (0.0)	
	Remembers things easily	14458 (48.5)	14505 (48.6)	828 (2.8)	50 (0.2)	
	Interested in maths	19086 (64.0)	9974 (33.4)	727 (2.4)	54 (0.2)	
	Interested in number games	19310 (64.7)	9843 (33.0)	634 (2.1)	54 (0.2)	
	Reads simple words	13854 (46.4)	15679 (52.5)	288 (1.0)	20 (0.0)	
	Reads complex words	4328 (14.5)	25062 (84.0)	437 (1.5)	14 (0.0)	
	Reads sentences	8666 (29.0)	20792 (69.7)	366 (1.2)	17 (0.0)	
	Writes simple words	15124 (50.7)	14586 (48.9)	120 (0.4)	11 (0.0)	
	Write simple sentences	8807 (29.5)	20737 (69.5)	254 (0.9)	53 (0.2)	
	Writing voluntarily	9551 (32.0)	20066 (67.2)	210 (0.7)	14 (0.0)	
	Sorts and classifies	22933 (76.9)	6459 (21.6)	378 (1.3)	71 (0.2)	
	1 to 1 correspondence	20959 (70.2)	8462 (28.4)	356 (1.2)	54 (0.2)	
	Counts to 20	17416 (58.4)	11933 (40.0)	422 (1.4)	70 (0.2)	
	Recognizes 1-10	18884 (63.3)	10618 (35.6)	266 (0.9)	73 (0.2)	
	Compares numbers	16335 (54.7)	12344 (41.4)	1077 (3.6)	85 (0.3)	
	Recognizes shapes	22932 (76.8)	6287 (21.1)	539 (1.8)	83 (0.3)	
	Time concepts	18602 (62.3)	10058 (33.7)	1105 (3.7)	76 (0.2)	
Communication skills & general knowledge	**Items**	**Poor/ very poor** ***n (%)***	**Average** ***n (%)***	**Very good/ good** ***n (%)***	**Don't know** ***n (%)***	**Missing** ***n (%)***

	Listens – English	8789 (29.5)	13121 (44.0)	7794 (26.1)	111 (0.4)	26 (0.1)
	Tells a story	16363 (54.8)	8145 (27.3)	5104 (17.1)	196 (0.7)	33 (0.1)
	Imaginative play	10406 (34.9)	12103 (40.6)	7056 (23.6)	247 (0.8)	29 (0.1)
	Communicates needs	13752 (46.1)	10167 (34.1)	5868 (19.7)	29 (0.1)	25 (0.0)
	Understands	11661 (39.1)	11708 (39.2)	6306 (21.1)	131 (0.4)	35 (0.1)
	Articulates clearly	14962 (50.1)	8824 (29.6)	5891 (19.7)	120 (0.4)	44 (0.1)
	Effective use – English	14331 (48.0)	9202 (30.8)	6203 (20.8)	69 (0.2)	36 (0.1)
	Items	**Never/ not true** ***n (%)***	**Sometimes/ somewhat true** ***n (%)***	**Often/ very true** ***n (%)***	**Don't know** ***n (%)***	**Missing** ***n (%)***
	Knowledge about world	8836 (29.7)	10599 (35.5)	10118 (33.9)	221 (0.7)	40 (0.1)

Underline represents endorsement frequencies > 80%.

Appendix 3I: Characteristics of the samples included and excluded from CFA

	Included in CFA analysis	**Excluded from CFA analysis**
Total	18431	11410
Gender		
Male *n (%)*	12756 (69.2)	8053 (70.6)
Female *n (%)*	5662 (30.7)	3341 (29.3)
Age		
Mean age (SD)	5.79 (0.42)	5.80 (0.83)

Appendix 3J: Results of the Confirmatory Factor Analysis (CFA) using the MLR estimator with FIML

Domains	Chi-square (df); p value	CFI	TLI	RMSEA (90% CI)
Physical health & wellbeing	27527.839 (65); p < 0.001	0.800	0.760	0.119 (0.118-0.120)
Social competence	149567.719 (299); p < 0.001	0.755	0.733	0.130 (0.129-0.130)
Emotional Maturity	303227.839 (405); p < 0.001	0.471	0.432	0.159 (0.158-0.159)
Language & cognitive development	86388.908 (899); p < 0.001	0.796	0.778	0.099 (0.098-0.099)
Communication skills & general knowledge	11318.355 (20); p < 0.001	0.935	0.909	0.138 (0.136-0.140)
Five-Factor Model	1178237.60 (5140); p < 0.001	0.953	0.952	0.111 (0.111-0.111)

MLR=robust maximum likelihood estimation; FIML=full information maximum likelihood;
CFI=comparative fit index; TLI=Tucker-Lewis index; RMSEA=Root mean square error of approximation

4.0 The socioeconomic gradient in the developmental health of children with special needs

4.1 Introduction

This chapter presents an investigation of the socioeconomic gradient in the developmental health of Canadian children with special needs at school entry (population is defined in Section 1.1.1 and Section 1.2). Specifically, developmental health at school entry, measured using the EDI, is correlated with an index of neighborhood-level SES. An introduction to this investigation is presented in Chapter 1 (Section 1.6) and interpretation and discussion of the results are contained in Chapter 5 (Section 5.2).

4.1.1 Hypotheses

The objective of this chapter is to explore the association between EDI outcomes in children with special needs and neighborhood SES, using a Pan-Canadian database on children's developmental outcomes (Chapter 2). It was hypothesized that a socioeconomic gradient would be observed in the developmental health of children with special needs at school entry, with children residing in lower SES neighborhoods experiencing worse developmental outcomes. Parents of children with disabilities of higher SES find it easier to meet expensive rehabilitation needs, to provide their children with additional stimulating recreational and educational activities outside of the classroom, and to act as their children's advocates in contacts with educational and healthcare institutions (1). Additionally, parents of lower SES disproportionately deal with mental health issues and marital stress, which may negatively impact their parenting practices and subsequently children's development (1-3). In addition to effects conferred through the SES characteristics of the family, we expect higher SES neighborhoods to have a protective effect on children's development and lower SES neighborhoods to adversely impact children's development. Higher SES neighborhoods have more shared community resources, including access to services that benefit children's development (4). Lower SES neighborhoods have less collective efficacy in intervening in child misbehavior, in addition to issues with safety and housing stability, which may adversely impact children's development (4).

4.2 Analytic methods

All data analysis was conducted in SAS™ software using the GLIMMIX procedure (5). The REG procedure was used for computing diagnostic statistics not available in GLIMMIX.

4.2.1 Hierarchical Generalized Linear Modelling

Given that EDI domain scores are skewed and restricted in range, and that children are clustered within neighborhoods, the data were analyzed using hierarchical generalized linear modelling (HGLM). HGLM is a variant of generalized linear modelling (GLM) for clustered data. For this analysis, the identity link and gamma distribution were used. The identity link, instead of the logarithmic link, was chosen because it was expected that that predictors would have an additive effect on EDI domain scores, whereas the gamma distribution was chosen because it produces strictly positive scores and can accommodate skew – two characteristics of EDI domain scores. The gamma distribution has also been previously shown to perform well with EDI data (6). The fit of other distributions (i.e., exponential, normal) and link functions (i.e., logarithmic) was also assessed.

Unlike ordinary GLM that assumes independence of observations, hierarchical models accommodate observations that are correlated with one another. The assumption of independence is violated for EDI data as EDI domain scores of children that reside within the same neighborhood are more likely to be similar than EDI domain scores of children from different neighborhoods and schools. For this analysis, only neighborhood of residence was included as a cluster variable. This is because of data sparseness, and the subsequent biased estimation of regression coefficients that would result by also including classrooms and schools in the model, in addition to issues with model non-convergence (7).

For this analysis, EDI domain scores, which are negatively skewed, were subtracted from 11, thus transforming negatively skewed EDI domain scores to positively skewed data that can be represented by the gamma distribution. All models were performed using the Laplace approximation, a quasi-likelihood method which, unlike pseudo-likelihood estimation methods, allows estimation of likelihood statistics (i.e., deviance, Akaike information criterion (AIC), Bayesian information criterion (BIC)). In comparison to other methods, such as penalized quasi-likelihood, the Laplace approximation has been shown to perform well with regard to accuracy, precision, convergence rates, and computing speed (8).

4.2.2 Model building

For each EDI domain, the analysis was performed hierarchically in three steps. First, an intercept-only model was constructed. This model provides an overall estimate of the average transformed EDI domain scores across all neighborhoods, as well as the variability in average transformed EDI domain scores between neighborhoods. Second, a model with child-level predictors as fixed-effects was constructed. Age, sex, and EFSL status have been significant predictors of children's developmental health in previous studies (9, 10), and hence were included as covariates. Additionally, dummy variables for year of data collection and province were included to control for variations in data collection procedures across time points and provinces. The interaction between year and province was also included due to different data collection procedures across provinces at data collection timepoints and waves. Finally, to evaluate the impact of SES on developmental health, a third model including both child-level characteristics and the SES index score was examined. Random effects of each of the individual predictors were added to the final model, one-by-one, and individually tested for significance using partial likelihood ratio tests. Goodness-of-fit indices were also compared between models with and without random effects.

An intraclass correlation coefficient (ICC) was calculated for each model to estimate the percentage of total variability in EDI domain scores that is accounted for by differences between neighborhoods. To assess whether the inclusion of child-level characteristics (age, sex, EFSL status) and SES significantly improved the fit of the model, partial likelihood ratio tests were performed, and goodness-of-fit indices were compared between the three stages in the model building process.

4.2.3 Diagnostics and sensitivity analyses

Model goodness-of-fit was evaluated using deviance, AIC, and BIC statistics. Deviance statistics can only be compared across nested models using the same dataset as they are not adjusted for model complexity and rely on the likelihood function which is dependent on the number of observations. Hence, lower deviance statistics will be seen in models with fewer observations or models that are more complex, regardless of whether the goodness-of-fit of the model is appreciably different. Lower deviance statistics suggest better model fit and can be used to conduct likelihood ratio tests by subtracting the deviance of the full model from the deviance of the reduced model. This statistic follows a chi square distribution with degrees of freedom equal to the number of additional parameters in the full model. AIC and BIC statistics are also measures of model goodness-of-fit, which also rely on the likelihood function and so are also dependent on the number of observations. Smaller AIC and BIC statistics indicate better goodness-of-fit. Unlike deviance statistics, AIC and BIC statistics are adjusted for model complexity, and so can also be used to compare models which are not nested. AIC and BIC statistics are different in their adjustment for model complexity, shown in Equations 4.1 and 4.2, where *k* is the number of parameters estimated by the model and *n* is the number of observations.

$$AIC = Deviance + 2k$$

Equation 4.1: Akaike Information Criterion (AIC)

$$BIC = Deviance + k \ln n$$

Equation 4.2: Bayesian Information Criterion (BIC)

Multicollinearity was tested by examining variance inflation factor (VIF) statistics for age, gender, EFSL status, and the SES index. VIF statistics are calculated by taking the reciprocal of 1 minus the R^2 value of a regression of a predictor on all other covariates included in the model. VIF statistics are not presented for province of residence, time of data collection, and their interaction as these produced artificially high VIF statistics due to having been dummy coded and included in the model with relatively few predictors. However, these predictors were included as part of the regression models used to calculate VIF statistics for other covariates.

Since data were analyzed using HGLM, no assumptions were made regarding the distribution and variance of residuals (11, 12). Leverage statistics, along with plots of raw, Pearson, and studentized residuals were used to identify outliers and influential observations. Leverage statistics indicate the distance between the values of an observation on independent variables from the means of those variables. Observations with leverage statistics more than twice the mean of all leverage values were investigated for data entry error. Pearson residuals are standardized raw residuals and studentized residuals are Pearson residuals that have also been adjusted for leverage. Scatterplots, histograms, QQ plots, and boxplots of raw, Pearson, and studentized residuals were constructed to allow visualization of conditional and overall distributions. A sensitivity analysis was conducted where observations with outlying studentized residuals, defined as studentized residuals with absolute values greater than 2, were excluded in the estimation of the models. Regression coefficients produced from this sensitivity analysis were compared with those from the primary analysis.

4.2.4 Sample size calculation

A sample size calculation was done to ensure that the regression analyses would be adequately powered (≥ 80%). Currently, little guidance exists on conducting power and sample size calculations for HGLM. Consequently, a simplified sample size calculation was done (Appendix 4A). As per the calculation, approximately 1445 children in 489 neighborhoods are needed to achieve a power of 80%. It must be noted that this calculation is likely an underestimation of the actual sample size required for the designated power. This is because the simplified method does not consider the number of children within each neighborhood and the skewed distribution of the outcome variable. However, given that population-level data were available for this analysis, it is unlikely that the analysis is underpowered.

4.2.5 Missing data

A total of 438 (1.48%), 453 (1.53%), 600 (2.03%), 542 (1.84%), 421 (1.43%) children were missing PHWB, SC, EM, LCD, and CSGK scores, respectively. Additionally, a total of 898 (3.04%) children were missing data on predictor variables. Given that children with missing data comprised only a small portion of the total study population, and that no important differences in demographic characteristics between children with missing EDI domain scores and the analytic sample were observed (Appendices 4C to 4G), imputation methods were not attempted.

4.3 Results

4.3.1 Population characteristics

A total of 29,520 children with special needs were identified in the database. Population characteristics are presented in Table 4.1.

Table 4.1: Population characteristics

Gender	**N (% of population of children with special needs)**
Female	8906 (30.2)
Male	20585 (69.7)
Missing	29 (0.1)
Age	
Mean (SD)	5.79 (0.41)
Missing	114 (0.39)
EFSL Status	**N (%)**
Yes	3637 (12.3)
No	25402 (86.0)
Missing	481 (1.6)
Province	**N (%)**
Alberta	2099 (7.1)
British Columbia	5044 (17.1)
Manitoba	2468 (8.4)
New Brunswick	327 (1.1)
Newfoundland	641 (2.2)
Nova Scotia	1083 (3.7)
Northwest Territories	65 (0.2)
Ontario	13198 (44.7)
Prince Edward Island	29 (0.1)
Quebec	3023 (10.2)
Saskatchewan	1440 (4.9)
Yukon	103 (0.3)
Year of data collection	**N (%)**
2004	474 (1.6)
2005	2332 (7.9)

2006	4304 (14.6)
2007	1471 (5.0)
2008	1762 (6.0)
2009	4786 (16.2)
2010	2658 (9.0)
2011	3494 (11.8)
2012	5140 (17.4)
2013	2711 (9.2)
2014	388 (1.3)
Mean (SD) EDI domain scores	
PHWB	7.02 (2.12)
SC	5.71 (2.63)
EM	6.13 (1.99)
LCD	6.18 (3.01)
CSGK	4.37 (3.27)

PHWB=Physical health & wellbeing; EM=Emotional maturity; LCD=Language & cognitive development; CSGK=communication skills & general knowledge

These children resided in 2,016 neighborhoods. Neighborhood characteristics are presented in Table 4.2. Forty (1.95%) neighborhoods in the database were excluded from the analysis due to not having any children with special needs. Descriptive characteristics for these neighborhoods are presented in Appendix 4B. Neighborhoods excluded from analysis included fewer children, were of higher SES, and were a disproportional representation of Canadian provinces. Most neighborhoods excluded from analysis were from Quebec and Alberta. This is in contrast to neighborhoods included in the analysis, most of which were from Ontario and Quebec.

Table 4.2: Neighborhood characteristics (N=2016)

Province	**Number of neighborhoods (%)**
Alberta	259 (12.8)
British Columbia	298 (14.7)
Manitoba	75 (3.7)
New Brunswick	48 (2.4)
Newfoundland	41 (2.0)
Nova Scotia	57 (2.8)
Northwest Territories	3 (0.1)
Ontario	795 (39.4)
Prince Edward Island	6 (0.3)
Quebec	373 (18.5)

Saskatchewan	55 (2.7)
Yukon	6 (0.3)
Median (IQR) number of children with special needs in each neighbourhood	11 (6 – 19)
Median (IQR) number of children in each neighborhood	128 (87 – 194)

Characteristics of children missing any one of the five EDI domain scores are presented in Appendices 4C through 4G. Overall, there were no important differences in demographic characteristics between the analytic sample and children missing EDI domain scores, apart from year and province, which was expected given differences in data collection procedures.

4.3.2 Intraclass correlation coefficient (ICC)

ICCs for each of the five models are presented in Table 4.3. The lowest ICC was observed for the CSGK domain and the highest was observed for the LCD domain. This suggests that neighborhoods accounted for the lowest and highest amount of variation in the CSGK and LCD domains, respectively.

Table 4.3: Intraclass correlation coefficients for each of the five models

Coefficients	PHWB	SC	EM	LCD	CSGK
Neighbourhood level variance (SE)	0.24 (0.02)	0.19 (0.02)	0.12 (0.01)	0.39 (0.04)	0.13 (0.04)
Individual level variance (SE)	0.31 (0.00)	0.31 (0.00)	0.20 (0.00)	0.42 (0.00)	0.38 (0.00)
Intraclass correlation coefficient (ICC)	0.44	0.38	0.38	0.48	0.25

All neighborhood and individual level variance coefficients are significant at the $p<0.0001$ level. PHWB=Physical health & wellbeing; SC=Social competence; EM=Emotional maturity; LCD=Language & cognitive development; CSGK=communication skills & general knowledge; SE=Standard error

4.3.3 Model results

Regression coefficients, their levels of significance, and goodness-of-fit indices for each of the EDI domains are presented in Tables 4.4 through 4.8 at the end of this chapter. The gamma distribution with an identity link produced the best fit for most domains, as assessed by AIC and BIC statistics (Appendix 4H). The normal distribution with identity link produced the best fit for the EM and CSGK domains. To maintain consistency, results are only presented for models constructed using the gamma distribution. Regression coefficients produced using the normal distribution for the EM and CSGK domains were only marginally different from those produced using the gamma distribution. Random effects of predictors did not significantly improve fit and so they were not included in the final model.

The results of the regression analysis indicate that child-level characteristics and SES are significant predictors of children's EDI domain scores, as indicated by decreasing deviance, AIC, and BIC statistics across models by addition of child-level and SES characteristics, and significant likelihood ratio tests (Appendix 4I). The AIC statistics decreased by addition of child-level and SES characteristics for all domains. BIC statistics decreased across models by addition of child-level and SES characteristics for all domains except LCD. For the LCD domain, the BIC statistic increased from the addition of child-level characteristics, and then decreased for the model including neighborhood SES. The BIC statistic for the model containing neighborhood SES was lower than for the other two models, suggesting that SES is still an important predictor of LCD scores.

Year, province, and the interaction between them were statistically significant for all domains. Age was statistically significant for all domains except PHWB. The LCD domain was positively associated with age. Age was negatively associated with SC, EM, and CSGK. Apart from the PHWB domain, the smallest effect due to age was seen for the EM domain and the largest was seen for the SC and CSGK domains. Gender was statistically significant for all EDI domains and, on average, girls scored higher than boys on all domains of the EDI. The smallest and largest gender differences were seen for the LCD and EM domains, respectively. EFSL status was only statistically significant for the EM, LCD, and CSGK domains. EFSL status was positively associated with EM scores and negatively associated with LCD and CSGK scores. The smallest and largest absolute effects were observed for the EM and CSGK domains, respectively. Finally, the SES index was a statistically significant predictor for all EDI domains and was consistently positively associated with EDI domain scores. The smallest and largest effects were observed for the EM and LCD domains, respectively.

Age and EFSL status were retained in the final model despite not being statistically significant predictors for PHWB and PHWB and SC domain scores, respectively. This was to maintain comparability across regression models for all EDI domains. Furthermore, age and EFSL status have been significant predictors of developmental health in other populations (9).

4.3.4 Diagnostics and sensitivity analyses

VIF statistics are presented in Table 4.9. Excluding dummy coded categorical variables, all VIF statistics were below the cut-off of 10 and ranged from 1.05 and 1.10. Multicollinearity was not suspected among categorical variables for which VIF statistics are not presented.

Table 4.9: Variance Inflation Factor (VIF) statistics

Predictor	VIF
Age	1.10
Gender	1.10
EFSL	1.05
SES z-score	1.04

EFSL= English/French as a second language

Leverage statistics are presented in Table 4.10. A total of 44 observations with leverage statistics more than twice the mean leverage were investigated for data entry error. No data entry error was found.

Table 4.10: Leverage statistics

Mean (SD) leverage	0.00095 (0.002)
Number of observations > twice mean leverage statistics	44

Raw, Pearson, and studentized residuals for each of the five EDI models are presented in Appendices 4J through 4N. Generally, residuals were positively skewed with decreasing variance.

Studentized residuals were used to identify influential and outlying observations. The results of the sensitivity analysis excluding cases with absolute studentized residual values greater than 2 are presented in Appendices 4O through 4S. A total of 697 (2.36%), 317 (1.07%), 409 (1.39%), 619 (2.10%), and 2 (0.01%) children were excluded for the PHWB, SC, EM, LCD, and CSGK analyses, respectively. The effect of all predictors, including the SES index, increased in nearly all models after the exclusion of outliers. This was most evident in the LCD domain, most likely due to the fact that more outlying cases were excluded.

4.4 References

1. Conger RD, Conger KJ, Martin MJ. Socioeconomic status, family processes, and individual development. Journal of Marriage and Family. 2010;72(3):685-704.
2. Anthony LG, Anthony BJ, Glanville DN, Naiman DQ, Waanders C, Shaffer S. The relationships between parenting stress, parenting behaviour and preschoolers' social competence and behaviour problems in the classroom. Infant and Child Development. 2005;14(2):133-54.
3. Lovejoy MC, Graczyk PA, O'Hare E, Neuman G. Maternal depression and parenting behavior: A meta-analytic review. Clinical psychology review. 2000;20(5):561-92.
4. Leventhal T, Brooks-Gunn J. The neighborhoods they live in: the effects of neighborhood residence on child and adolescent outcomes. Psychological bulletin. 2000;126(2):309.
5. Feng HPV, P.; Guo, Z.; Liu, F.; Panebianco, D.; Levine, V.; Caro, L.; Butterton, J.; Iwamoto, M.; Yeh, W. No Pharmacokinetic Interaction Between the Hepatitis C Virus Inhibitors Elbasvir/Grazoprevir and Famotidine or Pantoprazole. Clinical and Translational Science. 2017.
6. Patel S. Integrated early childhood program participation, parenting, and child development outcomes: The Toronto First Duty project: Citeseer; 2009.
7. Schunck R. Cluster Size and Aggregated Level 2 Variables in Multilevel Models. A Cautionary Note. Methods, data, analyses: a journal for quantitative methods and survey methodology (mda). 2016;10(1):97-108.
8. Kim Y, Choi Y-K, Emery S. Logistic regression with multiple random effects: a simulation study of estimation methods and statistical packages. The American Statistician. 2013;67(3):171-82.
9. Janus M, Offord DR. Development and psychometric properties of the Early Development Instrument (EDI): A measure of children's school readiness. Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement. 2007;39(1):1.
10. Goldfeld S, O'Connor M, Sayers M, Moore T, Oberklaid F. Prevalence and correlates of special health care needs in a population cohort of Australian children at school entry. Journal of Developmental & Behavioral Pediatrics. 2012;33(4):319-27.
11. Bolker BM, Brooks ME, Clark CJ, Geange SW, Poulsen JR, Stevens MHH, et al. Generalized linear mixed models: a practical guide for ecology and evolution. Trends in ecology & evolution. 2009;24(3):127-35.
12. Gill J. Generalized linear models: a unified approach: Sage Publications; 2000.

Table 4.4: Hierarchical Generalized Linear Model (HGLM) for the Physical Health & Wellbeing (PHWB) Domain of the Early Development Instrument (EDI)

Parameter	Model 1				Model 2				Model 3			
	B coefficient (SE)	F-statistic	DF	P-value	B coefficient (SE)	F-statistic	DF	P-value	B coefficient (SE)	F-statistic	DF	P-value
Intercept	3.98 (0.02)	47093.34	1, 2013	<0.0001	4.75 (1.07)	19.80	1, 2002	<0.0001	4.65 (1.07)	19.10	1, 2002	<0.0001
Year (categorical)						3.95	10, 26117	<0.0001		4.18	10, 26116	<0.0001
Province (categorical)						13.94	11, 26117	<0.0001		13.54	11, 26116	<0.0001
Year*Province						2.54	53, 26117	<0.0001		2.91	53, 26116	<0.0001
Age					0.03 (0.03)	1.04	1, 26117	0.3089	0.04 (0.03)	1.29	1, 26116	0.2558
Gender (M=0; F=1)					-0.13 (0.03)	22.96	1, 26117	<0.0001	-0.14 (0.03)	24.11	1, 26116	<0.0001
EFSL (no=0; yes=1)					-0.02 (0.04)	0.19	1, 26117	0.6638	-0.04 (0.04)	0.94	1, 26116	0.3325
SES z-score									-0.17 (0.02)	116.76	1, 26116	<0.0001
Deviance	118982.4				118334.9				118222.1			
AIC	118988.4				118494.9				118384.1			
BIC	119005.2				118943.5				118838.4			
Pearson Chi-Square	7394.78				7475.81				7495.20			

Note the sign (+/-) of correlation coefficients reflects direction of correlation with transformed EDI domain scores (11 – EDI domain scores).
DF=degrees of freedom; EFSL=English/French as a second language AIC=Akaike Information Criterion; BIC-Bayesian Information Criterion

Table 4.5: Hierarchical Generalized Linear Model (HGLM) for the Social Competence (SC) Domain of the Early Development Instrument (EDI)

Parameter	Model 1				Model 2				Model 3			
	B coefficient (SE)	F-statistic	Df	P-value	B coefficient (SE)	F-statistic	Df	P-value	B coefficient (SE)	F-statistic	Df	P-value
Intercept	5.31 (0.02)	62975.90	1, 2014	<0.0001	4.62 (1.26)	13.47	1, 2004	0.0003	4.46 (1.25)	12.67	1, 2003	0.0004
Year (categorical)						2.83	10, 26106	0.0016		2.56	10, 26106	0.0043
Province (categorical)						10.27	11, 26106	<0.0001		10.25	11, 26106	<0.0001
Year*Province						2.76	53, 26106	<0.0001		2.76	53, 26106	<0.0001
Age					0.13 (0.04)	8.99	1, 26106	0.0027	0.13 (0.04)	10.12	1, 26106	0.0015
Gender (M=0; F=1)					-0.75 (0.04)	439.63	1, 26106	<0.0001	-0.76 (0.04)	447.29	1, 26106	<0.0001
EFSL (no=0; yes=1)					0.12 (0.06)	4.82	1, 26106	0.0284	0.10 (0.05)	3.07	1, 26106	0.0798
SES z-score									-0.17 (0.02)	69.10	1, 26106	<0.0001
Deviance	134806.2				134020.8				133955.4			
AIC	134812.2				134180.8				134117.4			
BIC	134829.0				134629.5				134571.7			
Pearson Chi-Square	6654.52				6723.87				6736.70			

Note the sign (+/-) of correlation coefficients reflects direction of correlation with transformed EDI domain scores (11 – EDI domain scores).
DF=degrees of freedom; EFSL=English/French as a second language AIC=Akaike Information Criterion; BIC-Bayesian Information Criterion

Table 4.6: Hierarchical Generalized Linear Model (HGLM) for the Emotional Maturity (EM) Domain of the Early Development Instrument (EDI)

Parameter	Model 1				Model 2				Model 3			
	B coefficient (SE)	F-statistic	Df	P-value	B coefficient (SE)	F-statistic	Df	P-value	B coefficient (SE)	F-statistic	Df	P-value
Intercept	4.88 (0.02)	47093.34	1, 2014	<0.0001	4.28 (0.96)	19.71	1, 2003	<0.0001	4.18 (0.95)	19.00	1, 2003	<0.0001
Year (categorical)						2.68	10, 25974	0.0029		2.42	10, 25793	<0.0001
Province (categorical)						9.22	11, 25974	<0.0001		9.04	11, 25793	<0.0001
Year*Province						2.12	53, 25974	<0.0001		2.06	53, 25793	<0.0001
Age					0.08 (0.03)	6.17	1, 25974	0.0130	0.08 (0.03)	6.63	1, 25793	0.0101
Gender (M=0; F=1)					-0.81 (0.03)	970.94	1, 25974	<0.0001	-0.81 (0.03)	969.06	1, 25793	<0.0001
EFSL (no=0; yes=1)					-0.11 (0.04)	7.29	1, 25974	0.0070	-0.12 (0.04)	10.01	1, 25793	0.0016
SES z-score									-0.12 (0.01)	65.82	1, 25793	<0.0001
Deviance	119448.7				118202.7				118136.1			
AIC	119454.7				118362.7				118298.1			
BIC	119471.6				118811.3				118752.3			
Pearson Chi-Square	4465.48				4421.32				4428.30			

Note the sign (+/-) of correlation coefficients reflects direction of correlation with transformed EDI domain scores (11 – EDI domain scores).
DF=degrees of freedom; EFSL=English/French as a second language AIC=Akaike Information Criterion; BIC-Bayesian Information Criterion

Table 4.7: Hierarchical Generalized Linear Model (HGLM) for the Language & Cognitive Development (LCD) Domain of the Early Development Instrument (EDI)

Parameter	Model 1				Model 2				Model 3			
	B coefficient (SE)	F-statistic	Df	P-value	B coefficient (SE)	F-statistic	Df	P-value	B coefficient (SE)	F-statistic	Df	P-value
Intercept	4.82 (0.02)	37229.70	1, 2014	<0.0001	4.36 (1.33)	10.69	1, 2003	0.0011	4.17 (1.33)	9.80	1, 2003	0.0017
Year (categorical)						3.78	10, 26022	0.0029		3.49	10, 26021	<0.0001
Province (categorical)						6.32	11, 26022	<0.0001		7.01	11, 26021	<0.0001
Year*Province						2.13	53, 26022	<0.0001		2.28	53, 26021	<0.0001
Age					-0.11 (0.04)	6.34	1, 26022	0.0118	-0.10 (0.04)	5.01	1, 26021	0.0252
Gender (M=0; F=1)					-0.13 (0.04)	10.35	1, 26022	0.0013	-0.13 (0.04)	10.42	1, 26021	0.0013
EFSL (no=0; yes=1)					0.48 (0.06)	58.32	1, 26022	<0.0001	0.43 (0.06)	47.13	1, 26021	<0.0001
SES z-score									-0.29 (0.02)	160.80	1, 26021	<0.0001
Deviance	135595.0				135045.0				134891.0			
AIC	135601.0				135205.0				135053.0			
BIC	135617.8				135653.7				135507.3			
Pearson Chi-Square	10372.47				10458.52				10531.822			

Note the sign (+/-) of correlation coefficients reflects direction of correlation with transformed EDI domain scores (11 – EDI domain scores).
DF=degrees of freedom; EFSL=English/French as a second language AIC=Akaike Information Criterion; BIC-Bayesian Information Criterion

Table 4.8: Hierarchical Generalized Linear Model (HGLM) for the Communication Skills & General Knowledge (CSGK) Domain of the Early Development Instrument (EDI)

Parameter	Model 1				Model 2				Model 3			
	B coefficient (SE)	F-statistic	Df	P-value	B coefficient (SE)	F-statistic	Df	P-value	B coefficient (SE)	F-statistic	Df	P-value
Intercept	6.65 (0.03)	63312.62	1, 2014	<0.0001	6.11 (1.78)	11.76	1, 2003	0.0006	4.65 (1.07)	19.10	1, 2002	0.0007
Year (categorical)						3.95	10, 26141	0.0247		1.74	10, 26140	0.0657
Province (categorical)						13.94	11, 26141	<0.0001		5.94	11, 26140	<0.0001
Year*Province						2.54	53, 26141	0.0109		1.51	53, 26140	0.0094
Age					0.13 (0.06)	2.05	1, 26141	0.0258	0.13 (0.05)	5.19	1, 26140	0.0227
Gender (M=0; F=1)					-0.42 (0.05)	7.24	1, 26141	<0.0001	-0.43 (0.05)	70.12	1, 26140	<0.0001
EFSL (no=0; yes=1)					1.15 (0.08)	1.50	1, 26141	<0.0001	1.11 (0.08)	173.86	1, 26140	<0.0001
SES z-score									-0.19 (0.02)	55.05	1, 26140	<0.0001
Deviance	151991.9				151438.8				151384.1			
AIC	151997.9				151598.8				151544.1			
BIC	152014.7				152047.5				151992.8			
Pearson Chi-Square	6272.57				6810.50				6817.77			

Note the sign (+/-) of correlation coefficients reflects direction of correlation with transformed EDI domain scores (11 – EDI domain scores).
DF=degrees of freedom; EFSL=English/French as a second language AIC=Akaike Information Criterion; BIC-Bayesian Information Criterion

Appendix 4A: Sample size calculation for the HGLM analysis of EDI domain scores and SES

The sample size of a regression model can be calculated by the following equation (Kleinbaum et al., 2013).

$$n_s \geq \left[\frac{Z_{1-a/2} + Z_{1-B}}{\frac{1}{2} In\left((1+\rho)/(1-\rho)\right)}\right]^2$$

$Z_{1-a/2}$ = 1.96

Z_{1-B} = 1.28

A small effect size was expected. Based on results reported by Oliver et al. (2007) using data from typically developing children, it was estimated that approximately 5% of the variance in PHWB scores could be explained by SES characteristics.

ρ = 0.22

Therefore, n_s = 210

The sample size can be adjusted for correlation between the SES index, and other covariates. This correlation was calculated as r = 0.159

$$N_s = \frac{n_s}{1 - 0.159^2}$$

N_s = 215

The sample size can also be adjusted for the clustering effect of the study design. For a cluster design study to have the equivalent power of a non-cluster design study, the required sample size should be inflated by the design effect (Campbell et al., 2001):

$$1 + (average\ number\ of\ subjects\ per\ cluster - 1) \times ICC$$

$$= 1 + (14 - 1) \times 0.44$$

$$= 6.72$$

$$215 \times 6.72 = 1444.8$$

Therefore, the analysis requires approximately 1445 children.

As the predictor of interest is at the cluster-level, the number of clusters should be approximately equal to the product of the number of individuals required given a non-clustered study design and the reciprocal of the ICC.

$$215 \times \left(\frac{1}{0.44}\right) = 488.6$$

Hence, approximately 489 neighborhoods are needed. However, this does not take into account that the number of children in each neighborhood is not consistent.

References

1.Kleinbaum D, Kupper L, Nizam A, Rosenberg E. Applied regression analysis and other multivariable methods: Nelson Education; 2013

Appendix 4B: Descriptive characteristics of neighborhoods excluded from analysis (n=40)

Province	**Number of neighborhoods (%)**
Alberta	8 (20)
New Brunswick	4 (10)
Ontario	5 (12.5)
Quebec	23 (57.5)
Median (IQR) number of children in each neighbourhood	83 (56-141)
Mean (SD) of standardized SES index	0.38 (0.88)

Appendix 4C: Descriptive characteristics of population of children with missing PHWB scores (n=446)

Gender	**N (%)**
Female	123 (27.6)
Male	318 (71.3)
Missing	5 (1.1)
Age	
Mean (SD)	5.78 (0.40)
Missing	7 (1.57)
EFSL Status	**N (%)**
Yes	61 (13.7)
No	379 (85.0)
Missing	6 (1.3)
Province	**N (%)**
Alberta	82 (18.4)
British Columbia	9 (2.0)
Manitoba	122 (27.4)
New Brunswick	1 (0.2)
Newfoundland	3 (0.7)
Nova Scotia	15 (3.4)
Northwest Territories	1 (0.2)
Ontario	193 (43.3)
Prince Edward Island	0 (0)
Quebec	5 (1.1)
Saskatchewan	8 (1.8)
Yukon	0 (0)
Year of data collection	**N (%)**
2004	3 (0.7)
2005	19 (4.3)
2006	46 (10.3)
2007	26 (5.8)
2008	33 (7.4)
2009	50 (11.2)
2010	51 (11.4)
2011	96 (21.5)
2012	51 (11.4)
2013	71 (15.9)
2014	0 (0)
Mean (SD) EDI domain scores	
SC	5.42 (2.97)
EM	5.90 (2.53)
LCD	5.39 (3.31)
CSGK	3.80 (3.34)

PHWB=Physical health & wellbeing; EM=Emotional maturity; LCD=Language & cognitive development; CSGK=communication skills & general knowledge

Appendix 4D: Descriptive characteristics of population of children with missing SC scores (n=453)

Gender	**N (%)**
Female	138 (30.5)
Male	311 (68.7)
Missing	4 (0.9)
Age	
Mean (SD)	5.73 (0.4)
Missing	6 (1.3)
EFSL Status	**N (%)**
Yes	61 (13.5)
No	386 (85.2)
Missing	6 (1.3)
Province	**N (%)**
Alberta	84 (18.5)
British Columbia	17 (3.8)
Manitoba	117 (25.8)
New Brunswick	1 (0.2)
Newfoundland	6 (1.3)
Nova Scotia	14 (3.1)
Northwest Territories	1 (0.2)
Ontario	192 (42.4)
Prince Edward Island	0 (0)
Quebec	3 (0.7)
Saskatchewan	13 (2.9)
Yukon	0 (0)
Year of data collection	**N (%)**
2004	3 (0.7)
2005	17 (3.8)
2006	44 (9.7)
2007	23 (5.1)
2008	34 (7.5)
2009	55 (12.1)
2010	48 (10.6)
2011	96 (21.2)
2012	56 (12.4)
2013	74 (16.3)
2014	3 (0.7)
Mean (SD) EDI domain Scores	
PHWB	5.06 (2.17)
EM	5.42 (1.44)
LCD	1.98 (2.38)
CSGK	0.86 (1.91)

PHWB=Physical health & wellbeing; EM=Emotional maturity; LCD=Language & cognitive development; CSGK=communication skills & general knowledge

Appendix 4E: Descriptive characteristics of population of children with missing EM scores (n=600)

Gender	**N (%)**
Female	166 (27.7)
Male	429 (71.5)
Missing	5 (0.8)
Age	
Mean (SD)	5.78 (0.4)
Missing	8 (1.3)
EFSL Status	**N (%)**
Yes	76 (12.7)
No	511 (85.2)
Missing	13 (2.2)
Province	**N (%)**
Alberta	92 (15.3)
British Columbia	41 (6.8)
Manitoba	131 (21.8)
New Brunswick	4 (0.7)
Newfoundland	6 (1.0)
Nova Scotia	20 (3.3)
Northwest Territories	2 (0.3)
Ontario	241 (40.2)
Prince Edward Island	0 (0)
Quebec	33 (5.5)
Saskatchewan	19 (3.2)
Yukon	0 (0)
Year of data collection	**N (%)**
2004	7 (1.2)
2005	29 (4.8)
2006	77 (12.8)
2007	39 (6.5)
2008	43 (7.2)
2009	70 (11.7)
2010	57 (9.5)
2011	113 (18.8)
2012	80 (13.3)
2013	84 (14.0)
2014	1 (0.2)
Mean (SD) EDI domain Scores	
PHWB	6.70 (2.33)
SC	5.47 (2.54)
LCD	5.51 (3.15)
CSGK	3.77 (3.06)

PHWB=Physical health & wellbeing; EM=Emotional maturity; LCD=Language & cognitive development; CSGK=communication skills & general knowledge

Appendix 4F: Descriptive characteristics of population of children with missing LCD scores (n=542)

Gender	**N (%)**
Female	154 (28.4)
Male	384 (70.8)
Missing	4 (0.7)
Age	
Mean (SD)	5.76 (0.4)
Missing	6 (1.1)
EFSL Status	**N (%)**
Yes	77 (14.2)
No	457 (84.3)
Missing	8 (1.5)
Province	**N (%)**
Alberta	91 (16.8)
British Columbia	45 (8.3)
Manitoba	121 (22.3)
New Brunswick	1 (0.2)
Newfoundland	3 (0.6)
Nova Scotia	21 (3.9)
Northwest Territories	1 (0.2)
Ontario	222 (41.0)
Prince Edward Island	1 (0.2)
Quebec	15 (2.8)
Saskatchewan	14 (2.6)
Yukon	0 (0)
Year of data collection	**N (%)**
2004	3 (0.6)
2005	21 (3.9)
2006	61 (11.3)
2007	32 (5.9)
2008	39 (7.2)
2009	69 (12.7)
2010	58 (10.7)
2011	113 (20.8)
2012	67 (12.4)
2013	79 (14.6)
2014	0 (0)
Mean (SD) EDI domain Scores	
PHWB	6.82 (2.09)
SC	4.78 (2.33)
EM	5.65 (1.89)
CSGK	2.93 (2.74)

PHWB=Physical health & wellbeing; EM=Emotional maturity; LCD=Language & cognitive development; CSGK=communication skills & general knowledge

Appendix 4G: Descriptive characteristics of population of children with missing CSGK scores (n=421)

Gender	**N (%)**
Female	128 (30.4)
Male	289 (68.6)
Missing	4 (1.0)
Age	
Mean (SD)	5.76 (0.41)
Missing	7 (1.66)
EFSL Status	**N (%)**
Yes	59 (14.0)
No	355 (84.3)
Missing	7 (1.7)
Province	**N (%)**
Alberta	85 (20.2)
British Columbia	7 (1.7)
Manitoba	113 (26.8)
New Brunswick	0 (0)
Newfoundland	5 (1.2)
Nova Scotia	15 (3.6)
Northwest Territories	1 (0.2)
Ontario	173 (41.1)
Prince Edward Island	0 (0)
Quebec	7 (1.7)
Saskatchewan	10 (2.4)
Yukon	0 (0)
Year of data collection	**N (%)**
2004	2 (0.5)
2005	12 (2.9)
2006	46 (10.9)
2007	21 (5.0)
2008	32 (7.6)
2009	43 (10.2)
2010	43 (10.2)
2011	97 (23.0)
2012	53 (12.6)
2013	72 (17.1)
2014	0 (0)
Mean (SD) EDI domain Scores	
PHWB	7.71 (1.96)
SC	5.97 (2.98)
EM	6.31 (1.36)
LCD	6.29 (3.46)

PHWB=Physical health & wellbeing; EM=Emotional maturity; LCD=Language & cognitive development; CSGK=communication skills & general knowledge

Appendix 4H: The goodness-of-fit of other distributions and links

Table 4H-1: Goodness-of-fit of different distributions and link functions for the physical health & wellbeing domain

Goodness-of-fit statistics	Exponential	Gamma	Normal
	Identity link		
AIC	134241.6	118384.1	121141.6
BIC	134684.7	118838.4	121595.8
	Log link		
AIC	134240.4	118399.9	121147.4
BIC	134683.5	118854.2	121601.6

AIC=Akaike information criterion; BIC=Bayesian information criterion; NC=not converged

Table 4H-2: Goodness-of-fit of different distributions and link functions for the social competence domain

Goodness-of-fit statistics	Exponential	Gamma	Normal
	Identity link		
AIC	150247.6	113417.4	133234.4
BIC	150690.7	134571.7	133688.7
	Log link		
AIC	150247.5	134128.9	NC
BIC	150690.6	134583.2	NC

AIC=Akaike information criterion; BIC=Bayesian information criterion; NC=not converged

Table 4H-3: Goodness-of-fit of different distributions and link functions for the emotional maturity domain

Goodness-of-fit statistics	Exponential	Gamma	Normal
	Identity link		
AIC	144859.5	118298.1	116476.9
BIC	145302.6	118752.3	116931.2
	Log link		
AIC	144859.8	118310	NC
BIC	145302.8	118764.3	NC

AIC=Akaike information criterion; BIC=Bayesian information criterion; NC=not converged

Table 4H-4: Goodness-of-fit of different distributions and link functions for the language & cognitive

development domain

Goodness-of-fit statistics	Exponential	Gamma	Normal
Identity link			
AIC	144457.3	135053.0	140742
BIC	144900.3	135507.3	141196.3
Log link			
AIC	144457.1	135069.7	140754.4
BIC	144900.2	135524	141208.7

AIC=Akaike information criterion; BIC=Bayesian information criterion; NC=not converged

Table 4H-5: Goodness-of-fit of different distributions and link functions for the communication skills & general knowledge domain

Goodness-of-fit statistics	Exponential	Gamma	Normal
Identity link			
AIC	163276.5	151544.1	146002.4
BIC	163719.5	151992.8	146456.7
Log link			
AIC	163274.7	151539.4	NC
BIC	163717.8	151988.1	NC

AIC=Akaike information criterion; BIC=Bayesian information criterion; NC=not converged

Appendix 4I: Likelihood ratio tests for EDI models

Physical health & wellbeing domain
Model 1 deviance: 118982.4
Model 2 deviance: 118334.9
Model 3 deviance: 118222.1

Model 1 vs Model 2
118982.4 – 118334.9 = 647.5
Degrees of freedom = 77
$p < 0.0001$

Model 2 vs Model 3
118334.9 – 118222.1 = 112.8
Degrees of freedom = 1
$p < 0.0001$

Social competence
Model 1 deviance: 134806.2
Model 2 deviance: 134020.8
Model 3 deviance: 133955.4

Model 1 vs Model 2
134806.2 – 134020.8 = 785.4
Degrees of freedom = 77
$p < 0.0001$

Model 2 vs Model 3
134020.8 – 133955.4 = 65.4
Degrees of freedom = 1
$p < 0.0001$

Emotional maturity
Model 1 deviance: 119448.7
Model 2 deviance: 118202.7
Model 3 deviance: 118136.1

Model 1 vs Model 2
119448.7 – 118202.7 = 1246
Degrees of freedom = 77
$p < 0.0001$

Model 2 vs Model 3
118202.7 – 118136.1 = 66.6

Degrees of freedom = 1
$p < 0.0001$

Language & cognitive development
Model 1 deviance: 135595.0
Model 2 deviance: 135045.0
Model 3 deviance: 134891.0

Model 1 vs Model 2
135595.0 – 135045.0 = 550
Degrees of freedom = 77
$p < 0.0001$

Model 2 vs Model 3
135045.0 – 134891.0 = 154
Degrees of freedom = 1
$p < 0.0001$

Communication skills & general knowledge
Model 1 deviance: 151991.9
Model 2 deviance: 151438.8
Model 3 deviance: 151384.1

Model 1 vs Model 2
151991.9 – 151438.8 = 553.1
Degrees of freedom = 77
$p < 0.0001$

Model 2 vs Model 3
151438.8 – 151384.1 = 54.7
Degrees of freedom = 1
$p < 0.0001$

Appendix 4J – Physical health & wellbeing residuals

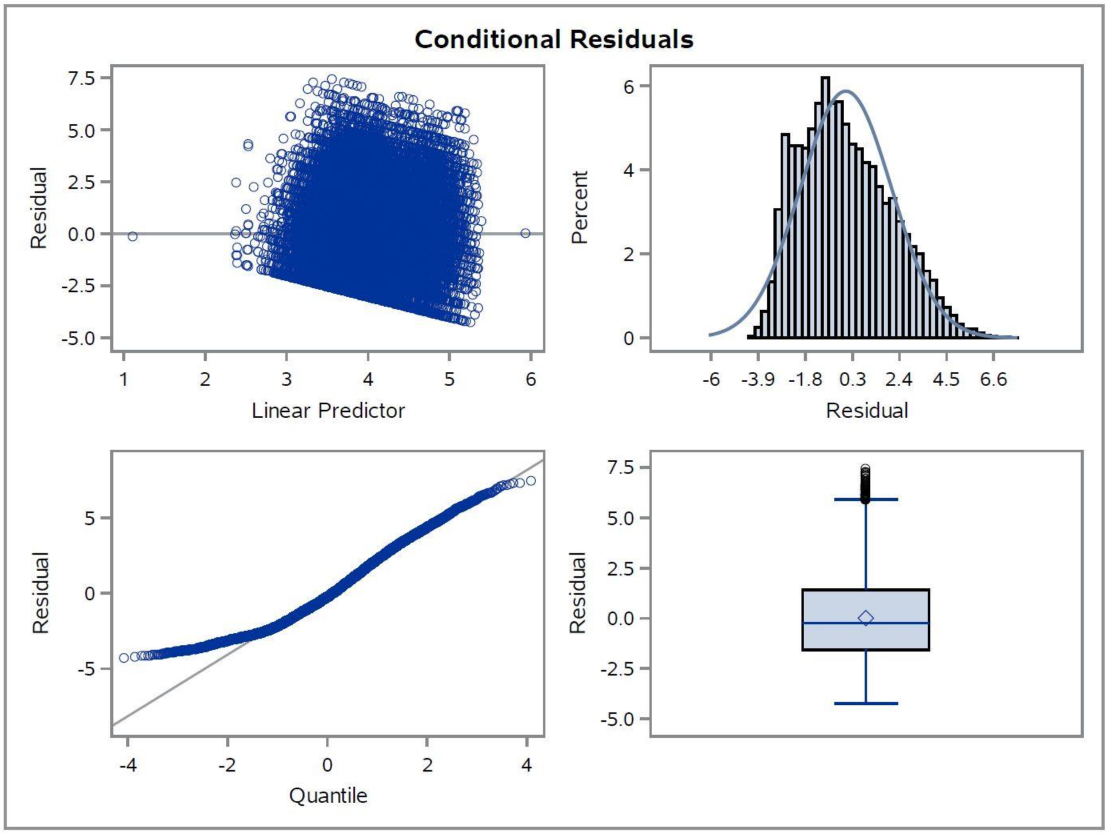

Figure 4J-1: Raw residuals for the final physical health & wellbeing model

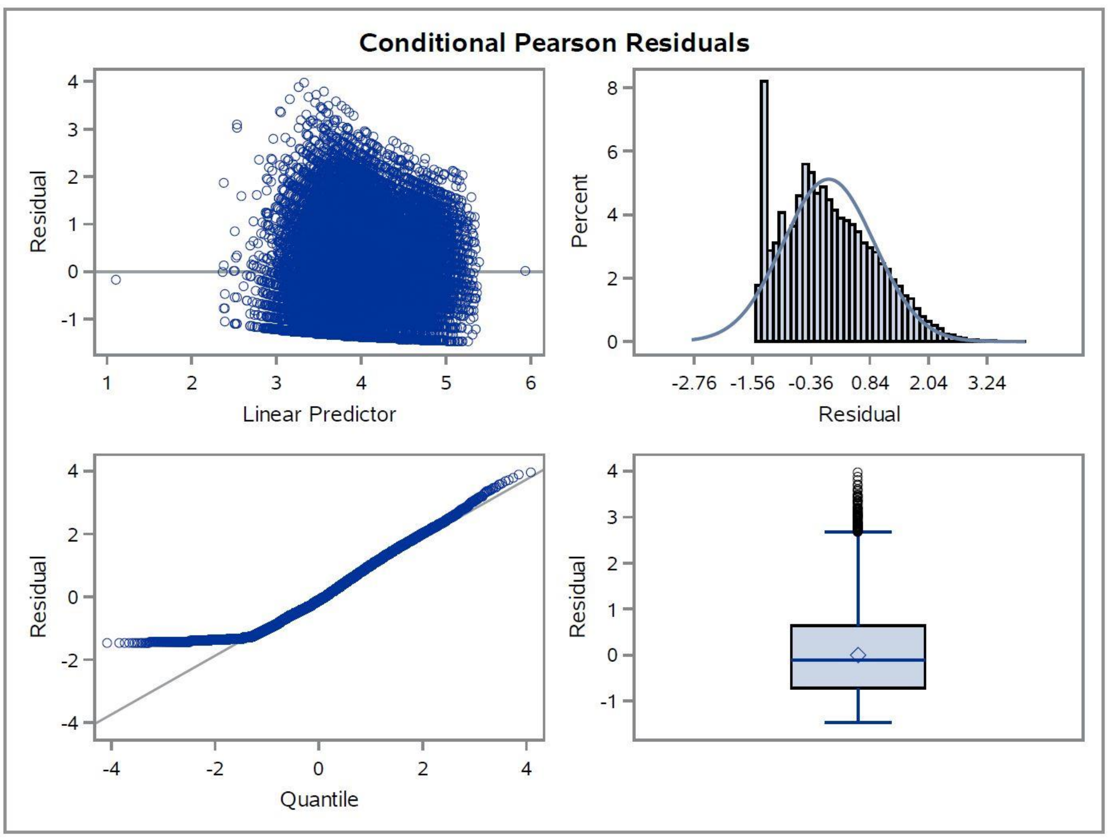

Figure 4J-1: Pearson residuals for the final physical health & wellbeing model

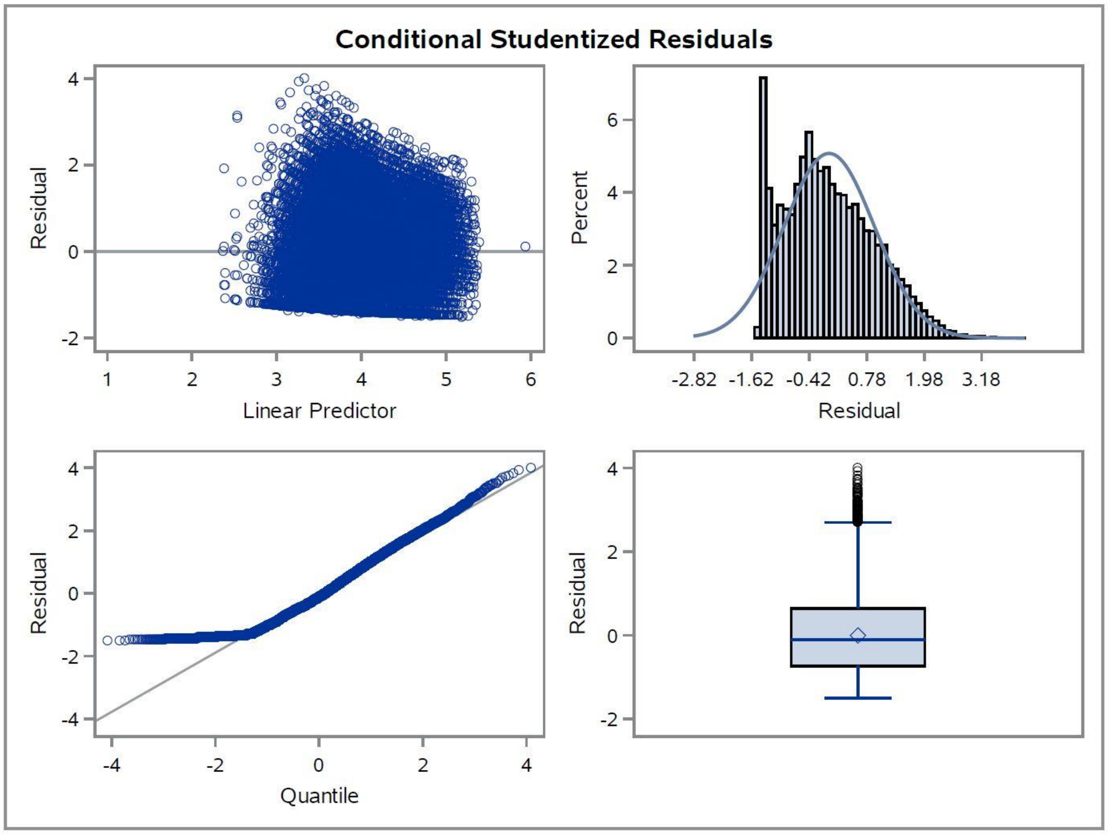

Figure 4J-2: Studentized residuals for the final physical health & wellbeing model

Appendix 4K – Social competence residuals

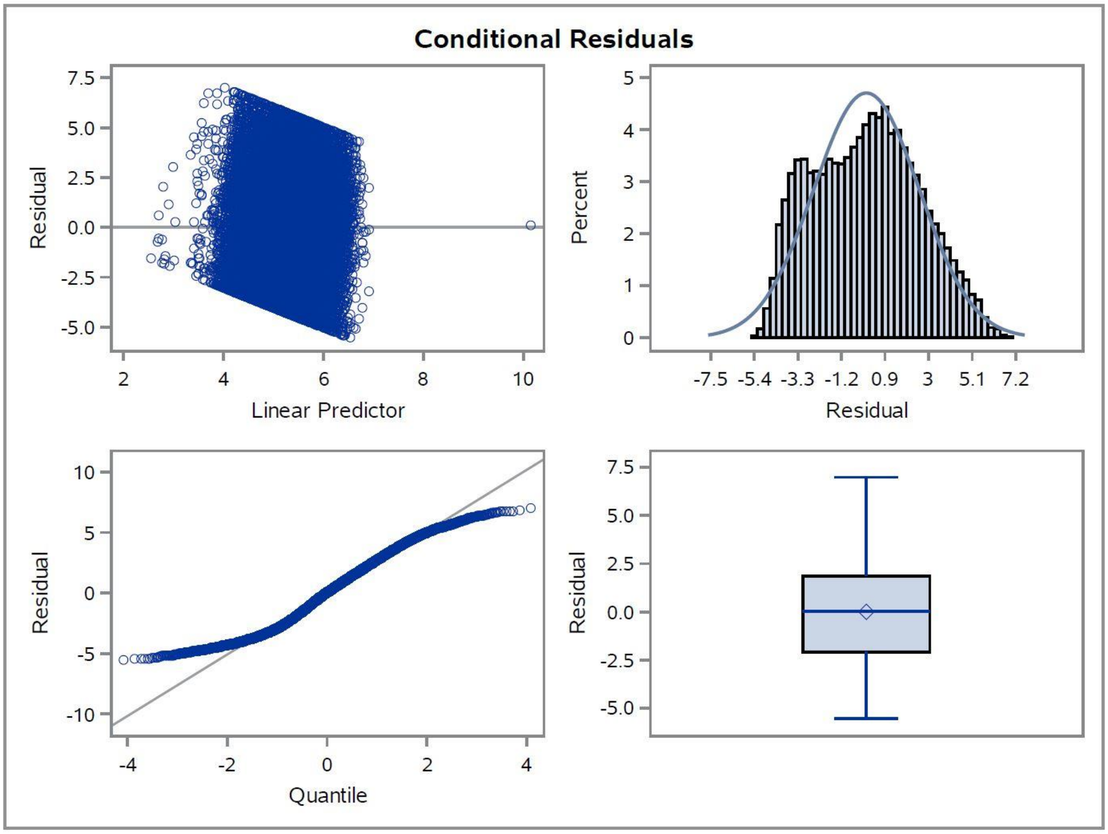

Figure 4K-3: Raw residuals for the final social competence model

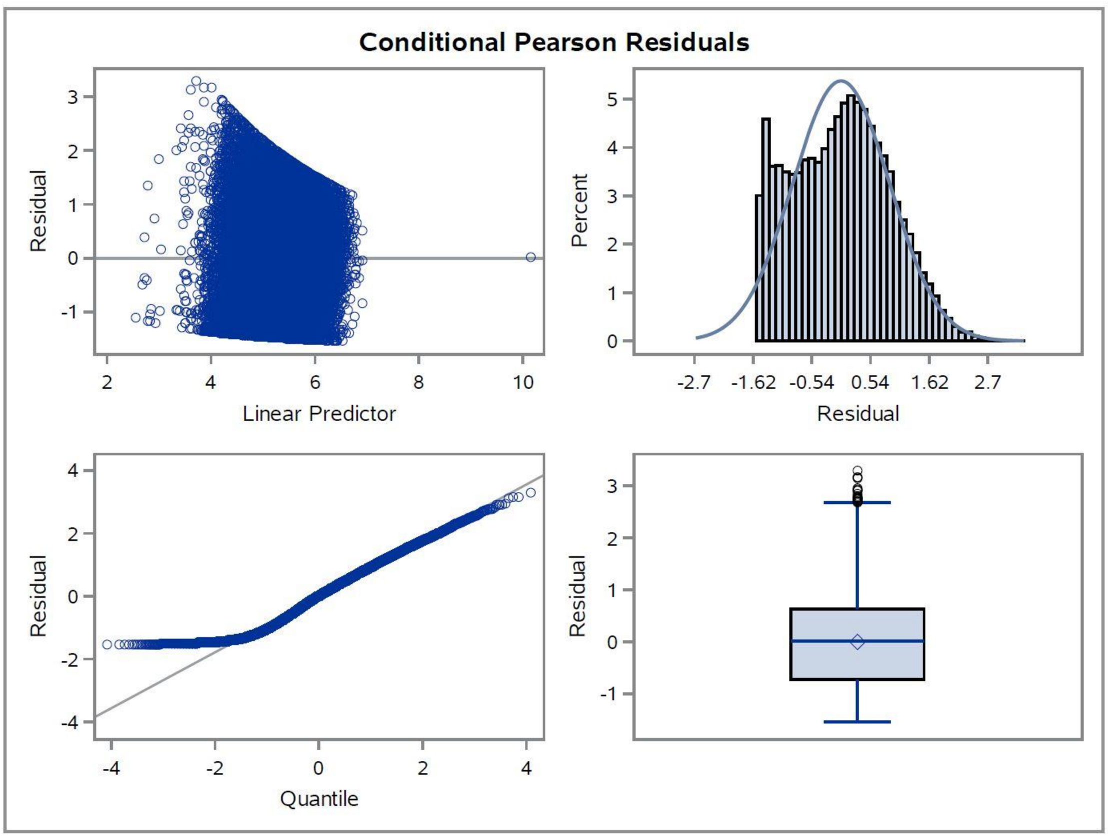

Figure 4K-4: Pearson residuals for the final social competence model

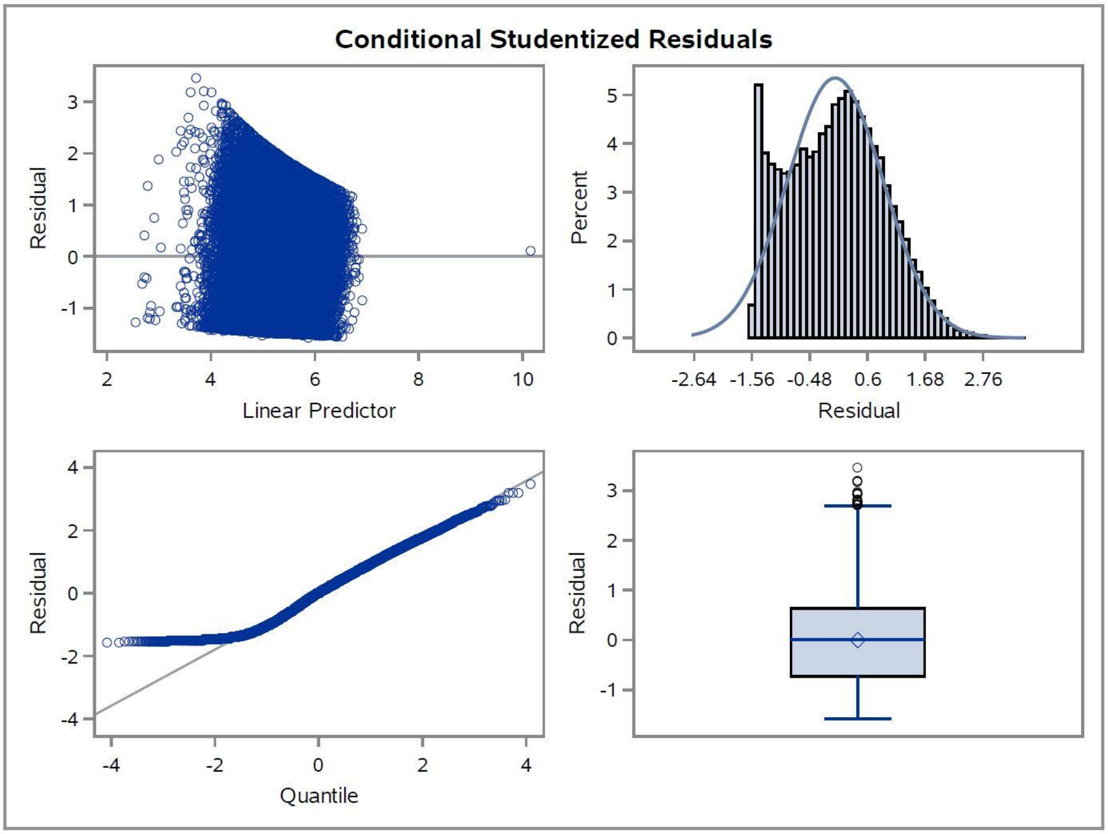

Figure 4K-5: Studentized residuals for the final social competence model

Appendix 4L – Emotional maturity residuals

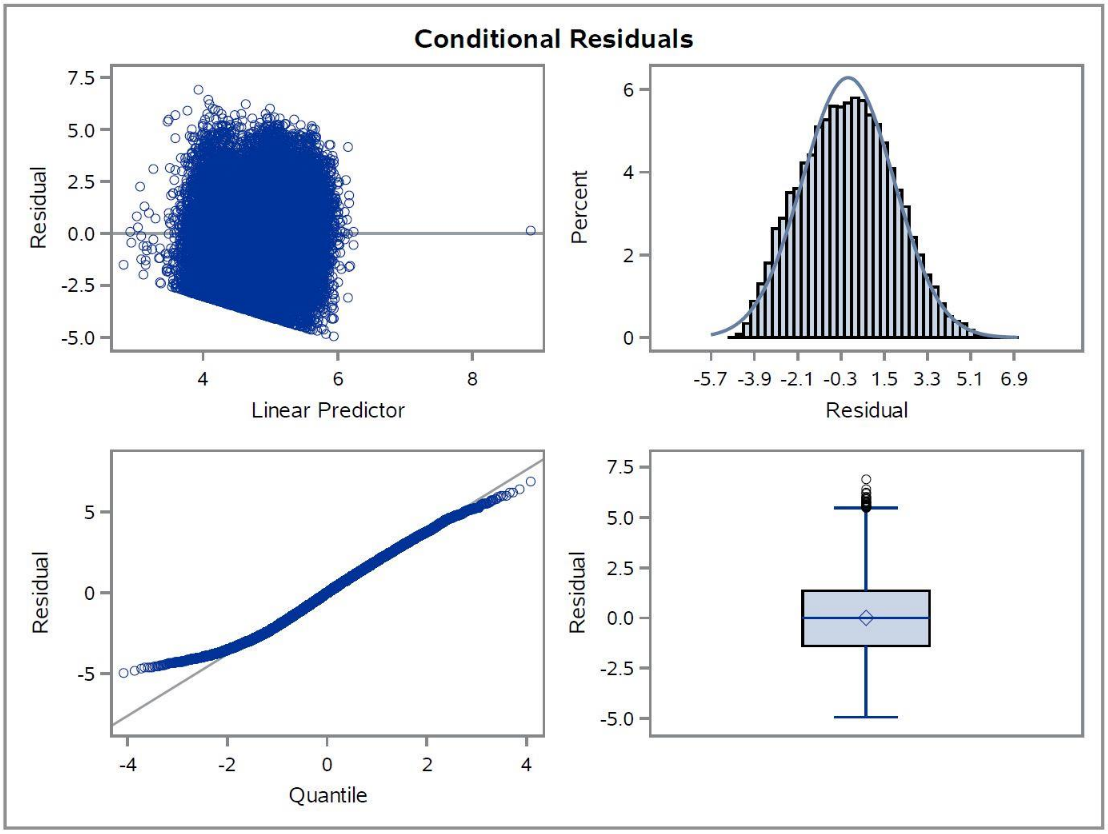

Figure 4L-6: Raw residuals for the final emotional maturity model

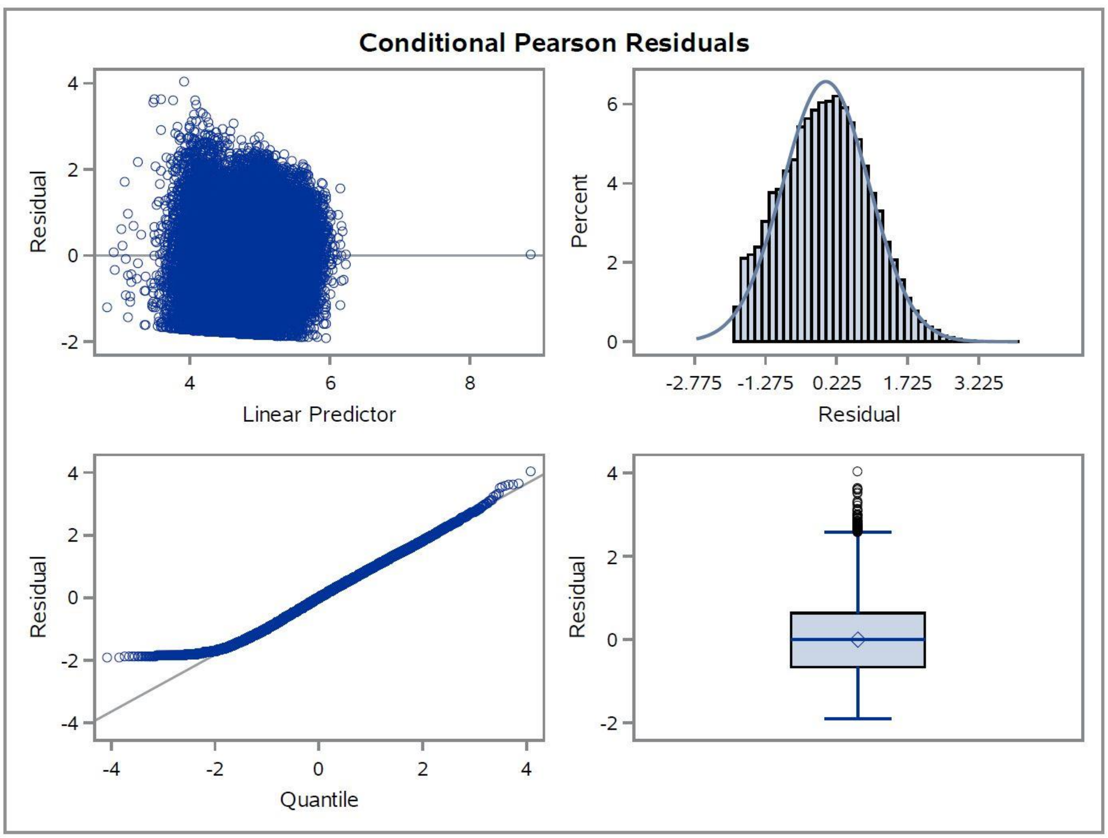

Figure 4L-2: Pearson residuals for the final emotional maturity model

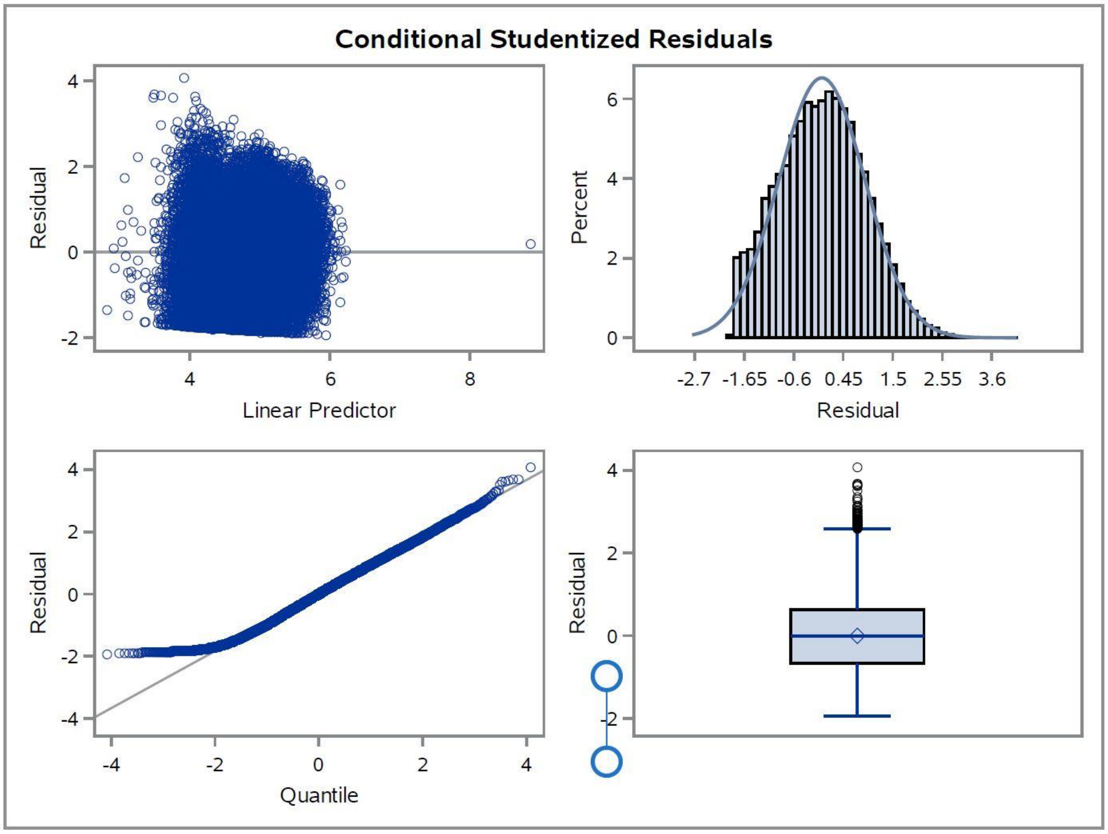

Figure 4L-3: Studentized residuals for the final emotional maturity model

Appendix 4M – Language & cognitive development residuals

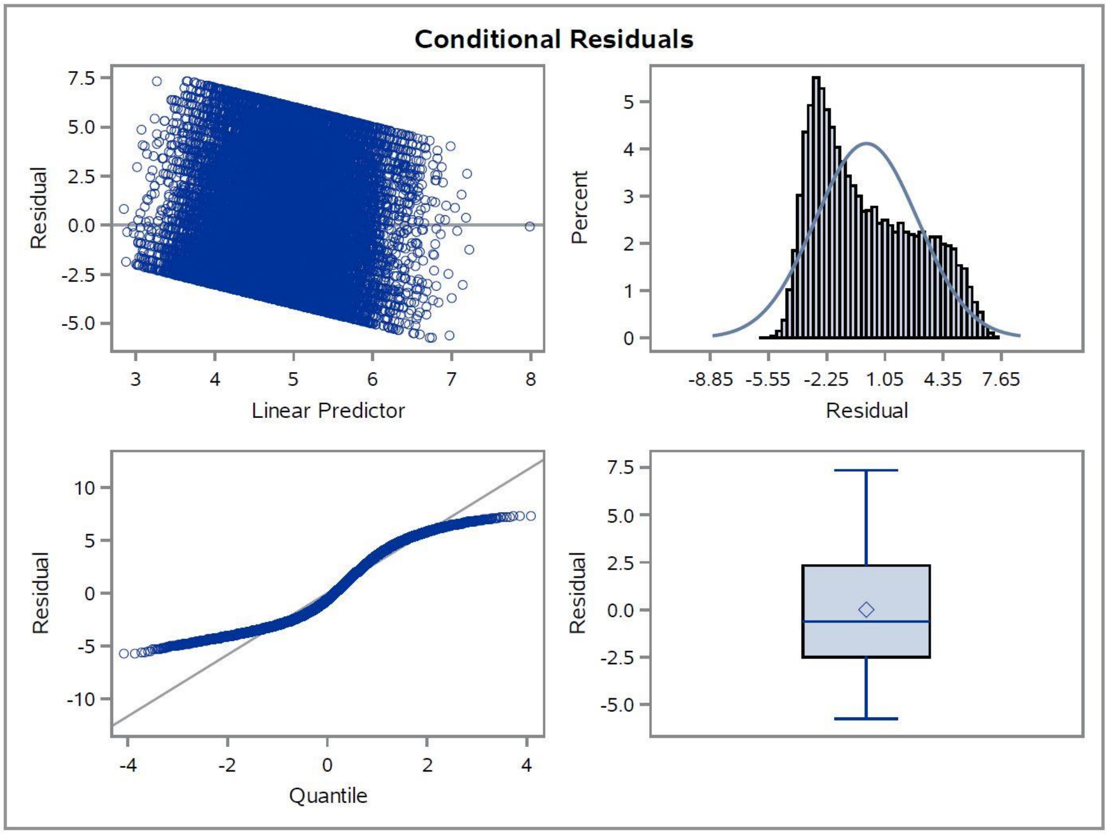

Figure 4M-7: Raw residuals for the final language & cognitive development model

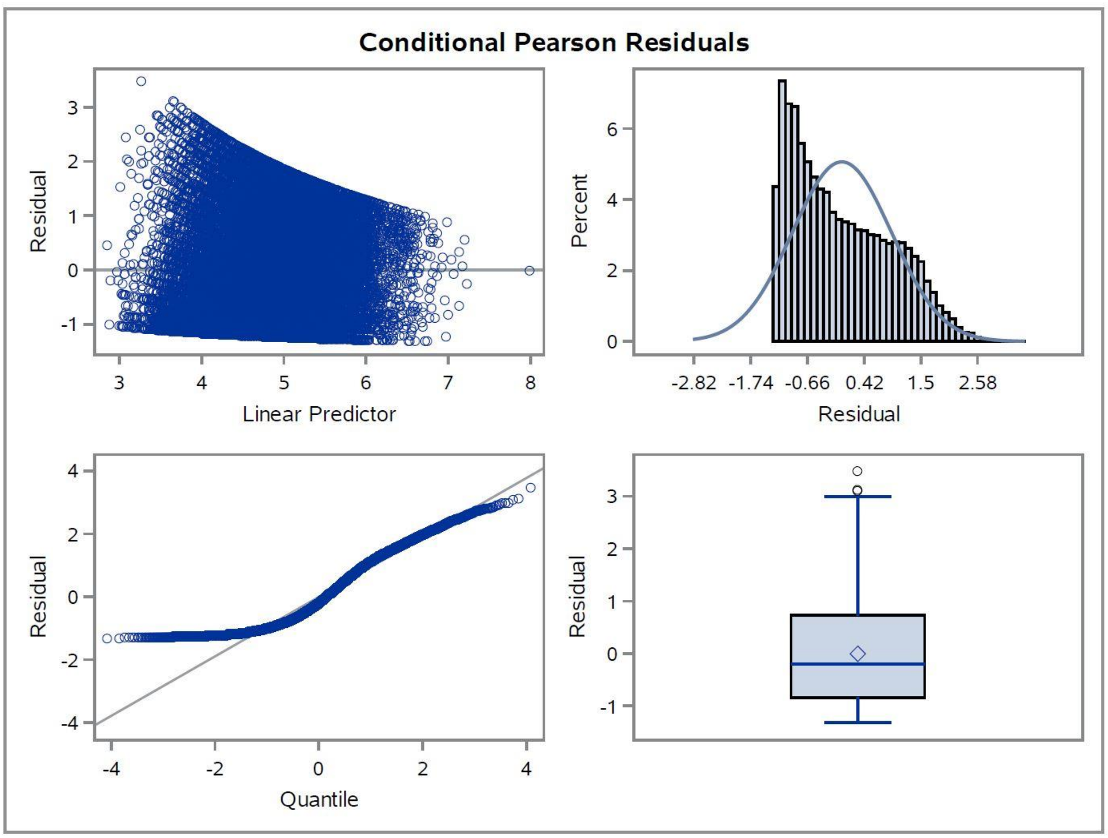

Figure 4M-8: Pearson residuals for the final language & cognitive development model

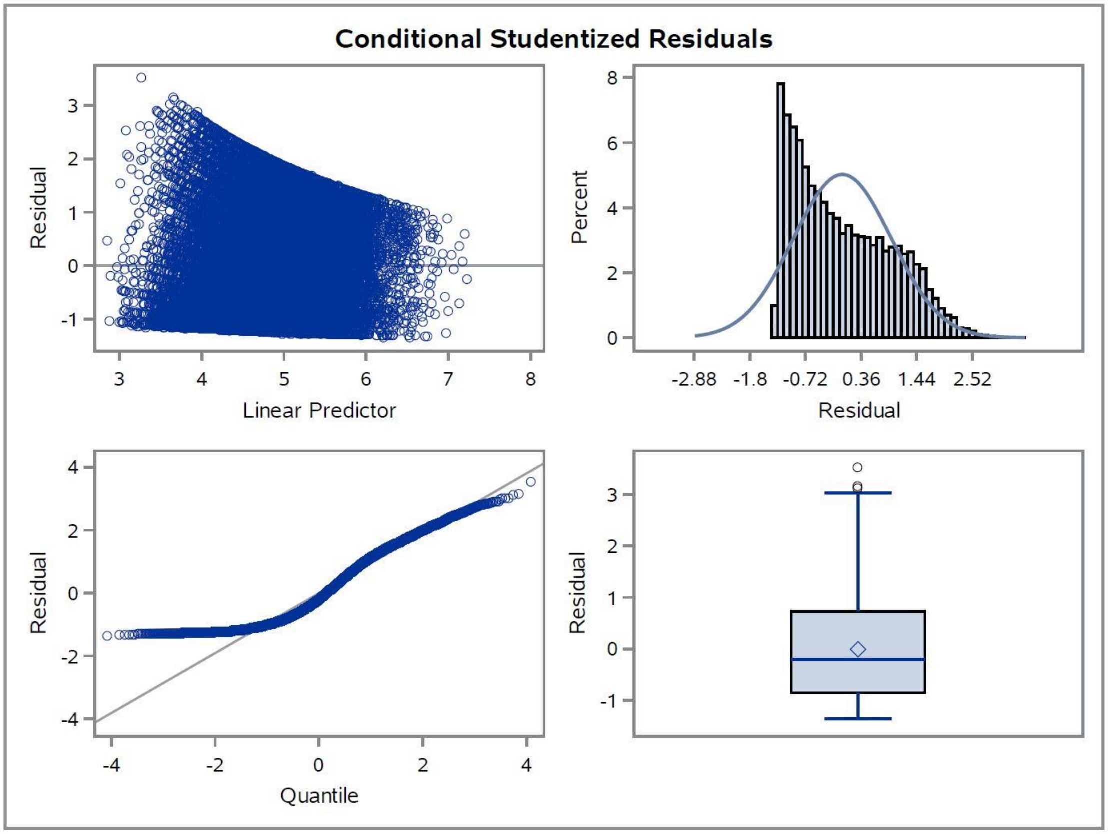

Figure 4M-9: Studentized residuals for the final language & cognitive development model

Appendix 4N – Communication skills & general knowledge residuals

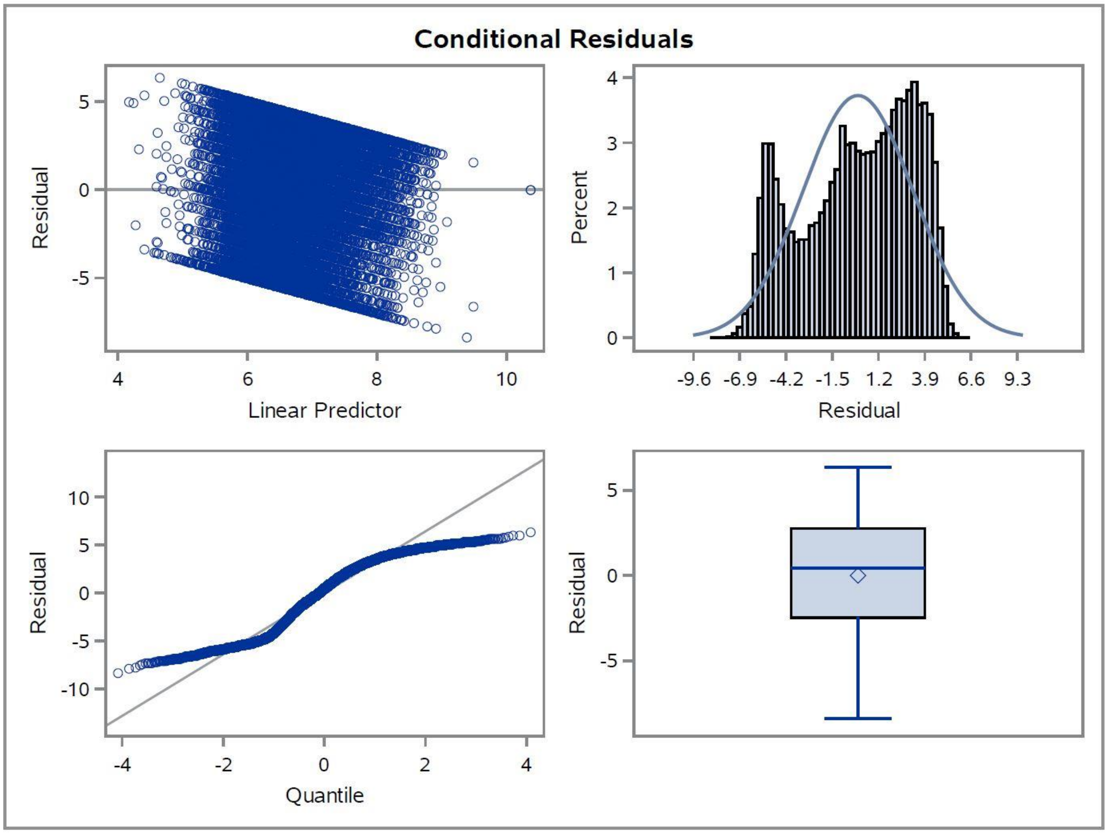

Figure 4N-10: Raw residuals for the final communication skills & general knowledge model

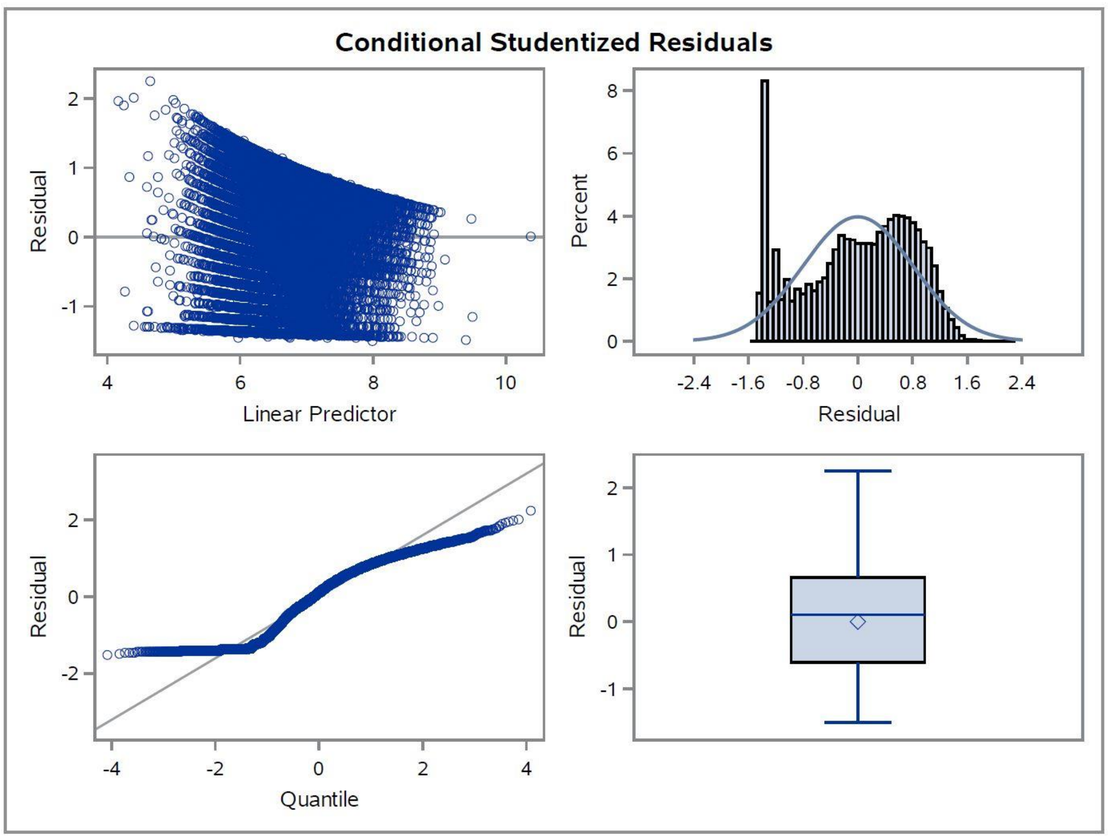

Figure 4N-11: Pearson residuals for the final communication skills & general knowledge model

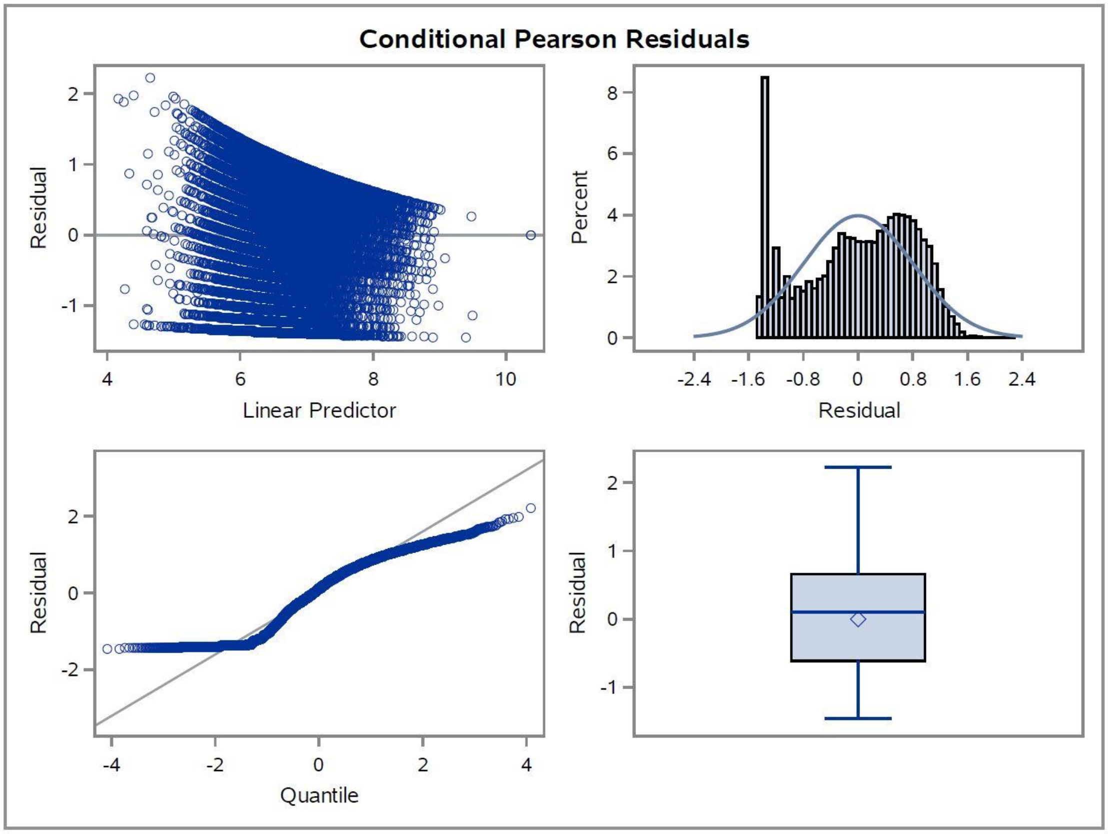

Figure 4N-12: Studentized residuals for the final communication skills & general knowledge model

Appendix 4O: Hierarchical Generalized Linear Model (HGLM) for the Physical Health & Wellbeing (PHWB) Domain of the Early Development Instrument (EDI) excluding outlying and influential cases (n = 687 excluded)

	B coefficient (SE)	F-statistic	Df	P-value
Intercept	4.70 (1.03)	20.70	1, 1999	<0.0001
Year (categorical)		6.03	10, 25432	<0.0001
Province (categorical)		19.14	11, 25432	<0.0001
Year*Province		4.14	53, 25432	<0.0001
Age	0.02 (0.03)	0.63	1, 25432	0.4265
Gender (M=0; F=1)	-0.21 (0.03)	60.10	1, 25432	<0.0001
EFSL (no=0; yes=1)	-0.09 (0.04)	5.07	1, 25432	0.0243
SES z-score	-0.19 (0.02)	4.14	1, 25432	<0.0001

EFSL=English/French as a second language; Df=degrees of freedom

Appendix 4P: Hierarchical Generalized Linear Model (HGLM) for the Social Competence (SC) Domain of the Early Development Instrument (EDI) excluding outlying and influential cases (n = 317 excluded)

	B coefficient (SE)	F-statistic	Df	P-value
Intercept	4.54 (1.24)	13.47	1, 2002	0.0003
Year (categorical)		5.26	10, 25790	<0.0001
Province (categorical)		14.83	11, 25790	<0.0001
Year*Province		4.43	53, 25790	<0.0001
Age	0.13 (0.04)	9.48	1, 25790	0.0021
Gender (M=0; F=1)	-0.94 (0.03)	736.81	1, 25790	<0.0001
EFSL (no=0; yes=1)	0.07 (0.05)	1.74	1, 25790	0.1862
SES z-score	-0.18 (0.02)	86.23	1, 25790	<0.0001

EFSL=English/French as a second language; Df=degrees of freedom

Appendix 4Q: Hierarchical Generalized Linear Model (HGLM) for the Emotional Maturity (EM) Domain of the Early Development Instrument (EDI) excluding outlying and influential cases (n = 409 excluded)

	B coefficient (SE)	F-statistic	Df	P-value
Intercept	3.36 (0.91)	13.54	1, 2001	0.0002
Year (categorical)		3.84	10, 25566	<0.0001
Province (categorical)		12.32	11, 25566	<0.0001
Year*Province		3.04	53, 25566	<0.0001
Age	0.10 (0.03)	10.68	1, 25566	0.0011
Gender (M=0; F=1)	-0.91 (0.03)	1307.36	1, 25566	<0.0001
EFSL (no=0; yes=1)	-0.13 (0.04)	11.97	1, 25566	0.0005
SES z-score	-0.14 (0.01)	88.74	1, 25566	<0.0001

EFSL=English/French as a second language; Df=degrees of freedom

Appendix 4R: Hierarchical Generalized Linear Model (HGLM) for the Language & Cognitive Development (LCD) Domain of the Early Development Instrument (EDI) excluding outlying and influential cases (n = 619 excluded)

	B coefficient (SE)	F-statistic	Df	P-value
Intercept	3.43 (1.27)	12.11	1, 2002	0.0005
Year (categorical)		5.87	10, 25403	<0.0001
Province (categorical)		13.29	11, 25403	<0.0001
Year*Province		4.16	53, 25403	<0.0001
Age	-0.20 (0.04)	22.42	1, 25403	<0.0001
Gender (M=0; F=1)	-0.23 (0.04)	36.93	1, 25403	<0.0001
EFSL (no=0; yes=1)	0.50 (0.06)	67.66	1, 25403	<0.0001
SES z-score	-0.39 (0.02)	278.45	1, 25403	<0.0001

EFSL=English/French as a second language; Df=degrees of freedom

Appendix 4S: Hierarchical Generalized Linear Model (HGLM) for the Communication Skills & General Knowledge (CSGK) Domain of the Early Development Instrument (EDI) excluding outlying and influential cases (n = 2 excluded)

	B coefficient (SE)	F-statistic	Df	P-value
Intercept	6.02 (1.78)	11.49	1, 2002	0.0007
Year (categorical)		1.81	10, 26139	0.0527
Province (categorical)		7.35	11, 26139	<0.0001
Year*Province		1.63	53, 26139	0.0027
Age	0.13 (0.06)	5.09	1, 26139	0.0241
Gender (M=0; F=1)	-0.43 (0.05)	71.08	1, 26139	<0.0001
EFSL (no=0; yes=1)	1.11 (0.08)	173.83	1, 26139	<0.0001
SES z-score	-0.19 (0.03)	54.80	1, 26139	<0.0001

EFSL=English/French as a second language; Df=degrees of freedom

5.0 Discussion

5.1 Psychometric properties of the Early Development Instrument (EDI) in the Canadian population of children with special needs

5.1.1 Summary of findings

The objective of this investigation was to evaluate the psychometric properties of the EDI in the population of Canadian children with special needs and to compare these properties to those observed in typically developing children (1). The performance of EDI items and domains in children with special needs was generally similar to their performance in typically developing children. Only two notable issues were observed. First, one item in the EM domain ("is shy") was negatively correlated with the total EM domain score. This negative correlation was marginal (-0.05) and though it was statistically significant, it was not deemed to be meaningful. Second, there was some evidence of heterogeneity in the PHWB domain. Possible item redundancy was also observed, however, this is common to the performance of the EDI in typically developing children as well (1).

The original factor structure of the EDI was applicable in children with special needs, according to the primary CFA using the WLSMV estimator (2, 3). The results of the primary analysis suggested suboptimal fit, which was expected given the theoretical, rather than statistical, construction of EDI domains (1). Suboptimal fit was mainly indicated by the RMSEA statistics, which did not meet suggested cut-offs. However, cut-offs should generally be interpreted with caution, as they can be impacted by factors unrelated to model fit such as sample size and normality (4). Overall, goodness-of-fit indices were similar to, if not slightly better, than those observed in typically developing children (5). The results of the sensitivity analysis using the MLR estimator, with FIML to account for missing data, indicated poor fit. It is likely that the observed poor fit is due to the MLR estimator which does not perform well with indicators with less than five response options (6), like EDI items, rather than the subset of the population with missing data that was excluded from the CFA using the WLSMV estimator.

Finally, the construct validity of the EDI was evaluated by examining the association between EDI domain scores with gender and age. In typically developing children, on average, boys have lower scores on all EDI domains compared to girls (1). Systematic differences between typically developing boys and girls in skills such as self-regulation and mathematical thinking have previously been reported in the literature (7-9). These may be due to biological differences in cognitive development and physical maturation and disparate cultural expectations. Older typically developing children also have higher EDI domain scores than younger children (1), which can be attributed to the combination of maturational development and learning. In children with special needs, girls, on average, have higher scores than boys in all domains of the EDI. The magnitude of difference was similar to the magnitude of difference observed between genders in typically developing children (1). These findings indicate that the observed gender differences in children with special needs are likely driven by the same factors as in typically developing children rather than boys having more severe disabilities than girls. As expected, a positive trend was also observed between EDI domain scores and age in children with special needs, although it was not consistent across the oldest age band (>6 years, 4 months). The relationship was not statistically significant, most likely because it was not linear, which may be because children with more severe needs, on average, start school later than those with mild disabilities (10). Further investigation is necessary to identify the exact reason behind this non-linear trend.

5.1.2 Consistency with previous studies

The results from this investigation are aligned with the few published studies that have used EDI data from children with special needs. It has been previously illustrated that children with special needs, on average, have lower scores than typically developing children on all domains of the EDI (11, 12). Additionally, this population has been reported to be overrepresented in the bottom 10th percentile of EDI domain scores (13, 14). This difference in EDI domain scores between children with special needs and typically developing children is also supported by evidence based on other assessments which consistently shows this population to, on average, face more academic, social, and emotional challenges (Section 1.1.3). No published studies to date have reported on the performance of EDI items and domains, the factor structure of the EDI, or the construct validity of the EDI in children with special needs.

5.1.3 Strengths of investigation

The strengths of this investigation include the use of population-level data collected across multiple years and provinces and the non-categorical approach to special needs. The benefits of the use of population level-data include the external validity of our findings, in addition to being able to study children with disabilities who are few in number across individual schools. The non-categorical approach to child illness and use of the comprehensive classification of special needs also allowed us to overcome the difficulty of studying individual diagnoses, which are many with low incidence rates, and to make findings more relevant for research and service delivery (Section 1.2).

5.1.4 Limitations of investigation

The reliability and predictive validity of the EDI in children with special needs were not assessed as it was considered outside the scope of this investigation. Given that reliability poses an upper boundary for the validity of an instrument, the re-assessment of reliability, specifically test-retest reliability, is important to ensure that responses to EDI items for children are consistent over short durations (15). Future assessment of test-retest reliability in this population poses significant challenges as it requires additional data collection and given that there are few children with special needs across individual schools at any given time, it will likely lead to an insufficient sample. Assessing predictive validity is also challenging because children with special needs are often exempt from standardized achievement tests during middle childhood and adolescence and those that do complete such assessments are likely not representative of the entire special needs population (14, 16). Nevertheless, given that the reliability and predictive validity of the EDI have been well-established in typically developing children and given that we found the performance of the EDI in children with special needs to be very similar to its performance in typically developing children, it is reasonable to assume that EDI data from this population is likely also reliable, with acceptable predictive validity.

We also found significant missing data in this population. A total of 1,646 (5.22%) children were excluded from the study due to ineligible EDI records and an additional 11,410 (36.24%) children were excluded from the CFA due to missing EDI items. Although no significant differences in demographic characteristics between the analytic sample and the sample excluded from analyses were identified, it is still possible that missingness is not random. This would mean that findings from this investigation only confirm the acceptable performance of the EDI for the population of children with special needs who have complete EDI records. This is not problematic because researchers and decision makers will only use EDI data that have met specific criteria for eligibility recommended by the authors (1), which include guidelines regarding the maximum proportion of items that can be missing for the record to be considered valid. However, the external validity of EDI data from this population may still be adversely impacted because those with complete EDI records may not be representative of all children with special needs. Furthermore, the external validity of these results may also be limited by the lack of data on children with special needs not enrolled in public schools and potential inaccuracies in identification of children with special needs on the EDI.

The only analytic limitation was that the nesting of children within classrooms and schools was not taken into account for the CFA. A single level CFA allowed direct comparison of goodness-of-fit statistics to those reported by Janus et al. (2011) for typically developing children (5). Future investigations may also conduct measurement invariance CFA to further bolster the evidence on the similarity of the factor structure of the EDI between children with special needs and typically developing children.

5.1.5 Implications

This investigation found the psychometric performance of the EDI in children with special needs to be similar to its performance in typically developing children. Based on these results, researchers and decision makers can be more confident using EDI data collected from this population. As only a few minor problems were identified, modification of the instrument, which would jeopardize its comparability across locations and time points, is not warranted. These results provide guidance for more careful interpretation of specific items (i.e., "is shy") or data from specific age groups (i.e., >6 years, 4 months). Although the current validation was only undertaken with Canadian children with special needs, Janus (2011) showed that EDI outcomes for this population are relatively consistent across countries, and therefore, the EDI is likely valid in all children with special needs (12). The replication of these analyses for children with special needs in other countries can further strengthen these findings.

This investigation also further confirms that it is possible to use measures that were originally validated in typically developing children for special needs populations. This is supported not only by our findings but also by findings from other researchers who have used developmental assessments in both typically developing children and children with special needs (17, 18). The development and use of assessments that are valid in all children is a step towards the equitable monitoring of academic and social outcomes. This is important as education policies move further toward the inclusion of children with special needs in regular schools and classrooms (19).

5.1.6 Future steps

Although children with all types of special needs were included in this investigation, the results may not be completely applicable to very rare diagnoses which only made up a small proportion of the conditions studied. To further establish the reliability and validity of the EDI across all childhood disabilities, the analyses presented may be replicated for specific diagnoses. Due to the multiplicity of diagnoses, and given that diagnoses often do not reflect the actual abilities and needs of children (Section 1.4), we do not recommend the replication of these analyses for all possible childhood conditions individually. Rather, we recommend these analyses to be replicated if investigators have specific concerns regarding the performance of the EDI for a particular condition.

The reliability and validity of the EDI for children with special needs may also be assessed using the Rasch measurement model. The Rasch model provides alternative techniques for evaluating scale performance, homogeneity, factor structure, and differential item functioning. Differential item functioning occurs when an item operates differently across subgroups of the population, and its assessment can provide further evidence as to whether item performance for children with special needs and typically developing children is sufficiently similar.

5.1.7 Conclusion

This investigation replicated the basic psychometric properties of the EDI in the population of Canadian children with special needs. The evidence presented here supports the validity of EDI data from children with special needs, thus enabling its more extensive use for research, as well as policy and service development and evaluation. Future steps may include testing of its predictive validity, as well as further testing of its basic psychometric properties through the use of alternative analytic methods (e.g., measurement invariance CFA, Rasch analysis), in this population.

5.2 The socioeconomic gradient in the developmental health of children with special needs

5.2.1 Summary of findings

The objective of this investigation was to explore the association between neighborhood-level SES and developmental health in children with special needs, and in effect determine the importance of contextual factors in predicting outcomes in this population. The results of this investigation (presented in Chapter 4) indicate that neighborhood-level SES is a consistent and significant predictor of EDI domain scores in children with special needs. An average difference of 0.12 to 0.29 points in EDI domain scores was observed per standard deviation difference in SES, with higher EDI domain scores being observed in higher SES neighborhoods. Neighborhood-level SES had the strongest association with the LCD domain and weakest with the EM domain.

5.2.2 Consistency with previous studies

Comparing the magnitude of association between SES and developmental health with previous literature is difficult due to differences in the definition and operationalization of these constructs, in addition to differences in analytic methods. While normally the amount of variation in developmental health explained by SES can be compared across studies using different measures by calculation of the coefficient of determination (R^2), the use of HGLM in this analysis precludes the calculation of this statistic (20). However, the existence and direction of association between SES and developmental health reported in the literature can still be compared with findings from this investigation.

Previous studies, mostly conducted in typically developing children (21), have either explored the direct association between SES and developmental health (22-26) or investigated mediators of this relationship, including parent/child interactive activities, access to a computer, parental expectations, participation in organized classes and activities, maternal mental health, and parental investment (27-29). Most studies, with few exceptions (24-26), measure SES at the individual family level and all demonstrate a positive association between social and economic variables and developmental health.

Among studies done in typically developing children, four use EDI outcomes, with three of these four including neighborhood-level measures of SES (24-26). All studies demonstrated a positive association between SES and EDI outcomes. The most recent study by Webb et al. (2017) looked at neighborhood effects using four published neighborhood SES indices (25). The strength of association between the indices and EDI domains varied, depending on the specific index. Similar to this investigation, the strongest association was most often found for the LCD and CSGK domains.

The few studies done in children with disabilities also report a positive association between SES and academic and social outcomes (30-35). These studies are different from this investigation in that they only focus on a few high-incidence diagnoses, collect outcomes only during middle childhood and adolescence, and do not measure SES at the neighborhood-level.

5.2.3 Strengths of investigation

In comparison to previous studies, this investigation has four strengths. The first is the use of population-level data from Canadian kindergarten children with special needs designation, thereby maximizing external validity and statistical power and minimizing possible selection bias. Additionally, the use of population data makes studying groups of diagnoses with low incidence possible as cases accumulate across time points and provinces. Second, it focuses on early childhood, a time that is likely to critically impact children's long-term academic and social trajectory (36). Third, the non-categorical approach to child disabilities (Section 1.4) reflects current thinking in the field of child development and findings that diagnostic categories often do not fully reflect the actual abilities and needs of children (37-39). The non-categorical approach makes the results of this investigation applicable for service and policy planning and evaluation, which cannot occur at the diagnostic level due to the multiplicity of diagnoses and low incidence rates in individual communities. Finally, the strong analytic methods used in this investigation appropriately take into account the skewed distribution and nesting of EDI data. Compared to ordinary linear regression, HGLM is more robust to deviations from conditional normality and also adjusts for the violation of the independence assumption (20). HGLM has not been extensively used with EDI data in the past given that it is newer than alternative statistical techniques (40), with advanced model diagnostics only recently emerging (41, 42).

5.2.4 Limitations of investigation

This investigation is also subject to five limitations. First, due to the cross-sectional design of this study, causality between SES and developmental outcomes could not be established. In fact, the observed relationship between SES and developmental outcomes may be a result of reverse causation. There is evidence that developmental problems in children may increase parental stress and thus impact the general socioeconomic wellbeing of the family (43, 44). Longitudinal cohort studies may be able to ascertain the direction of this relationship, however, these studies are difficult to conduct due to the low prevalence of special needs across schools and communities. Qualitative studies, where parents are queried about factors that have impacted family economics, are a more feasible alternative (45). There is also the issue of self-selection into neighborhoods, where families with similar experiences may choose to reside within similar neighborhoods. For example, families of children with severe cystic fibrosis may choose to reside within neighborhoods close to a tertiary care center. These neighborhoods may in turn be of disproportionately lower SES. Whether the relationship between SES and developmental outcomes is causal does not alter the implications for identifying at-risk children, or for service and policy planning. Regardless of causality or lack thereof, these results show that children with special needs that have poor developmental outcomes are more likely to reside in low SES neighborhoods. Hence, service and policy efforts to improve the developmental health of this vulnerable population must take into account contextual factors, such as neighborhood of residence, to maximize effectiveness. Based on these findings, it can be inferred that policy efforts and services that target disadvantaged areas and which are accessible in low SES neighborhoods are likely to have the greatest impact on improving the developmental health of this population.

Second, the socioeconomic index may not accurately reflect the socioeconomic condition of the neighborhoods in which children were raised. Taxfiler and Census variables used to construct the SES index come from the years 2005 and 2006, respectively, whereas EDI data were collected between 2004 and 2014. It is possible that changes in neighborhoods may render the SES index unreflective of the conditions of neighborhoods during the early developmental years of some cohorts of children. Additionally, children may spend their early years in one neighborhood and relocate to another neighborhood with different SES characteristics at the time of school entry. However, empirical evidence indicates that it is unlikely that neighborhood characteristics drastically change over time or that families move to neighborhoods which are greatly different from their previous ones (46).

Third, as neighborhood-level analysis was conducted, ecological fallacy, where deductions about individuals are made based on groups, is possible. There are relatively few children with special needs in each neighborhood, and so it is possible that socioeconomic characteristics of neighborhoods are not reflective of the SES of some families within those neighborhoods, as well as families' experiences and perception of their neighborhoods' SES characteristics. Additionally, we were unable to control for family-level SES in the models. Thus, it is difficult to determine whether this association is largely driven by neighborhood or family social and economic characteristics.

Fourth, the external validity of findings may be limited by data collection procedures. For example, children with special needs not enrolled in public schools are included in the database. These may be children from higher SES backgrounds that attend private institutions. Additionally, there may be potential inaccuracies in the identification of children with special needs designation on the EDI, particularly children with mild disabilities.

Finally, the distributions of residuals from the models were not normal. The normality of residuals in generalized linear models is subject to debate, with some arguing that it is not required (20, 42) and others arguing that it is a necessary precondition for hypothesis testing (47). Obtaining normally distributed residuals with EDI data is difficult, because the data are skewed and restricted in range between 0 and 10. Nevertheless, generalized linear models are overall more robust to deviations in normality than ordinary linear regression.

5.2.5 Implications

The findings of this study suggest that the relationship between SES and developmental outcomes (22-26) also holds for children with special needs, despite their diverse abilities and needs, and highlights the importance of taking into account where children live when identifying children with special needs that are especially vulnerable to poor developmental outcomes, predicting prognosis, and developing treatment and education plans. Although many clinicians focus on biological factors such as family history of disabilities and harmful in utero exposures, social influences may prove more predictive of longer-term developmental and academic outcomes and more amenable to change. In fact, in a cohort of two-year-old children without diagnosed disabilities, social variables such as parental education and household income, had equal or better predictive ability of academic performance and behavioral problems at kindergarten entry than parent-reported family history of learning disability and family health status (22). According to survey data, clinicians are receptive to screening for social determinants of health outside of the purview of clinical care, suggesting that the findings of this investigation are likely to be relevant and acceptable to those in the clinical community (48).

Additionally, this investigation highlights the need for policies and interventions that target the social and economic context in which children are raised rather than targeted interventions delivered at the individual child-level with no or limited focus on the family or the social context. There is evidence that social policies targeting parental employment, access to early childhood education, and funding for schools in underprivileged areas can lead to better behaviour, cognitive, and academic outcomes for children (49). These results are encouraging because they suggest that large scale policy interventions can help in reducing the observed disparity in developmental outcomes.

5.2.6 Future steps

Despite robust and informative results, additional work may still contextualize findings further. Specifically, this analysis can be replicated to explore whether the relationship between SES and developmental outcomes is consistent across data collection time points and provinces. Lack of such consistency might suggest the existence of cohort effects due to changes in neighborhood SES characteristics over time. Lack of consistency across provinces would call for additional analysis of early childhood development practices and education policies to help explain provincial differences.

The consistency and relative strength of the relationship between SES and developmental outcomes across subgroups of physical, behavioral, and learning disabilities, as well as subgroups based on severity of condition and time of diagnosis, can also be explored. This information can be useful for policy makers and service providers in making decisions about the types of services that need to be offered across socioeconomic groups.

Because this analysis was conducted on cross-sectional data, it is impossible to ascertain when the relationship between SES and health can first be detected. This relationship may be due to genes which increase the risk for disability, lead to lower socioeconomic position later in life, and are passed on to future offspring, and/or early childhood and in utero exposures. Conversely, reverse causation is possible where this association comes about after the identification of the disability where parental stress may be increased and adversely impact family economics. Although longitudinal studies are ideal for detecting temporal relationships between exposures and outcomes, they may not be ideal for studying children with special needs due to low incidence rates. A more feasible alternative is linkages between databases which include measures on children's health at multiple timepoints throughout their development and SES variables.

Finally, studying the mediators of this relationship can be informative for developing strategies to eliminate the socioeconomic gradient in developmental health. These may include factors that have been shown to mediate the association between SES and developmental health in typically developing children, including early education opportunities, participation in recreational activities, the physical environment including the stability and condition of housing, parenting practices, and engagement in home learning activities (22, 28, 29).

5.2.7 Conclusion

The results from this investigation show neighborhood SES to be significantly associated with the developmental health of children with special needs at school-entry. These findings have implications for policy development, service planning and provision, and draw attention to the potential importance of contextual factors. Future steps may include untangling family and neighborhood effects, and exploring mediators of this association.

5.3 References

1. Janus M, Offord DR. Development and psychometric properties of the Early Development Instrument (EDI): A measure of children's school readiness. Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement. 2007;39(1):1.
2. Muthén B. A general structural equation model with dichotomous, ordered categorical, and continuous latent variable indicators. Psychometrika. 1984;49(1):115-32.
3. Muthen B, du Toit S, Spisic D. Robust inference using weighted least squares and quadratic estimating equations in latent variable modeling with categorical and continuous outcomes. 1987. Retrieved 2007/01/08/, from http://www.gseis.ucla.edu/faculty/muthen/articles/Article_075.pdf; 2010.
4. Marsh HW, Hau K-T, Wen Z. In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. Structural equation modeling. 2004;11(3):320-41.
5. Janus M, Brinkman SA, Duku EK. Validity and psychometric properties of the early development instrument in Canada, Australia, United States, and Jamaica. Social Indicators Research. 2011;103(2):283-97.
6. Li C-H. Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares. Behavior research methods. 2015:1-14.
7. Matthews J, Ponitz CC, Morrison FJ. Early gender differences in self-regulation and academic achievement. Journal of Educational Psychology. 2009;101(3):689.
8. Bornstein MH, Hahn C-S, Haynes OM. Specific and general language performance across early childhood: Stability and gender considerations. First Language. 2004;24(3):267-304.
9. Fennema E, Carpenter TP, Jacobs VR, Franke ML, Levi LW. A longitudinal study of gender differences in young children's mathematical thinking. Educational researcher. 1998;27(5):6-11.
10. Brent D, May DC, Kundert DK. The incidence of delayed school entry: A twelve-year review. Early Education and Development. 1996;7(2):121-35.
11. Curtin M, Baker D, Staines A, Perry IJ. Are the special educational needs of children in their first year in primary school in Ireland being identified: a cross-sectional study. BMC pediatrics. 2014;14(1):52.
12. Janus M. Impact of impairment on children with special needs at school entry: comparison of school readiness outcomes in Canada, Australia, and Mexico. Exceptionality Education International. 2011;21(2):29-44.
13. Goldfeld S, O'Connor M, Sayers M, Moore T, Oberklaid F. Prevalence and correlates of special health care needs in a population cohort of Australian children at school entry. Journal of Developmental & Behavioral Pediatrics. 2012;33(4):319-27.

14. Lloyd JE, Irwin LG, Hertzman C. Kindergarten school readiness and fourth-grade literacy and numeracy outcomes of children with special needs: a population-based study. Educational Psychology. 2009;29(5):583-602.
15. Streiner DL, Norman GR, Cairney J. Health measurement scales: a practical guide to their development and use: Oxford University Press, USA; 2015.
16. GUIDE for Accommodations, Special Provisions and Exemptions2015.
17. Ho DST, Leung C, Lo SK. Validation of the Gumpel Readiness Inventory for preschool children in Hong Kong. Research in developmental disabilities. 2013;34(10):3066-76.
18. Leung C, Mak R, Lau V, Cheung J, Lam C. Development of a preschool developmental assessment scale for assessment of developmental disabilities. Research in developmental disabilities. 2010;31(6):1358-65.
19. Hutchinson NL. Inclusion of exceptional learners in Canadian schools: A practical handbook for teachers: Pearson Education Canada; 2013.
20. Gill J. Generalized linear models: a unified approach: Sage Publications; 2000.
21. Letourneau NL, Duffett-Leger L, Levac L, Watson B, Young-Morris C. Socioeconomic status and child development: A meta-analysis. Journal of Emotional and Behavioral Disorders. 2013;21(3):211-24.
22. Nelson BB, Dudovitz RN, Coker TR, Barnert ES, Biely C, Li N, et al. Predictors of poor school readiness in children without developmental delay at age 2. Pediatrics. 2016:e20154477.
23. Guhn M, Gadermann AM, Hertzman C, Zumbo BD. Children's development in kindergarten: A multilevel, population-based analysis of ESL and gender effects on socioeconomic gradients. Child Indicators Research. 2010;3(2):183-203.
24. Oliver LN, Dunn JR, Kohen DE, Hertzman C. Do neighbourhoods influence the readiness to learn of kindergarten children in Vancouver? A multilevel analysis of neighbourhood effects. Environment and Planning A. 2007;39(4):848-68.
25. Webb S, Janus M, Duku E, Raos R, Brownell M, Forer B, et al. Neighbourhood socioeconomic status indices and early childhood development. SSM-Population Health. 2017;3:48-56.
26. Lapointe VR, Ford L, Zumbo BD. Examining the relationship between neighborhood environment and school readiness for kindergarten children. Early Education and Development. 2007;18(3):473-95.
27. Hsu H-C, Wickrama KA. Linking family economic hardship to early childhood health: An investigation of mediating pathways. Maternal and child health journal. 2015;19(12):2636-45.
28. Larson K, Russ SA, Nelson BB, Olson LM, Halfon N. Cognitive ability at kindergarten entry and socioeconomic status. Pediatrics. 2015;135(2):e440-e8.
29. Shah R, Sobotka SA, Chen Y-F, Msall ME. Positive parenting practices, health disparities, and developmental progress. Pediatrics. 2015:peds. 2014-3390.
30. Turner S, Alborz A, Gayle V. Predictors of academic attainments of young people with Down's syndrome. Journal of Intellectual Disability Research. 2008;52(5):380-92.
31. Turner S, Sloper P, Knussen C, Cunningham CC. Socio-economic factors: their relationship with child and family functioning for children with Down's syndrome. Journal of Applied Research in Intellectual Disabilities. 1991;4(1):80-100.
32. Szumski G, Karwowski M. School achievement of children with intellectual disability: The role of socioeconomic status, placement, and parents' engagement. Research in developmental disabilities. 2012;33(5):1615-25.
33. King G, McDougall J, DeWit D, Hong S, Miller L, Offord D, et al. Pathways to children's academic performance and prosocial behaviour: Roles of physical health status, environmental, family, and child factors. International Journal of Disability, Development and Education. 2005;52(4):313-44.
34. Emerson E, Hatton C, MacLean J, William E. Contribution of socioeconomic position to health inequalities of British children and adolescents with intellectual disabilities. American Journal on Mental Retardation. 2007;112(2):140-50.

35. Hauser-Cram P, Durand TM, Warfield ME. Early feelings about school and later academic outcomes of children with special needs living in poverty. Early Childhood Research Quarterly. 2007;22(2):161-72.
36. Irwin LG, Siddiqi A, Hertzman C. Early child development: A powerful equalizer. Final report to the WHO Commission on social determinants of health, Geneva. 2007.
37. Stein R, Jessop DJ. A noncategorical approach to chronic childhood illness. Public health reports. 1982;97(4):354.
38. McDowell M, O'Keeffe M. Public services for children with special needs: discrimination by diagnosis? Journal of paediatrics and child health. 2012;48(1):2-5.
39. Rosenbaum P, Gorter J. The ‘F-words’ in childhood disability: I swear this is how we should think! Child: care, health and development. 2012;38(4):457-63.
40. Lee Y, Nelder JA. Hierarchical generalized linear models. Journal of the Royal Statistical Society Series B (Methodological). 1996:619-78.
41. Nakagawa S, Schielzeth H. A general and simple method for obtaining R2 from generalized linear mixed-effects models. Methods in Ecology and Evolution. 2013;4(2):133-42.
42. Bolker BM, Brooks ME, Clark CJ, Geange SW, Poulsen JR, Stevens MHH, et al. Generalized linear mixed models: a practical guide for ecology and evolution. Trends in ecology & evolution. 2009;24(3):127-35.
43. Anderson L, Larson S, Lakin C, Kwak N. Children with disabilities: social roles and family impacts in the NHIS-D. DD data brief. 2002;4(1):1-12.
44. Hayes SA, Watson SL. The impact of parenting stress: A meta-analysis of studies comparing the experience of parenting stress in parents of children with and without autism spectrum disorder. Journal of autism and developmental disorders. 2013;43(3):629-42.
45. Siddiqua A, Janus M. Experiences of parents of children with special needs at school entry: a mixed method approach. Child: care, health and development. 2017.
46. Kunz J, Page ME, Solon G. Are point-in-time measures of neighborhood characteristics useful proxies for children’s long-run neighborhood environment? Economics Letters. 2003;79(2):231-7.
47. Hoffmann JP. Generalized linear models: An applied approach: Pearson College Division; 2004.
48. Garg A, Butz AM, Dworkin PH, Lewis RA, Serwint JR. Screening for basic social needs at a medical home for low-income children. Clinical Pediatrics. 2009;48(1):32-6.
49. Kamerman SB, Neuman M, Waldfogel J, Brooks-Gunn J. Social policies, family types and child outcomes in selected OECD countries. 2003.