Fine Motor and Visual Motor Skills as a Component of School Readiness

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Abstract

Understanding school readiness is of the utmost importance. The purpose of this study was to determine the extent to which fine motor/visual motor (FM/VM) skills are related to school readiness at a population level through: creating a FM/VM Index from Early Development Instrument (EDI) items; describing children with Vulnerable FM/VM skills; determining if Vulnerable FM/VM skills are related to readiness on other EDI constructs; and determining if the FM/VM Index provides information not provided by the EDI's Gross and Fine Motor (G&FM) Sub-Domain. A Delphi process and ROC curves identified an 11 questions FM/VM Index with a vulnerability cutoff of <80. Children with Vulnerable versus Not Vulnerable FM/VM skills were statistically different on a wide variety of child, environmental and health at birth variables. Logistic regressions for select EDI domains/sub-domains showed that better FM/VM skills decreased the odds of being Not Ready or Vulnerable on these domains/sub-domains. The addition of the FM/VM Index and G&FM Sub-Domain into these models provided a better model fit with the FM/VM Index models being generally preferable. Overall, this work suggests that FM/VM skills are an important skill set associated with school readiness and therefore need to be considered when evaluating school readiness.

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Literature Review

The importance of school readiness becomes evident when one considers that high school dropout rates have been linked to poor skills early in school (Entwisle, Alexander, & Olson, 2005; Vitaro, Brendgen, Larose, & Tremblay, 2005). The failure to complete high school has been linked to social, health and economic difficulties (Freudenberg & Ruglis, 2007). As such, achieving school readiness is considered one of the most important developmental tasks facing preschool–aged children (Lemelin et al., 2007) and identifying the early life determinants of school readiness is a top cross–sectoral priority for policymakers (Santos, Brownell, Ekuma, Mayer, & Soodeen, 2012).

If school readiness is considered an important step on the way to success in school and adulthood, it follows that there needs to be a way to measure school readiness. In Canada, the Early Development Instrument (EDI) (Janus, & Offord, 2007) has established itself as the tool to assess the successes of policies, programming and investments in the early years as well as to identify the strengths and challenges related to children's school readiness at a community level (Early Development Instrument, 2016-a). It allows for reporting on populations of children in different communities, monitoring of these populations over time and prediction of how they will perform in elementary school (Offord Centre for Child Studies, 2012). EDI results also help communities assess their efforts in supporting young children and their families in preparing for school.

This literature review explores the factors that affect children's readiness to meet the demands of a school environment. It begins with an exploration of what factors are likely to place a child at risk of not being ready for school. From there, it considers the EDI as the tool used to measure population level school readiness in Manitoba and goes on to explore the role of fine motor and visual motor (FM/VM) skills in school readiness. This exploration will focus on the need for FM/VM skills in a classroom, the research and theoretical basis for the importance of FM/VM skills, and the relationship between FM/VM skills and other domains of school readiness. Altogether, this literature review presents evidence for the need for a population level FM/VM Index of school readiness.

What Affects Children's Readiness for School?

Several factors affect the likelihood of being ready, or not ready, for school. While a genetic component is certainly present, recent evidence indicates a substantial environmental contribution to school readiness, even after accounting for genetic contributions (Lemelin et al., 2007). The field of epigenetics helps to explain the relationship between genetic and environmental factors. Through the study of epigenetics, environmental factors and early life experiences are seen to cause epigenomes to turn certain genes on or off. In turn, the resulting variation in the expression of these genes impacts the formation of neural pathways and therefore influences learning and behaviour. In some instances, these patterns of turned on and turned off genes can be passed on to the next generation, and thus parents pass risk factors or protective factors to their children (McCain, Mustard, & Shanker, 2007).

Identifying specific familial determinants of school readiness, especially those that are amenable to policy intervention, is essential for improving school readiness in the population. In 2012, Santos et al. produced a report that identified several important points to consider when identifying factors associated with children being not ready for school at age five. The three most at risk groups were children born to mothers who were teenagers when their first child was born; children in families that have at some point been on income assistance; and children involved with Child and Family Services (i.e. child welfare services). The more these three risk factors are applicable to a child, the greater their risk.

Santos et al. (2012) also found that proportionally more children living in lower income neighbourhoods did not have the skills expected at school entry (termed Vulnerable on the EDI). Income is a widely studied environmental factor which impacts children's school readiness. Evidence from many cross–sectional studies supports the idea that low income is associated with poor EDI outcomes at both individual and neighbourhood levels (Cushon, Vu, Janzen, & Muhajarine, 2011; Janus & Duku, 2007; Kershaw, Forer, Irwin, Hertzman, & Lapointe, 2007; Lapointe, Ford, & Zumbo, 2007; Lesaux, Vukovic, Hertzman, & Siegel, 2007; Puchala, Vu, & Muhajarine, 2010). Longitudinal evidence indicates that the neighbourhood socioeconomic conditions of kindergarten children predict their development four (Lloyd & Hertzman, 2010) and seven years later (Lloyd, Li & Hertzman, 2010), over and above their EDI outcomes in kindergarten.

Santos et al. (2012) also found that there were several child characteristics related to readiness for school. These characteristics include younger children being more likely to be at risk than older ones and boys being more likely to be at risk than girls. Further, health status at birth (low birth weight, ICU stay 3+ days at birth) either directly or through increasing the risk of major illness, and to a lesser degree minor illness, is associated with EDI outcomes.

When considering the reasons why children might not be ready in one or more areas of development, it is important to consider components of the child (such as age and sex), the family (such as involvement with child and family services, mother's age and use of income assistance) and the environment (such as neighbourhood income levels). This brief summary of factors that affect school readiness is certainly not exhaustive. The work by Santos et al. (2012) focuses on a Manitoban population with data access similar to the current study; it was therefore thought to be most applicable and most practical when looking at shaping this research.

Early Development Instrument

The EDI is based on a readiness to learn concept and measures preparedness (whether children are demonstrating the skills they need in the classroom) more so than neurological readiness (whether children are able to sufficiently process information) (Janus, & Offord, 2000). It reflects the idea that physical health and well-being, social competence, emotional maturity, language and cognitive development, and communication skills and general knowledge are the five domains of development that contribute to school readiness. Factor analysis, using the principal component analyses with varimax rotation, was carried out on normative sample data. The results demonstrated that while there were five distinct domain areas, four of these could be subdivided for greater precision (Janus, Walsh, & Duku, 2005). The result was 16 sub-domains. (See Table 1.)

Table 1: EDI Domains and Sub-Domains

Domain	Sub-Domains
Physical Health and Well-Being	Physical Readiness for School Physical Independence Gross and Fine Motor
Social Competence	Overall Social Competence Responsibility and Respect Approaches to Learning Readiness to Explore New Things
Emotional Maturity	Prosocial and Helping Behaviour Anxious and Fearful Behaviour Aggressive Behaviour Hyperactivity and Inattention
Language and Cognitive Development	Basic Literacy Interest in Literacy/Numeracy and Memory Advanced Literacy Basic Numeracy
Communication Skills and General Knowledge	

Within the five domains, a child is considered Not Ready if their score for that domain places them in the bottom 10th percentile of EDI scores as determined by a national normative sample (Early Development Instrument, 2016-b). Challenge cutoff scores have been created for each sub-domain (Early Development Instrument, 2016-b). The Offord Centre created cutoff points that identified developmentally vulnerable children who met few to none of the expectations of the sub-domain. The identification of Vulnerable children on the sub-domains is distribution-free (Early Development Instrument, 2016-b), meaning they are not measured against the Canadian baseline sample. However, it is unclear exactly how these cutoffs were established. Children are considered to have 'multiple challenges' if they are 'vulnerable' in nine or more sub-domains (Early Development Instrument, 2016-b). Throughout this paper, the term 'Not Ready' will be used when referring to children who score below the 10th percentile on any EDI domain and the term 'Vulnerable' will be used when referring to those children whose scores are below the challenge cutoff on any EDI sub-domain.

In Manitoba, kindergarten teachers in all 37 public school divisions complete the EDI for each of their students in the winter on behalf of Healthy Child Manitoba. This data provides a census of early childhood outcomes and school readiness every other year beginning in 2006/07 (Santos et al., 2012). At the time of this study, data were available from the 2005/6, 2006/7, 2008/9, and 2010/11 kindergarten cohorts.

Several reports have been compiled using the Manitoba EDI data. Of particular relevance to this project are reports related to motor skill. The Manitoba EDI report from 2012/13 (Healthy Child Manitoba, n.d.-b) indicated that 23.9% of children were vulnerable on the Gross & Fine Motor (G&FM) Sub-Domain. Only Pro-Social and Helping Behaviour (37.2%) and Communication Skills and General Knowledge (29.7%) had higher percentages of children who were at risk. For the years included in this study, the following percentages of children were deemed at risk on the G&FM Sub-Domain: 2005/06 – 24.8%, 2006/07 – 24.0%, 2008/09 – 26.8%, 2010/11 – 24.7% (Healthy Child Manitoba, n.d.-a). These findings suggest that many children will have difficulties meeting the motor demands of school. The percentages of children who are vulnerable on the G&FM sub-domain were stable over time with no significant five-year trends identified in the 2014/15 report (Healthy Child Manitoba, n.d.-b). As the sub-domain with the third highest proportion of children who are vulnerable, further exploration of the G&FM skills is warranted.

Why a Fine Motor/Visual Motor Index?

This section will briefly discuss why a FM/VM Index was proposed given that the EDI already contains a G&FM sub-domain. Gross motor skills rely on the movement of the large muscle groups while fine motor skills are the complex movement patterns that allow for controlled and varied movements of small muscles in the hands. As Henderson and Pehoski (2006) noted in the introduction to their book, *"The hand is incredibly versatile. It can be a platform, a hook or a vise. It can hold a football, a hammer or a needle. It can explore objects, express emotion or communicate language."*(p. ix)

Gross motor and fine motor skills do not always occur together. One needs only to look to examples of athletes or visual artists to see that exceptional skill in one of these areas does not always occur with exceptional skill in the other. The development of fine motor and gross motor skills are however intertwined with participation in gross motor activities being largely responsible for the development of postural control, balance and strength in the larger muscle groups, which in turn allow for skilled use of the hands (Tomchek & Schneck, 2006). The resulting skills are often functionally used in very different ways. In the school setting, challenges with gross motor skills can result in challenges with personal space, physical education classes, drama, outdoor play, maintaining stamina for extended periods of seated or standing work, and staying still for periods of work, waiting, or lining up (Jenkinson, Hyde & Ahmad, 2008). Challenges with fine motor skills impact manipulating materials (cutting, gluing, play), pencil and paper work (grasps, stamina, speed), dressing and eating (Jenkinson, et al., 2008). While gross motor and fine motor skills are developmentally linked, they are functionally used separately in school and represent distinct areas of performance. Considering gross and fine motor skills together makes it difficult to truly identify which aspects of school performance are at risk, especially when a child is not performing as expected.

The visual system plays an important role in the development of fine motor skills. Early fine motor skills are voluntary actions that are cognitively controlled. The development of fine motor skills takes place over an extended period beginning at birth and continuing into adolescence. This long developmental period is necessary as the motor functions of the hand are among some of the most complex human motor skills (Henderson & Pehoski, 2006). As children's fine motor skills develop, they gain strength and coordination in the small muscles of the hand, allowing them to complete increasingly complex actions. These actions are adapted and refined through feedback from the sensory systems (Henderson & Pehoski, 2006). Feedback from the visual system is so integral to many fine motor skills that they are considered to be visual-motor skills. Visual motor skills are those which rely on vision to ensure that one's hands are in the right place at the right time (Röshland, 2006). Like fine motor skills, visual motor skills also begin to develop in infancy. Children as young as five days old have been shown to be learning to reach for objects (vonHofsten, 1982). Unlike the distinction that exists between fine motor and gross motor skills, fine motor skills are so frequently used in coordination with the visual system to complete visual motor tasks that fine motor and visual motor skills are often considered one thing (Tomchek & Schneck, 2006). In fact, all of the school-related fine motor skills listed in the previous paragraph are also visual motor skills.

Occupational therapists are seen as experts in the areas of FM/VM skills. The theory and practice of the profession recognizes that functional participation in daily activities generally requires the simultaneous use of fine motor and visual skills and FM/VM assessment is prevalent in many areas of occupational therapy practice. The connection between these two skill areas is sufficiently frequent that the terms 'fine motor' and 'visual motor' are often used to describe activities with both a fine motor and visual motor component in reporting and assessment (Beery & Beery, 2004; Miller, 2006; Folio & Fewell, 2000).

Briefly, it is due to the wide recognition of the interconnectedness of fine motor skills and visual motor skills which lead to the decision to group these two areas together on a single index. This reflects the fact that fine motor and visual motor skills are so intertwined that functionally they are almost exclusively used together.

Fine Motor Skills/Visual Motor Skills and their Link to EDI Domains

Not only are FM/VM skills on their own predictive of success in school, research has also linked FM/VM ability to other developmental predictors of school success. This link is not new; as far back as 1916 Wallin reported the connection between motor and cognitive skills (Wallin, 1916). The importance of many different skill areas, including fine motor skills, as predictors for school achievement was recently highlighted in a Manitoba Centre for Health Policy report

> *The strongest specific predictors* [of school achievement] *include math, reading, and attention skills (Duncan et al., 2007; Grimm, Steele, Mashburn,*

> *Burchinal, & Pianta, 2010; Hooper, Roberts, Sideris, Burchinal, & Zeisel, 2010; Pagani, Fitzpatrick, Archambault, & Janosz, 2010; Romano, Babchishin, Pagani, & Kohen, 2010); fine motor skills (Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010; Pagani et al., 2010); social and emotional behaviours (Grimm et al., 2010; Pagani et al., 2010; Romano et al., 2010); and general knowledge (Grissmer et al., 2010).*
>
> (Santos et al., 2012, p.1)

In addition to Wallen (1916), more recent literature also provides theoretical support for a specific relationship between FM/VM skills and other skill areas such as cognition and language. As hand skills develop, children are able to interact with objects in more complex ways. Through these interactions, children learn about object characteristics, which are believed to be important for concept and language development (Ruff, McCarton, Kurtzber & Vaughan, 1984; Exner & Henderson, 2006). Despite this literature, published both in recent years and over a century ago, fine motor skills have been largely absent from policy and research into school readiness (Pagani et al., 2010).

As outlined earlier, the EDI considers readiness in five areas. One of these (physical health and well-being) contains, amongst other things, G&FM skills. The link between FM/VM skill and the other four domains (social competence, emotional maturity, language and cognitive development, and communication skills and general knowledge) is an important area to explore. A recent scoping review of the literature (Skelton & Leclair, 2013) highlighted research into interactions between FM/VM development and other areas of development. A list of studies included in the review can be found in Appendix 2. The review considered the relationship between FM/VM development and the following developmental areas.

- speech and language development
- cognitive development
- social and emotional development
- development of literacy and numeracy

While the studies reviewed were not unanimous, they did suggest FM/VM skills were correlated with speech/language, cognitive, social/emotional and literacy/numeracy skills. Especially strong support for the influence of FM/VM skills on numeracy was apparent.

Of the 112 studies included in this review, only 25 (Badian, 1982; Bart, Hajami, Bar-Haim, 2007; Butler, Marsh, Sheppard, Sheppard, 1982; Butler, Marsh, Sheppard, Sheppard, 1985; Davis, Pitchford, Jaspan, McArthur, Walker 2010; Davis, Pitchford, Limback, 2011; Dellatolas et al., 2003; Dyck, Piek, Kane, Patrick, 2009; Gaines & Missiuna, 2007; Grissmer et al., 2010; Katz, Curtiss, Tallal, 1992; Luo, Jose, Huntsinger, Pigott , 2007; Massoth & Levenson, 1982; McKay, 1985; Michel, Roethlisberger, Neuenschwander, Roebers, 2011; Pagani et al., 2010; Pianta, Smith, Reeve, 1991; Piek, Barrett, Smith, Rigoli, Gasson, 2010; Piek, Dawson, Smith & Gasson, 2008; Rhemtulla & Tucker-Drob, 2011; Schmidt & Perino, 1985; Simner, 1982; Son & Meisels, 2006; Tramontana, Hooper, Selzer, 1988) tracked skills across entry to school. This smaller group of studies is particularly useful as it suggested an ability to predict skill in school based on skill at or before kindergarten, which is largely the purpose of assessing readiness. Overall, these studies suggested an association between FM/VM skills in the preschool years and speech, language, cognitive, literacy and numeracy skill in the early school years. The association between FM/VM skills and social/emotional skills was uncertain.

Only two of the studies found (Pagani et al., 2010 and Grissmer et al., 2010) used population level data with most studies relying on small samples to draw their conclusions. Nevertheless, the relationships between different developmental areas suggested that not only were FM/VM skills predictive of success in school, they also related to the development of skill in other domains that contributed to school readiness. Given these relationships, inclusion of a FM/VM scale on school readiness assessments could add valuable information on the readiness of children to meet the demands of early school years.

Evidence from Neuroscience

Neuroscience has allowed for a better understanding of why, at a neurological level, a relationship exists between different areas of development. Much of the research has focused on the link between cognitive and motor development. This relationship will be further explored.

Historically, cognition and motor development were thought to operate independently of each other. Recent thought, however, has revealed a high degree of interrelation between these two developmental areas (Rao, 2006). The frequency with which a task contains both motor and cognitive components may partially explain a linkage between these two areas. However, the evidence suggests that the relationship is more complex. *"...even if cognitive development required no simultaneous usage of motor and cognitive skills, earlier motor skill development could have a significant impact on later cognitive development."* (Grissmer et al., 2010, p.1013). Diamond (2000) provided evidence that areas of the brain traditionally thought to be motor areas (cerebellum and basal ganglia) and areas of the brain traditionally thought of as cognitive areas (prefrontal cortex) are co-activated during certain motor and cognitive tasks. A common neural infrastructure used to control the learning process in both motor and cognitive development has been suggested (Grissmer et al. 2010).

In learning cognitive skills, a cognitive control capacity is used to initiate learning actions and employ executive functions. This cognitive control capacity is required for, and develops through, motor development. *"The cognitive capacity built during motor development may depend on the challenges encountered during motor development"* (Grissmer et al., 2010, p.1014). In conclusion, as suggested by Adolph (2008), motor development is linked to cognitive development as this is how children learn how to learn.

Evidence from Disorders

By examining the co-occurrence of disorders of various developmental areas, further support is given to the argument that developmental areas do not function independently, but rather, areas of development (readiness) are linked.

Many diagnoses related to childhood disability (e.g. Cerebral Palsy, Down Syndrome, Fetal Alcohol Spectrum Disorder) frequently result in delays in numerous areas of development. Children with some diagnoses that historically were thought to not have a motor component can demonstrate motor deficits. These include diagnoses related to attention, learning and reading as well as language delays or disorders (Diamond 2000; Kaplan, Wilson, Dewey, & Crawford, 1998; Visser 2003; Hill 2001). Specific examples include: attention deficit-hyperactivity disorder (Kadesjö & Gillberg, 2001), dyslexia (Geuze & Kalverboer, 1994), and autism (Hughes, 1996). As well, challenges with fine motor skills in children with specific speech and language disorder, developmental language impairment, developmental verbal apraxia or articulation disorders are prevalent in the literature (e.g. Bradford & Dodd, 1996; Estil, et al., 2003; Owen & McKinlay, 1997; Cermak, et al., 1986; Visscher, et al., 2007; Robinson, 1991; Webster et al., 2006).

Hill (2001) concluded that there is a co-occurrence of specific language impairments and motor skill deficits similar to those seen in developmental coordination disorder[1]. Further evidence also supports the recognition of co-occurrence between what were more commonly thought of as single system disorders. Studies have found developmental speech and language disorder (Cheng, Chen, Tsai, Chen, & Cherng, 2009) and language impairment (Archibald & Alloway, 2008) to be more prevalent in children with developmental coordination disorder. The overlap between developmental coordination disorder and other diagnoses such as reading disability and attention deficit hyperactivity disorder has also been identified (Piek, et al., 1999; Kaplan et al., 1998). Kaplan et al. (1998) concluded that overlap between these conditions was the rule rather than the exception.

The reason for this overlap is not yet clear; however, hypotheses include the possibility of a single underlying etiology or of multiple deficits being the result of an underlying immaturity of brain development (Hill, 2001). Regardless of the cause, the overlap in occurrence of these disorders is suggestive of a link between a child's performance at FM/VM activities and activities linked to other areas of school readiness.

Fine Motor/Visual Motor Skills and Participation in School

In part, the purpose of this thesis is to enable further exploration of FM/VM readiness given that EDI G&FM Sub-Domain results suggest that many children may have challenges in this area. Here, the need for FM/VM skills in school will be explored.

As children progress through school, performance in FM/VM skills remains important for successful participation in non-adapted classroom activities. However, as children move through school, the types of FM/VM activities in which they participate change (Exner 2005). The preschool

1 *"Developmental Coordination Disorder is a* "marked impairment in the development of motor coordination… only if this impairment significantly interferes with academic achievement or activities of daily living." (Missiuna, 2007)

classroom presents children with a variety of manipulative activities, including the use of crayons, scissors, small building materials, and puzzles, as well as simple cooking and art projects. During kindergarten and the early and middle elementary school years, the primary fine motor activities are paper-pencil tasks. Children are also cutting, folding, gluing, eating their own lunch, and carrying out simple science projects. By high school, adolescents are using their fine motor skills to manipulate materials in science, vocational, art and music classes. They are also used for keyboarding and managing high volumes of written work (Exner, 2005).

While there are many different visual motor skills, perhaps those that relate most closely to academic achievement from kindergarten to graduation are the controlled use of writing tools to print, draw and write. *"Handwriting is a very complex skill that encompasses visual motor coordination, higher-level cognitive processes, perceptual abilities, tactile and kinesthetic sensitivity, motor planning, spatial organization, temporal control and the integration of written language"* (Pollock et al., 2006, p.3) Adumdson noted in her chapter on pre-writing and writing skills that:

> *School consequences of handwriting difficulties may include (1) teachers assigning lower marks for the writing quality of papers with poorer legibility but not poorer content (Chase, 1986; Sweedler-Brown, 1992), (2) students' slow handwriting speed limiting compositional fluency and quality (Graham, Berninger, Abbott, Abbott, & Whitaker, 1997), (3) students taking longer to finish assignments than do their peers (Graham, 1992), (4) students having problems with taking notes in class (Graham, 1992) and reading them later, (5) students failing to learn other higher-order writing processes such as planning and grammar, and (6) writing avoidance and, later, arrested writing development (Berninger, Mizokawa, & Bragg, 1991).*
>
> (Adumdson, 2005, p588)

This quote makes it clear that poor handwriting affects students' grades, quality of work, ability to participate in class, and motivation.

The importance of handwriting in an age of widespread computer use is often debated. Research suggests that learning to print letters is important beyond handwriting as it has been shown to help the development of early literacy skills through letter recognition in a manner that learning to type does not (James, 2010; Longcamp et al., 2008). Research also supports the need for handwriting in the modern classroom for handwriting's sake. In 1992, McHale and Cermak published a study which indicated that 30%-60% of early years classroom time was spent on fine motor skills, of which 85% was handwriting. In 2016, McMaster and Roberts updated these numbers and found that primary students were spending between 18% and 47% of their classroom time on fine motor activities. 84% of this time was spent on handwriting. While time spent on fine motor skills in general and handwriting in particular has decreased, handwriting is still prevalent in the modern classroom.

Research into the effectiveness of intervention to improve FM/VM skills in children are often of less rigorous designs (e.g. cohorts, case series, single subject) and as such, drawing definitive conclusions can be difficult. Despite this, Case-Smith (2006) concluded that intervention such as occupational therapy is effective at improving fine motor skills in preschoolers. She also concluded that instructional approaches or comprehensive occupational therapy can improve writing legibility. Further, more specific treatment approaches such as Cognitive Orientation to Daily Occupational Performance (CO-OP) (Polatajko & Mandich, 2010), where children develop cognitive strategies to improve daily motor skills, have been shown to be effective for certain populations (Case-Smith, 2006).

Development of FM/VM skills begins in infancy and continues throughout the preschool and school years. FM/VM skills are required for successful participation in school. Without an adequate foundation of FM/VM skills, performance in school will likely suffer. As research suggests that FM/VM skill deficits are amenable to intervention, identification of children whose skills do not meet classroom demands would be beneficial.

Fine Motor/Visual Motor Skills as a Predictor of Success in School

Given the prevalence of school activities requiring FM/VM skills, it is logical to consider FM/VM skills as an important component of school readiness. This proposal is by no means the first piece of research to advocate consideration of FM/VM skills as a domain of school readiness.

In 1988, Tramontana, et al. published a review of 74 studies on school readiness it linked visual perceptual and visual motor abilities to the prediction of reading, math and general achievement in school (Tramontana et al., 1988). As discussed above, a more recent scoping review (Skelton & Leclair, 2013) included 25 studies which evaluated the impact of FM/VM skills on other developmental areas (cognitive, social/emotional, speech and language, numeracy and literacy) both before and after school entry. The authors found a relationship between FM/VM skills and these other developmental areas to be supported in all instances except for social/emotional development where the included studies had varied conclusions. This group of studies also suggested an ability to predict success in these developmental areas in school based upon FM/VM skill in or before kindergarten.

Despite the work of Tramontana and others, Duncan et al.'s 2007 influential study that sought to estimate links between school readiness skills and later academic achievement, did not consider motor skills as a component of readiness. Both Pagani et al. (2010) and Grissmer et al. (2010) published studies in response to the work of Duncan et al. focused on the omission of fine motor skills from his model.

Pagani et al. (2010) completed a study in which fine motor skills were included in regression models that predict achievement (reading, math and general – as assessed by the teacher's ranking of the child's skill on a five point scale) and classroom engagement (measured by the teacher's ratings of 10-items on a five point scale) at the end of the second grade. Fine motor skills were measured based on two questions: proficiency holding a writing tool and ability to manipulate objects. Using data from the Quebec Longitudinal Study of Child Development, the original model included measures of kindergarten achievement, kindergarten attention, kindergarten socioemotional skills and prior to school cognitive and attention skills. The researchers found that more of the variance could be accounted for with the addition of fine motor skills into the regression model. They demonstrated that fine motor skills contributed uniquely in predicting second grade reading, math and general achievement. (A change in R-square of 0.38 to 0.39 for reading, 0.40 to 0.41 for math and 0.42 to 0.43 for general achievement.) Further, the fine motor variable contributed as a factor in predicting classroom engagement. The coefficients for these associations were all significant at the $p<0.01$ or $p<0.001$ level. From the variables included in this study, only prior math (scores on the Number Knowledge Test one year prior to school entry), kindergarten math (Number Knowledge Test at the end of kindergarten) and kindergarten attention skills (from the Social Behavioural Questionnaire) were stronger predictors than fine motor skills for grade two reading, math and general achievement. Kindergarten receptive language (Peabody Picture Vocabulary Test at the end of kindergarten) was also a stronger predictor of kindergarten reading. Only kindergarten math, kindergarten aggression, kindergarten attention problems and kindergarten attention skills were stronger predictors of second grade classroom engagement. This study showed that although fine motor skills were not the strongest predictor of performance they were a significant contributor.

Grissmer et al. (2010) also published in response to Duncan et al.'s (2007) research. Amongst their study objectives, they sought to provide empirical evidence that fine motor skills were predictive of grade 5 school performance. They included six longitudinal data sets which used a variety of fine motor measures including copying figures on paper, draw-a-person, and using blocks to replicate a model. They found that these measures were highly significant predictors of later (grade 5) reading and math achievement when included in models with kindergarten reading and math, socioemotional skills and gross motor skills. Only early reading, early math and attention were more predictive of reading achievement and only early math and attention were more predictive of math achievement. When 'approaches to learning' or 'general knowledge' measures were added there was little change in the importance of fine motor skills indicating that fine motor skills contributed separately and independently.

Grissmer et al. removed the early math and reading scores from their additional models, as preliminary analysis suggested they were highly correlated with motor, attention and possibly other socioemotional measures and could underestimate the effect of motor skills. Subsequently, fine motor and attention measures had an increased significance for grade five reading and math. In fact, fine motor and attention combined were thought to have effect sizes around 0.5. Additionally, these models were also predictive of grade 5 science scores, with fine motor scores in particular remaining predictive.

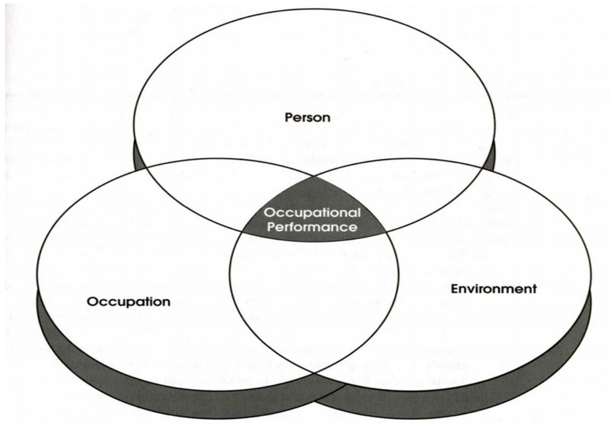
FM/VM skills are embedded in the EDI, but this tool does not allow for skill in this area to be evaluated separately. (As examples, there are fine motor skills grouped with gross motor skills in a G&FM Sub-Domain and visual motor skills imbedded within Basic and Advanced Literacy Skills Sub-Domains.) Given that both the discussed longitudinal studies with large data sets concluded that fine motor skills were predictive of later achievement, FM/VM skills are worthy of more consideration when assessing school readiness. If outcomes on school readiness measures are to be used to influence policy and programming, being able to identify when gaps exist in FM/VM development would help policy makers and front line staff make better decisions regarding fine motor programming in the early years.

Conceptual Framework for the Importance of Fine Motor and Visual Motor Skills

There is also a theoretical basis for the observed importance of FM/VM skills for school readiness. Some of this theoretical foundation comes from the work of developmental theorists who had explored the role of motor skill acquisition in overall development. The importance is also supported by theoretical approaches to the occupational therapy profession, which have added considerably to this body of literature by considering the need for FM/VM skills in completing daily activities across the lifespan.

Several different developmental theories could be applied to the acquisition of FM/VM skills; however, the most frequently cited is Piagetian theory (Inhelder, Sinclair, & Bovet, 1974). Piaget supported the role of movement in cognitive development. He spoke of a sensorimotor stage of development where infants are busy coordinating their sensory inputs and their motor capabilities. Through initially random movement, babies learn that they can control their actions to make changes to the world around them. Through this stage children learn important cognitive foundations such as object permanence and how to solve simple problems. Piaget believed that once children mastered the sensorimotor stage, they would enter the pre-operational stage where symbolic function emerges – with language being the most obvious use of symbols (Shaffer, Wood, & Willoughby, 2002). In essence, Piaget hypothesized that motor skills are the first stage of learning. Children learn to think as they learn to control their movements, and they will only begin to use language and symbols once a certain degree of mastery of their motor systems has taken place. Object manipulation remains important through the preschool years as it *"provides a context for using language to communicate and for using the mind to fantasize, plan strategies, and solve problems."* (Shaffer, et al., 2002, p.234).

Figure 1



(Adapted from Law et al, 1996. Canadian Journal of Occupational Therapy, 63, p. 18)

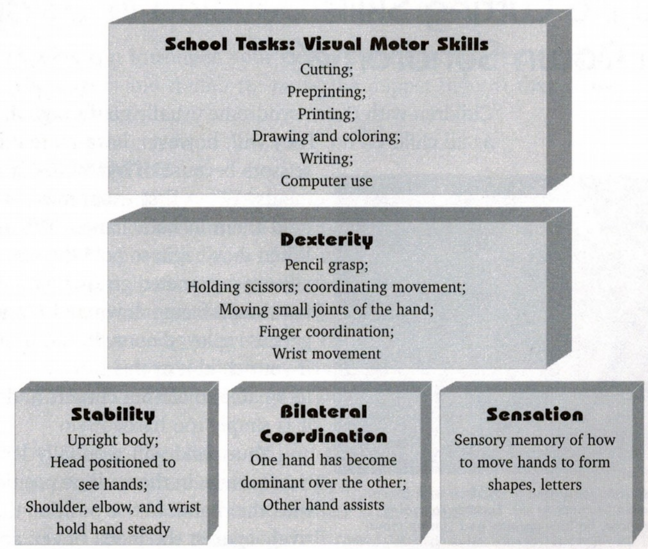
(CAOT, 1997, p.47)

To approach the theoretical basis for the importance of FM/VM skills from a different angle, one can look to the theoretical underpinnings of the practice of occupational therapy. Occupational therapists concern themselves with enabling occupation with occupation being: *"a group of activities and tasks of everyday life, named, organized, and given value and meaning by individuals and culture"* (Canadian Association of Occupational Therapists, 1997, p.34). This can include participation in a wide variety of activities but play is generally considered the primary occupation of childhood. Early childhood occupations also include participation in school (or other programming) and self-care activities (Case-Smith, 2005). Occupational therapists use several different models of practice. The presence of FM/VM skills, as an important component that impacts performance across different occupations, is consistent throughout these models. The Person-Environment-Occupation Model (Canadian Association of Occupational Therapists, 1997) is the dominant practice model in Canada. Figure 1 provides an overview of this model. It suggests that when the requirements of an occupation (task or activity), the abilities of a person (personal attributes and life experiences) and the demands of an environment (physical, social, cultural, socioeconomic, and institutional) align, occupational performance is achieved and a person is able to participate in dynamic activities within their environment (Law et al., 1996). In this model, FM/VM ability are considered sensorimotor traits within the person. In order to achieve occupational performance (successfully participate in the tasks and activities that comprise the day), one must have the FM/VM skills needed to meet the demands of the occupations in the environments in which they live.

In addition to incorporating the role of FM/VM skills in occupational performance, this model also highlights the importance of the environment (physical, social, cultural, socioeconomic, and institutional) and other aspects of the person (physical, cognitive, affective) on occupational performance. These person and environmental factors include many things that are known to affect readiness for school including age and gender (person factors) and involvement with child and family services, mother's age, use of income assistance, and neighbourhood income levels (environment factors).

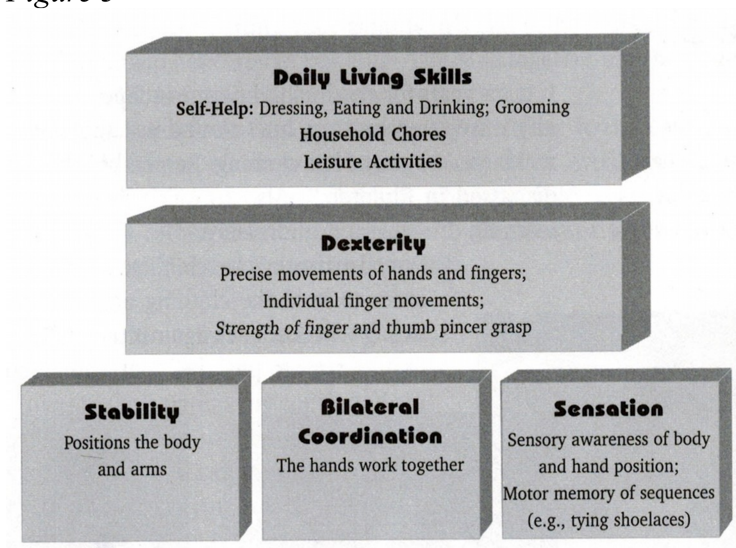
Occupational therapists working in pediatrics also use models of practice developed specifically for use within the context of a developing child. One of the popular models is the House Model of Fine Motor Skills (Bruni, 2006). Originally developed for use with children with Down Syndrome, this model is frequently used more broadly in practice (Skelton & Yeroschak, 2010; Occupational Therapy Department of Children's Hospital, 2012). This model suggests that children need a 'foundation' of stability, bilateral coordination and sensation skills upon which they build a 'first floor' of dexterity skills (grasp and release, pinch and thumb control, wrist movement, finger co-ordination) and finally a 'second floor' of daily living skills (or occupations). (See Figures 2 and 3.) It outlines how occupational therapists view FM/VM skills as a component of readiness for school tasks and daily life.

Figure 2



Bruni 2006, p.87

Figure 3



Bruni 2006, p.117

Developmental theory and occupational therapy theory both consider the role of FM/VM skills through very different lenses. Developmental theory highlights their importance for the development of higher-order skills, while occupational therapy theory focuses on the role FM/VM skills play in completing daily activities or occupations. What they both highlight is the importance of these skills in being ready and able to complete daily activities including those needed for success in school.

Summary of the Literature Review and Conceptual Framework

This literature review outlines the importance of considering FM/VM skills in discussions of school readiness. Through discussion of the complex maze of factors that impact school readiness, and the place of FM/VM skills within that maze, one can see the importance of measuring FM/VM readiness when measuring school readiness.

Several different environmental, child and health factors were identified as putting children's readiness for school at risk. These included having a mother who was a teenager when her first child was born; being in a family that had been on income assistance; having involvement with Child and Family Services; coming from a lower socioeconomic neighbourhood; being a younger child; being a boy; and having poor health at birth. The EDI has been shown to predict school readiness at the population level after considering these environmental, child and health characteristics in relation to the areas of physical health and well-being, social competence, emotional maturity, language & cognitive development, communication and general knowledge. Further, the EDI is used regularly in Manitoba (as well as across Canada and internationally) to identify populations who are at risk for poor performance in school.

A case was also outlined for the importance of including measures of FM/VM readiness in assessment of school readiness. The need to consider FM/VM readiness was seen through discussion of the importance of FM/VM skills in the classroom, the link between FM/VM skills and performance in school and the relationship between FM/VM skills, and the development of cognitive, social, emotional and language skills. Given the need to consider FM/VM skills as a component of school readiness, being able to use the EDI's regularly collected population level data to comment on FM/VM skill as a component of school readiness would be a valuable tool. It could allow institutions to track changes in FM/VM readiness across time and to compare readiness rates between geographical regions or other population groups. While the EDI does contain a G&FM Sub-Domain, it was argued that given the distinctions between fine and gross motor skills and the extreme interconnectedness of fine motor and visual motor skills, observations made on gross motor and fine motor skills are not a substitute for observations on FM/VM skills.

Finally, conceptual frameworks were briefly outlined. The first of these, Piagetian theory, considers fine motor skills as the foundation on which language and cognition develop. The second, practice models of the occupational therapy profession, consider fine motor skills one of the components necessary for successful participation in daily activity. These conceptual frameworks further support the need for FM/VM readiness if children are to be prepared to succeed in school.

Research Purpose and Objectives

The overall purpose of this study was to determine the extent to which FM/VM skills are related to school readiness. To this end, four objectives were set:

1. To create a FM/VM Index from questions on the EDI.
2. To describe the population of children considered vulnerable on the FM/VM Index.
3. To determine if being vulnerable on the FM/VM Index is related to being Not Ready/Vulnerable in other areas of readiness as measured by EDI domains and sub-domains.
4. To determine if the FM/VM Index provides additional information to what could be provided by the G&FM Sub-Domain.

Design and Methods

Data were obtained from a variety of databases available at the Manitoba Centre for Health Policy to complete this cross-sectional analysis. All data management, programming and analysis was performed using SAS® software version 9.4 (SAS Institute Inc., 2011).

Data Sources

The Manitoba Centre for Health Policy Data Repository contains a comprehensive collection of administrative, survey and registry data. Data are owned by the department where they are collected and copies housed within the data repository. The data in the Repository are anonymized with all identifying information removed.

The EDI data used for this analysis are available in the Data Repository for all children who attended kindergarten in the 2005/6, 2006/7, 2008/9 and 2010/11 school years. The special needs status variable on the EDI data was used to identify and exclude children with special needs from the analyses.

A number of covariates were extracted from a variety of data sources in the Repository for analyses (see Table 2). The covariates were chosen as they have been shown to be associated with school readiness skills (Santos et al., 2012; Brownell et al., 2012; Pagani et al., 2010) and EDI domain outcomes in past Manitoba research (Santos et al., 2012; Brownell et al., 2012).

Table 2 Source of Control Variables

Variable	Definition	Variable Type	Variable Source
Environmental Variables			
Low Maternal Education	The mother reported having not completed high school	dichotomous	FF/BF surveys[2]
Lone Parent Family	The mother identified as being a single parent at time of the FF/BF survey	dichotomous	FF/BF surveys
Low SES	The child lived in a low Income neighbourhood (Q1 and Q2 income quintiles)	dichotomous	Census
4+ Children	The child's mother had four or more children as of the child's fourth birthday	dichotomous	Manitoba Health Insurance Registry
Maternal Age at First Birth	The age of the child's mother at the birth of her first child	continuous	Manitoba Health Insurance Registry
Maternal Depression	The mother reported depression at the time of the FF/BF survey	dichotomous	FF/BF surveys
CFS Involvement	Involvement with Child and Family Services before the child's fourth birthday	dichotomous	CFS Intake and CFSIS
Income Assistance	The child's family member received income assistance prior to the child's fourth birthday	dichotomous	Social Allowances Management Income Network Data
Child Variables			
Age	The child's age in years, as of the EDI date	continuous	EDI

2 Family First(FF) and Baby First (BF) surveys. FF surveys were completed for children born from 2003 on. BF surveys were completed for children born from 2000-2002.

Variable	Definition	Variable Type	Variable Source
90%+ Minor ADGs[3]	The child accumulated more than the 90th percentile value of Minor ADG-years from birth to their fourth birthday	dichotomous	Hospital Abstracts/Medical Services Database
Number of Physician Visits	Number of times the child had an 'ambulatory visit' with a physician (GP or specialist) from birth discharge until their fourth birthday	continuous	Medical Services Database
Sex	Sex of child (female=0, male=1)	dichotomous	EDI
2+Major ADGs[4]	The child had two or more Major ADG-years from birth to their fourth birthday	dichotomous	Hospital Abstracts/ Medical Services Database
6+ Days in Hospital	The child spent six or more days admitted to hospital from birth discharge to their fourth birthday	dichotomous	Hospital Abstracts/ Medical Services Database
ICU	The child was admitted to an intensive care unit from birth discharge to their fourth birthday	dichotomous	Hospital Abstracts/ Medical Services Database
Health at Birth Variables			
Breastfeeding Initiation	Breastfeeding (exclusive or partial) was initiated during birth hospitalization	dichotomous	Hospital Abstracts
Long Birth Stay	The length of the birth hospitalization was above the 90th percentile	dichotomous	Hospital Abstracts
Low Birth Weight	The child weighed <2500 grams versus 2500 or more at birth	dichotomous	Hospital Abstracts
Premature	The child was born before 37 complete weeks of gestation	dichotomous	Hospital Abstracts
ICU Stay of 3+ Days at Birth	The child spent three or more days in an intermediate or intensive care nursery during their birth stay	dichotomous	Hospital Abstracts

*4. 2+ major ADGs (*Aggregated Diagnostic Groups) is a dichotomous measure of whether the child accumulated more than 2 major ADG-years from birth to their 4th birthday. This concept will be used as defined in Santos et al. (2012).

There are other variables that have been found to be associated with EDI outcomes in other

3 90%+ Minor ADGs (Aggregated Diagnostic Groups) is a dichotomous measure of whether the child accumulated more than the 90th percentile value (24) of Minor ADG-years from birth to their 4th birthday. This concept was used as defined in Brownell (2012). ADGs™ were created using The Johns Hopkins Adjusted Clinical Group® (ACG®) Case-Mix System version 9 (The John Hopkins University Bloomberg School of Public Health, 2011).

studies which are not included here. One of these is a set of variables used together in a prenatal health construct: smoking during pregnancy, drug and alcohol use during pregnancy and late initiation of prenatal care (Brownell et al., 2012). However, the significance of this construct was lost when factors related to material deprivation (such as Low SES, maternal high school education and use of income assistance) were included in the analysis. As variables that indicate material deprivation were included in this study, the prenatal health variables were not included in this analysis.

Objective 1: Creation of a Fine Motor/Visual Motor Index

This section outlines the steps required to achieve the first objective of this thesis: To create a FM/VM Index with a cutoff score below which children are considered Vulnerable with skills that do not meet the minimum requirement for school.

Step 1: Establishing Face Validity – Delphi Method. The process of establishing face validity ensured that the FM/VM Index looks like it is measuring what it is supposed to be measuring. Using a Delphi method (Boulkedid, Abdoul, Loustau, Sibony, & Alberti, 2011), participants identified items from the EDI to include on the FM/VM Index.

Potential participants were identified by contacting local organizations (Society for Manitobans with Disabilities, Rehabilitation Centre for Children, and Winnipeg Children's Hospital) that provide occupational therapy services to preschool and early school-aged children. Through contacts at these organizations, occupational therapists were invited to participate in the study by an e-mailed letter of introduction and link to the questionnaire. Interested participants could follow the link to an informed consent page and the first round of the survey.

Exploration of the literature revealed that the size of the panel of experts varied significantly from study to study with fewer participants being required when their backgrounds do not vary a great deal from one to the other (as was the case here). In this instance, a panel of 10-15 participants had been suggested to be sufficient (Stitt-Gohdes & Crews, 2004). This study aimed to recruit 10 to 15 therapists working with early school-age and/or preschool age groups.

In addition to collecting basic demographic information about the respondents, the first-round questionnaire asked them to rate all 58 questions in sections A through C of the EDI on a nine point scale ranging from 'definitely a visual motor or fine motor task' to 'definitely not a visual motor or fine motor task'. The 9-point scale was chosen to align with the RAND method (Fitch et al., 2001). Based on the results of the first-round questionnaire a second-round questionnaire was generated. This questionnaire had all questions where there was consensus that the item was not a VM/FM task (score 1-3) removed. The second round questionnaire included results from the first round (percentage of respondents who chose each score and any comments provided). Along with the second round questionnaire, participants were provided via email a PDF containing their responses from the first survey round. A third round was then completed in the same manner as the second (with results from both the first and second rounds included). Providing previous survey results as well as a copy of the individual's responses is an important component of the Delphi process (Fitch et al., 2001). No further rounds of the questionnaire were required as consensus was reached or results were consistent from round to round for each question. As was the case for establishing a panel size, the definition of consensus provided by the literature varied considerably from 55% to 100% agreement. Often, the definition of consensus is not reported (Powell, 2003). For this study, an item reached consensus when 75% or more of participants placed it in the same score range (1-3, 4-6 or 7-9) (Fitch et al., 2001).

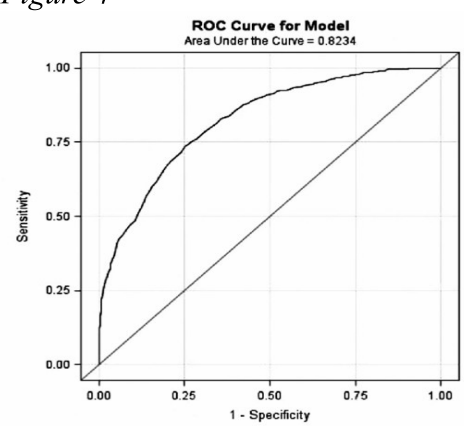
The English version of the EDI was used to establish the FM/VM Index. EDI's completed in either English or French were used in the subsequent analyses.

Step 2: Testing for Homogeneity. The internal consistency of this index was determined by calculating Cronbach's alpha. Establishing the internal consistency of the FM/VM Index was important as this process determined whether or not items included on the index produced similar outcomes. Establishing internal consistency provided statistical backing to the face validity established through the Delphi method. Cronbach's alphas were also computed on the existing sub-domains of the EDI for the study sample. These values were used as a basis of comparison for what is an acceptable degree of internal consistency on the EDI.

Step 3: Establishing cutoffs. The pre-existing domains each have a percentile below which children are considered not ready for that domain. Challenge cutoffs have also been created for each sub-domain. These cutoffs are valuable as they allow for identification and analysis of the children who are considered to be vulnerable in any one given area. Being able to identify the children who are vulnerable on the FM/VM Index would be useful in a similar way.

In order to identify children considered vulnerable, a cutoff point needed to be established for the new FM/VM Index. Towards this end, a series of ROC curve analyses were computed (Schatschneider, 2013; Søreide, Kørner, & Søreide, 2011). In ROC curve analysis, the sensitivity is plotted against false positive rate (or 1-specificity) for all possible cutoff points. Examination of the resulting curve allows the researcher to determine the cutoff point that provides the desired balance between sensitivity and specificity (Schatschneider, 2013; Singh, 2007).

Figure 4



(Schatschneider, 2013 p.74)

Prior to completing the ROC analysis, SAS randomly split the data set into three groups: a training set (comprising of 70% of the overall sample) to establish the cutoff; a test set (comprising of 15% of the overall sample) to tweak the established cutoff; and a validation set (comprising of the remaining 15% of the data set) to establish internal consistency of the FM/VM Index after the cutoff point was established. The 70:15:15 data split is consistent with what is recommended in Williams (2011).

Typically, when comparing ROC curves, the ROC curve for a new measure would be compared against the ROC curve of an existing gold standard measure. In this instance, a gold standard does not exist. Therefore, an ROC curve analysis was computed for a sub-set of domains and sub-domains that were highly correlated with the FM/VM Index. Correlation was determined using polychoric correlations. This type of correlation is indicated when *"an [unobserved] continuous variable is obtained through an observed ordinal variable that is derived from the unobserved variable by classifying its values into a finite set of discrete, ordered values."* (Base SAS, n.d.) EDI scores are ordinal (multiples of 5) but represent a continuous variable (readiness). This allowed for identification of the score on the FM/VM Index that would give the best balance of sensitivity and specificity for that domain or sub-domain.

Examining the area under the curve of these ROC curves allows comparison of the ability of a new tool (here the FM/VM Index) to predict being outcomes on an existing tool (here being vulnerable on domains/sub-domains) (Schatschneider, 2013; The Magnificent ROC, 2011). An area under the curve of 1 represents a test with perfect prediction whereas an area under the curve of 0.5 represents a very poor prediction. Computing the areas under the curves allows the result of some curves to be weighted more heavily than others in determining a single cutoff point. In the end, a judgement was made to determine a cutoff value below which FM/VM readiness for school will be considered Vulnerable in order to optimize sensitivity and specificity.

The cutoff point established through completion of the ROC curve analysis allowed the FM/VM Index, created through the Delphi process and confirmed through the test for internal consistency, to provide information on the proportion of children who were Vulnerable on the FM/VM Index. This allows the index to be used in a manner similar to the existing sub-domains in future analyses.

Objective 2: Who is vulnerable?

The second study objective was to describe the population of children considered Vulnerable on the FM/VM Index. Descriptive statistics for the entire sample and for the sub-set of children who were Vulnerable on the FM/VM Index, allowed understanding of the population as a whole and those children who would have difficulties with FM/VM skills at school.

Step 1: Population Descriptive Statistics. Descriptive statistics were computed in order to better understand the sample included in this analysis. Descriptive statistics of all the control variables listed in Table 2 were presented as either means (continuous variables) or the proportion with the risk factor (dichotomous variables).

Step 2: Descriptive Statistics of those who were vulnerable on the Fine Motor/Visual Motor Index. The same set of descriptive statistics computed in Step 1 were computed with the study populations who were Vulnerable and Not Vulnerable on the FM/VM Index to compare the children in these two groups.

Step 3: Logistic Regressions. In order to gain a greater understanding of how each covariate is associated with being Vulnerable, a stepwise logistic regression was computed with the FM/VM Index as the dependent variable and the control variables (see Table 2) as independent variables. Prior to running this regression, the FM/VM Index was rescaled so that a change of 1 represents a change of 5 points. Due to the structure of the EDI, scores can only change in increments of 5 points. As such, this rescaling was done to make interpretation of the results more practical.

Objective 3: Predicting Being Not Ready/Vulnerable

The third objective of this study was to determine if being Vulnerable on the FM/VM Index was related to being Not Ready/Vulnerable in other areas of readiness. A series of stepwise logistic regressions using each of the domains and sub-domains (that did not contain FM/VM Index items) as the dependent variable were computed with the control variables. Interpretation of models with overlap in the construct of the dependent and independent variables is complex and beyond the scope of this project. The FM/VM Index was then added to each of the above models in another set of logistic regressions. Comparison of the logistic regressions with and without the FM/VM Index helped explain if being vulnerable on the FM/VM Index added to our understanding of being Not Ready/Vulnerable in other areas of school readiness.

Step 1: Multicollinearity In preparation for the logistic regressions, the degree of multicollinearity between the control variables for each logistic regression was computed. A tolerance of 0.4 or less was set to define multicollinearity (Allison, 1999).

Step 2: Logistic Regressions. To determine if lower scores on the FM/VM Index were related to being Not Ready/Vulnerable in other areas of readiness, two series of logistic regressions were run. Once again, the FM/VM Index was rescaled so that a change of 1 represents a change of 5 points. The first series of logistic regressions used domains as the dependent variable with the domain dichotomized as Not Ready (bottom 10%) or Ready. For each domain that did not have any questions selected for inclusion of the FM/VM Index the following logistic regressions were run:

a) Stepwise logistic regression with control variables (see Table 2) only. In SAS, the stepwise selection method added control variables one at a time. After each addition, the resulting model was fit and only those control variables that remained significant in the results model were kept.

b) Resulting logistic regression from step 2a with the FM/VM Index added (continuous variable, input as rescaled raw score)

The second series of logistic regressions used sub-domains as the dependent variable (dichotomized as below and above the challenge cutoff). For each sub-domain that did not have any questions selected for inclusion of the FM/VM Index, the following logistic regressions were run:

c) Stepwise logistic regression with control variables (see Table 2) only

d) Resulting logistic regression from step 2c with the FM/VM Index added (continuous variable, input as rescaled raw score)

The results of these regression models ultimately answered the third objective of this study – to determine if scores on the FM/VM Index were related to being Not Ready on EDI domains and/or Vulnerable on EDI sub-domains.

Objective 4: Comparing the FM/VM Index to the G&FM Sub-Domain

The final objective of this study determined if the FM/VM Index provided additional information to what could be provided by the G&FM Sub-Domain. Towards this end, two more sets of logistic regressions were computed and compared to the previously run regressions for each of the domains and sub-domains. Logistic regressions were only computed for the domains/sub-domains included in the anaylses for Objective 3. As was done for the FM/VM Index, the scores for the G&FM Sub-Domain were rescaled so that a change of 1 represented a change of 5 points.

The first set of logistic regressions used domains as the dependent variable with the domain dichotomized as Not Ready (bottom 10%) or Ready. For each domain the following logistic regressions were computed and compared:

e) Control variables and the G&FM Sub-Domain (rescaled raw score)

f) Control variables and the FM/VM Index (rescaled raw score, previously computed in Objective 3)

The second set of logistic regressions used sub-domains as the dependent variable with the sub-domain dichotomized as below or above the challenge cutoff. For each sub-domain the following logistic regressions were computed and compared:

g) Control variables and the G&FM Sub-Domain (rescaled raw score)

h) Control variables and the FM/VM Index (rescaled raw score, previously computed in Objective 3)

These comparisons allowed for comment on whether the FM/VM Index was a better predictor of readiness as measured by the EDI than the existing G&FM Sub-Domain.

Results

The overall purpose of this study was to determine the extent to which FM/VM skills are related to school readiness. The following sections outline the results of the four study objectives.

Objective 1: Creation of a Fine Motor/Visual Motor Index

Establishing Face Validity – Delphi Method. During the first round of the Delphi, demographic information was requested from the survey participants. Completion of these questions was voluntary which resulted in some missing data. A summary of the resulting demographic information can be found in Table 3.

Table 3: Delphi Participant Demographics

	Round 1	Rounds 2 and 3
Total n	10	9
Female	8	7
Male	1	1
Age	24-50 (average 34.9)[a]	24-50 (average 34.3)[a]
Preschool caseload (3-5yo)	9	8
School-age caseload (K-gr3)	6	5
Years with preschool	1-26 (average 11.6)	1-26 (average 12.4)
Years with School-age	1-26 (average 9.0)	1-26 (average 9.8)
Years as OT	1-26 (average 13.0)	1-26 (average 12.8)
Bachelor level training	8	7
Masters level training	2	2

a. 2 missing

The initial round of the survey identified 10 out of a potential 58 questions for inclusion as at least 75% of participants scored the item in the 7-9 range (with 10 representing definitely a FM/VM task). Twelve questions were identified for exclusion as at least 75% of participants scored the item in the 1-3 range. Therefore, 36 questions remained for which the decision to include or exclude was not made. Round two of the survey identified another question for inclusion (total 11) and excluded another 19 (total 31). The third survey round did not identify any further questions for inclusion but did exclude another 9 questions. At the end of the three rounds, six questions remained uncategorized. Of these six 'no consensus' questions, all had responses trending towards exclusions. Five had no responses in the inclusion range (7-9) on the third round. The remaining question had 22% of respondents in the inclusion range on the third round. This percentage was down from 44% scoring it in the inclusion range in the second and 50% in the first round. Given these responses, it seemed unlikely the questions would be identified for inclusion in future rounds. Therefore no further survey rounds were conducted. See Figure 5 and Table 4 for a summary of these results.

Figure 5: Delphi Survey Results

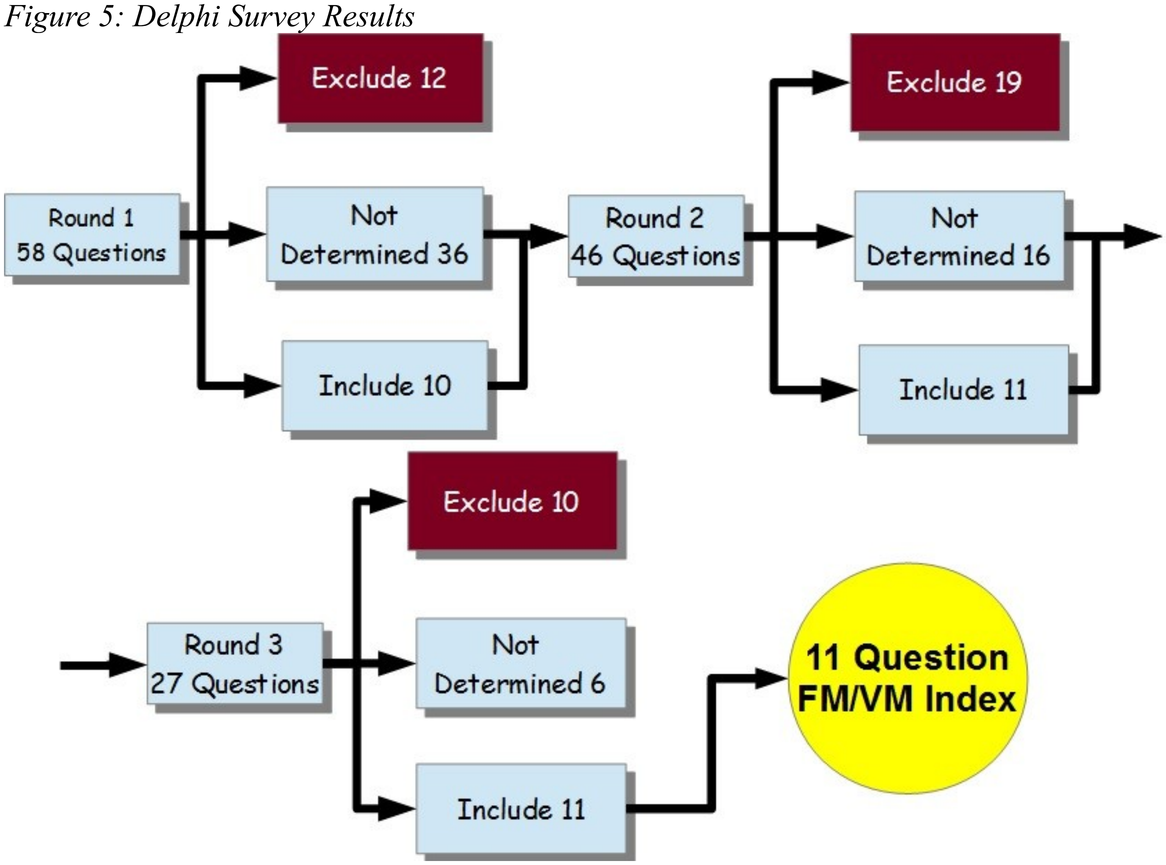


Table 4: Delphi Survey Results

	Number of Questions	Consensus (7-9)	Consensus (4-6)	Consensus (1-3)	No consensus
Round 1 Survey	58	10	0	12	36
Round 2 Survey	46	11	1	19 (31[a])	15
Round 3 Survey	27	11	3	7 (38[a])	6
FM/VM Index	11	11	-	-	-

a. includes previous round(s)

The resulting Fine Motor/Visual Motor Index comprised of the 11 questions outlined in Table 5. These 11 questions came from three different domains and five different sub-domains on the EDI. Three questions were from the Physical Health and Well-Being Domain (two from the Gross and Fine Motor Sub-Domain and one from the Physical Independence Sub-Domain). One question was from the Overall Social Competence Sub-Domain of the Social Competence Domain. Seven questions were from the Language and Cognitive Development Domain (four from the Basic Literacy Sub-Domain and three from the Advanced Literacy Sub-Domain).

Table 5: Questions Selected for Inclusion

Sub-Domain	Question
Physical Health and Well-Being Domain	
Physical Independence	1. Would you say that this child shows an established hand preference?
Gross and Fine Motor Skills	2. How would you rate this child's proficiency at holding a pen, crayons or a brush?
	3. How would you rate this child's ability to manipulate objects?
Social Competence Domain	
Approaches to Learning	4. Would you say that this child works neatly and carefully?
Language and Cognitive Development Domain	
Basic Literacy	5. Would you say that this child knows how to handle a book (e.g., turn a page)?
	6. Would you say that this child is experimenting with writing tools?
	7. Would you say that this child is aware of writing directions in English (left to right, top to bottom)?
	8. Would you say that this child is able to write his/her own name in English?
Advanced Literacy	9. Would you say that this child is interested in writing voluntarily (and not only under the teacher's direction)?
	10. Would you say that this child is able to write simple words?
	11. Would you say that this child is able to write simple sentences?

Testing for Homogeneity. Before testing for homogeneity, the EDI data were cleaned to leave only complete valid entries. The entire EDI data set contained 49330 subjects. Removing all subjects where responses were missing for either an index question or a domain/sub-domain resulted in 44658 subjects. The age of participants was then limited to after the fifth birthday but before the seventh (as all children should be in that age range in the new year of their kindergarten year when the EDI is completed). Further reducing the data set to 43603 subjects. Duplicate subjects were excluded resulting in a final EDI Data Set with 43519 subjects. This resulting data set was used when only EDI variables were included in the analysis as is the case for establishing the FM/VM Index characteristics. Further cleaning of the data with the introduction of co variates will be discussed later (see Objective 2).

The internal consistency (Cronbach's alpha) of the FM/VM index containing the 11 questions identified in Table 5 was calculated. The Cronbach's alphas for the existing EDI sub-domains were calculated for this study sample to allow for comparison (See Table 6). The published values for the EDI domains and sub-domains are also included. The Cronbach's alphas from the study sample and the published values are generally similar, although larger dependencies are observed between the study sample and published values for the Physical Independence sub-domain. For the study sample, the Cronbach's alpha of the FM/VM Index was higher than 6 of the 16 sub-domains. When using the published values as the comparison, the Cronbach's alpha of the FM/VM Index was higher than 7 of the 16 sub-domains.

Table 6: EDI Sub-Domains Cronbach's Alpha Values

Sub-Domain	Cronbach's Alpha Study Sample	Cronbach's Alpha Published Value [a]
FM/VM Index	*0.823*	--
Physical Readiness	0.641	0.715
Physical Independence	0.476	0.256
Gross & Fine Motor Skills	0.903	0.918
Responsibility and Respect	0.927	0.921
Approaches to Learning	0.924	0.911
Overall Social Competence	0.880	0.862
Readiness to Explore New Things	0.885	0.863
Prosocial and Helping Behaviour	0.948	0.944
Hyperactivity and Inattention	0.928	0.921
Anxious and Fearful Behaviour	0.811	0.808
Aggressive Behaviour	0.870	0.862
Basic Numeracy Skills	0.836	0.802
Advanced Literacy Skills	0.813	0.808
Interest in Literacy/Numeracy and Memory	0.794	0.779
Basic Literacy Skills	0.797	0.751
Communication and General Knowledge	0.938	0.931

a. (Janus M, Walsh C & Duku E, 2005)

Establishing cutoffs. Next, individual polychoric correlations were computed to establish the dependence of scores on the FM/VM Index and the EDI domains/sub-domains. Results of these correlations can be found in Table 7.

Table 7: Polychoric Correlations

Ordinal Variable	N	Correlation	LR Test Chi-Square	LR Test Pr > Chi Sq	Questions on FM/VM Index
Domains					
Communication and General Knowledge	43655	0.56908	8284.3613	<.0001	0
Emotional Maturity	43655	0.48569	5707.1258	<.0001	0
Language and Cognitive Development	43655	0.75451	16207.8865	<.0001	7 of 26 (27%)
Physical Health and Well-being	43655	0.59331	9011.4185	<.0001	3 of 13 (23%)
Social Competence	43655	0.60780	9422.8532	<.0001	1 of 26 (4%)
Sub-Domains					
Physical Readiness for School	43649	0.30628	1734.3722	<.0001	0
Physical Independence	43647	0.48468	5713.3756	<.0001	1 of 4 (25%)
Gross and Fine Motor	43650	0.66460	14737.1321	<.0001	2 of 5 (40%)
Overall Social Competence	43646	0.51209	6160.1329	<.0001	0
Responsibility and Respect	43650	0.46064	3554.2437	<.0001	0
Approaches to Learning	43650	0.64925	10177.0647	<.0001	1 of 9 (11%)
Readiness to Explore New Things	43643	0.46972	2679.9428	<.0001	0
Prosocial and Helping Behaviour	42978	0.39217	4449.5854	<.0001	0
Anxious and Fearful Behaviour	43647	0.23519	471.1461	<.0001	0
Aggressive Behaviour	43651	0.31099	1741.8977	<.0001	0
Hyperactivity and Inattention	43650	0.48266	6067.7119	<.0001	0
Basic Literacy	43648	0.70493	14909.4506	<.0001	4 of 8 (50%)
Interest in Literacy/ Numeracy and Memory	43606	0.62738	11150.9513	<.0001	0
Advanced Literacy	43573	0.83020	24888.4365	<.0001	3 of 6 (50%)
Basic Numeracy	43641	0.58216	10214.9400	<.0001	0

As all correlations were statistically significant, only the one domain and three sub-domains where question overlap was greater than 25% were chosen for ROC curve analysis. As a result, the Language and Cognitive Development Domain, Gross and Fine Motor Sub-Domain, Basic Literacy Sub-Domain, and Advanced Literacy Sub-Domain were used in the ROC curve analyses (shaded rows in Table 7). ROC curves are traditionally used to compare two approaches to measuring the same outcome – comparing a new method to an existing gold standard (Schatschneider, 2013). While the greater than 25% cutoff may seem arbitrary, it was thought that domains/sub-domains where this degree of overlap exists, should to some extent, have a similar scope as the FM/VM Index. The polychoric correlations demonstrated that these domains/sub-domains were the most highly correlated with the FM/VM Index (see Table 7).

Using the training set (comprised of 70% of the overall sample), ROC curves were computed for the Language and Cognitive Development Domain as well as the Gross and Fine Motor, Advanced Literacy, and Basic Literacy Sub-Domains. The higher the area under the curve (AUC), the more predictive the FM/VM index is of scores on the given domain/sub-domain. A score of 1 represents a perfect prediction and a score of 0.5 represents pure chance. The AUCs are shown in Table 8 and Figures 6-9. (Figures created using SAS 9.4.)

Table 8: Area Under the Curve

Domain/Sub-Domain	AUC
Sub-Domain: Advanced Literacy	0.9547
Sub-Domain: Gross Motor and Fine Motor Skills	0.8528
Sub-Domain: Basic Literacy	0.8960
Domain: Language and Cognitive Development	0.9322

Figure 6: ROC Curve - Gross Motor and Fine Motor Skills Sub-Domain

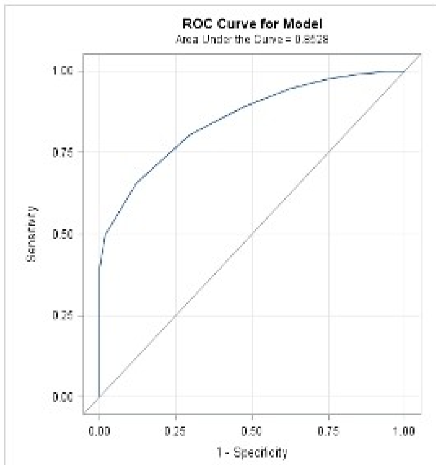


Figure 7: ROC Curve - Language and Cognitive Development Domain

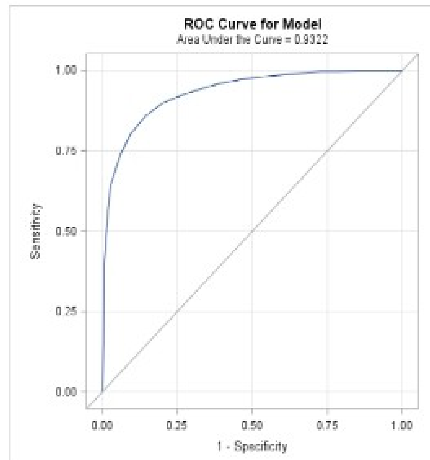


Figure 8: ROC Curve - Basic Literacy Sub-Domain

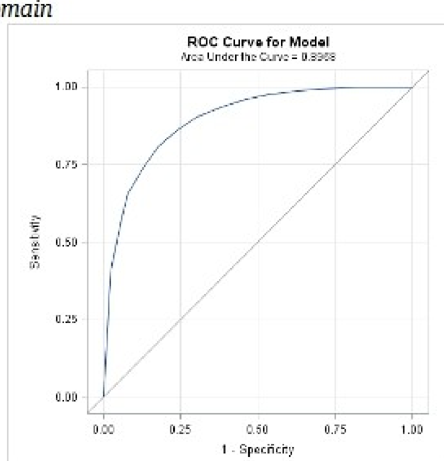
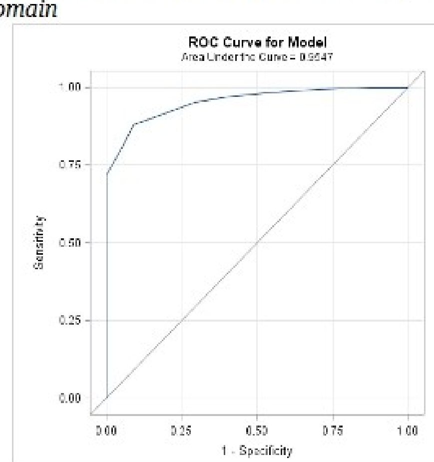


Figure 9: ROC Curve - Advanced Literacy Sub-Domain



Information for each potential cutoff point on sensitivity, specificity, % false positives, and % false negatives by domain/sub-domain was used to choose the cutoff point for the FM/VM Index (Table 9).

Table 9: Potential Cutoff Points – Training data set

Domain/Sub-Domain		Sensitivity	Specificity	% False Positive	% False Negative
Language and Cognitive Development	cutoff <75	0.9013	0.7945	8.61	2.63
	cutoff <80	0.8581	0.8555	12.37	1.85
	cutoff <85	0.8025	0.9075	17.22	1.18
	cutoff <90	0.7381	0.9393	22.84	0.78
Gross and Fine Motor Skills	cutoff <75	0.9224	0.4418	5.41	16.88
	cutoff <80	0.8933	0.5251	7.44	14.37
	cutoff <85	0.8514	0.6110	10.36	11.77
	cutoff <90	0.8046	0.7022	13.63	9.01
Basic Literacy	cutoff <75	0.9049	0.6961	8.04	4.69
	cutoff <80	0.8628	0.7593	11.61	3.72
	cutoff <85	0.8092	0.8233	16.14	2.73
	cutoff <90	0.7459	0.8669	21.49	2.05
Advanced Literacy	cutoff <75	0.9521	0.7071	3.77	6.23
	cutoff <80	0.9196	0.8003	6.33	4.25
	cutoff <85	0.8787	0.9085	9.55	1.95
	cutoff <90	0.8192	0.9451	14.81	1.17

Note: <80 chosen as final cutoff

As the EDI is used as a screening tool and its intention is to identify populations at risk, the decision was made to put more weight on the % false negatives than the % false positives in choosing the cutoff point. This way, the tool will err on the side of including those who aren't Vulnerable rather than excluding those who are. Based on the training data results, the cutoff point of <85 was chosen. A proc freq was then run in SAS with the test data set (comprised of 15% of the overall sample) to determine sensitivity, specificity, % false positives and % false negatives in that data set (see Table 10). At that time the choice of cutoff point was re-visited and adjusted to be <80 as the false positive rates between 9.8% and 17.54% were deemed too high (see Table 10). As is expected, this cutoff is consistent with the point where the ROC curves begin to flatten for most of the domains/sub-domains. The exception is the Gross and Fine Motor Skills Sub-Domain where the curve does not flatten out until a higher cutoff point. However, choosing a higher cutoff would have placed it well into the ceiling of the other domains/sub-domains of interest. Also, examining the AUC scores (Figures 5-8), revealed that the G&FM sub-domain had a lower value than the others, especially the Language & Cognitive Development Domain and the Advanced Literacy Sub-Domain. This lower value suggests that the FM/VM Index was less predictive of G&FM scores than of scores on the Language & Cognitive Development Domain and Advanced Literacy Sub-Domain. Therefore the G&FM Sub-Domain was a less appropriate substitute for the gold standard. In addition, the specificity of the G&FM Sub-domain was comparatively quite poor and this sub-domain’s properties were not as strong as the others'. Therefore a cutoff was chosen that optimized the result for Language and Cognitive Development, Basic Literacy and Advanced Literacy at the expense of optimizing Gross and Fine Motor Skills.

Table 10: Potential Cutoff Points – Test Data Set

Domain/Sub-Domain		Sensitivity	Specificity	% False Positive	% False Negative
Language and Cognitive Development	cutoff <80	0.8525	0.8757	12.82	1.62
	cutoff <85	0.7983	0.9250	17.54	0.98
Gross and Fine Motor Skills	cutoff <80	0.8883	0.5249	7.63	15.06
	cutoff <85	0.8491	0.6095	10.31	12.38
Basic Literacy	cutoff <80	0.8560	0.7697	12.13	3.63
	cutoff <85	0.8040	0.8319	16.51	2.65
Advanced Literacy	cutoff <80	0.9131	0.8023	6.80	4.31
	cutoff <85	0.8746	0.9092	9.80	1.98

Note: <80 chosen as final cutoff

Having established the cutoff point at <80, a proc freq was run on the validation data set (the remaining 15% o the overall sample). Table 11 contains the results of that analysis.

Table 11: FM/VM Index with cutoff of <80

Domain/Sub-Domain	Sensitivity	Specificity	% False Positive	% False Negative
Language and Cognitive Development	0.8584	0.8473	12.27	2.04
Gross and Fine Motor Skills	0.8978	0.5469	7.15	13.60
Basic Literacy	0.8647	0.7634	11.36	3.78
Advanced Literacy	0.9175	0.7957	6.46	4.41

Objective 2: Who is vulnerable?

In order to describe who is vulnerable on the FM/VM Index, data sources outside the EDI needed to be used. The availability of additional data (control variables) resulted in further cleaning of the dataset. The following were excluded from the 49,330 subjects present in the EDI data: those for whom an EDI domain or sub-domain score was missing (4,672 subjects), those with no age or an age outside the expected range (an additional 1047 subjects), those without special needs status reported (an additional 167 subjects), those without sex reported (an additional 8 subjects). Duplicate filePHINs were then removed (83 subjects) The result was a sub-set of the EDI data set with 43,353 subjects (87.88% of the EDI data set).

The records for these remaining subjects were then merged with the data sets containing the other control variables and only those for whom all variables were present were kept for analyses. The frequency of unavailable control variables are outlined in Table 12. Some variables tended to group together when missing (e.g. Low Maternal Education, Lone Parent Family and Maternal Depression). These data come from the same source (e.g. Family First/Baby First survey). A few control variables were assumed to be absent unless they were found to be present in the relevant data sets. These include 6+ Days in Hospital, ICU Stay, and ICU Stay of 3+ Days at Birth. Similarly, children were assumed to have had zero physician visits if none were found in the data.

A portion of this data is likely explained by the presence of children in the EDI data who were not born in Manitoba but attended kindergarten in the province as variables related to birth or early infancy (e.g. hospital birth record, Family First/Baby First surveys) were not available for these children. This final data set comprised 26,802 subjects (61.82% of the initial EDI data).

Table 12: Unavailable Control Variables

Variable	Number Missing	Percentage Missing[a]
Environmental Variables		
Low Maternal Education	15001	34.60
Lone Parent Family	14289	32.96
4+ Children	2592	5.98
Maternal Age at First Birth	2592	5.98
Maternal Depression	15080	34.78
CFS Involvement[b]	-	-
Income Assistance[b]	-	-
Child Variables		
90%+ Minor ADG	2477	5.71
Physician Visits[b]	-	-
2+ Major ADG	2477	5.71
6+ Days in Hospital[b]	-	-
ICU[b]	-	-
Health at Birth Variables		
Breastfeeding Initiation	8825	20.36
Long Birth Stay	8421	19.42
Low Birth Weight	8425	19.43
Premature	8640	19.93
ICU Stay of 3+ Days at Birth[b]	-	-

a. Percentage missing reflects the percentage of children for whom complete EDI data was available but the given variable was not; b. If children were not found to have one of this dichotomous variable in the relevant data sets then it was coded as being absent, therefore there is no value for missing data.

Comparison of the rates of being 'Not Ready' between subjects included and excluded from the Complete Data Set (but included in the EDI data) were computed to assess how these two groups differed on EDI results, Low SES, Income Assistance, CFS Involvement and the FM/VM Index. Tables 13-15 offer an overview of this comparison including statistical significance. The F statistic (one-way ANOVA) was used to determine statistical significance for the domain scores. Chi-squares were provided for statistical significance on sub-domains, Low SES, Income Assistance, CFS Involvement and vulnerability on the FM/VM Index. For all of the variables, differences between groups were statistically significant at the <0.0001 level except for Anxious and Fearful Behaviour where the difference was not statistically significant ($p = 0.1683$) and Physical Independence where statistical significance was achieved at $p= 0.0004$.

The quantity of unavailable data is of concern, especially considering that missing subjects were statistically different from included subjects on outcomes of interest. Complete case analysis (discarding of all cases with incomplete data) was performed despite the resulting likelihood of bias. Differences between included and excluded samples have been noted as a limitation in similar works (e.g. de Rocquigny, 2014).

Table 13: Excluded vs Included Populations – Domains

Variable	Mean Score Included Sample	Mean Score Excluded Sample	F stat (sig)
Communication and General Knowledge	7.7486	6.9598	<0.0001
Emotional Maturity	7.9206	7.7918	<0.0001
Language and Cognitive Development	8.2440	7.8380	<0.0001
Physical Health and Well-Being	8.7552	8.5810	<0.0001
Social Competence	8.3297	8.0187	<0.0001

Table 14: Excluded vs Included Populations – Sub-Domains and FM/VM Index

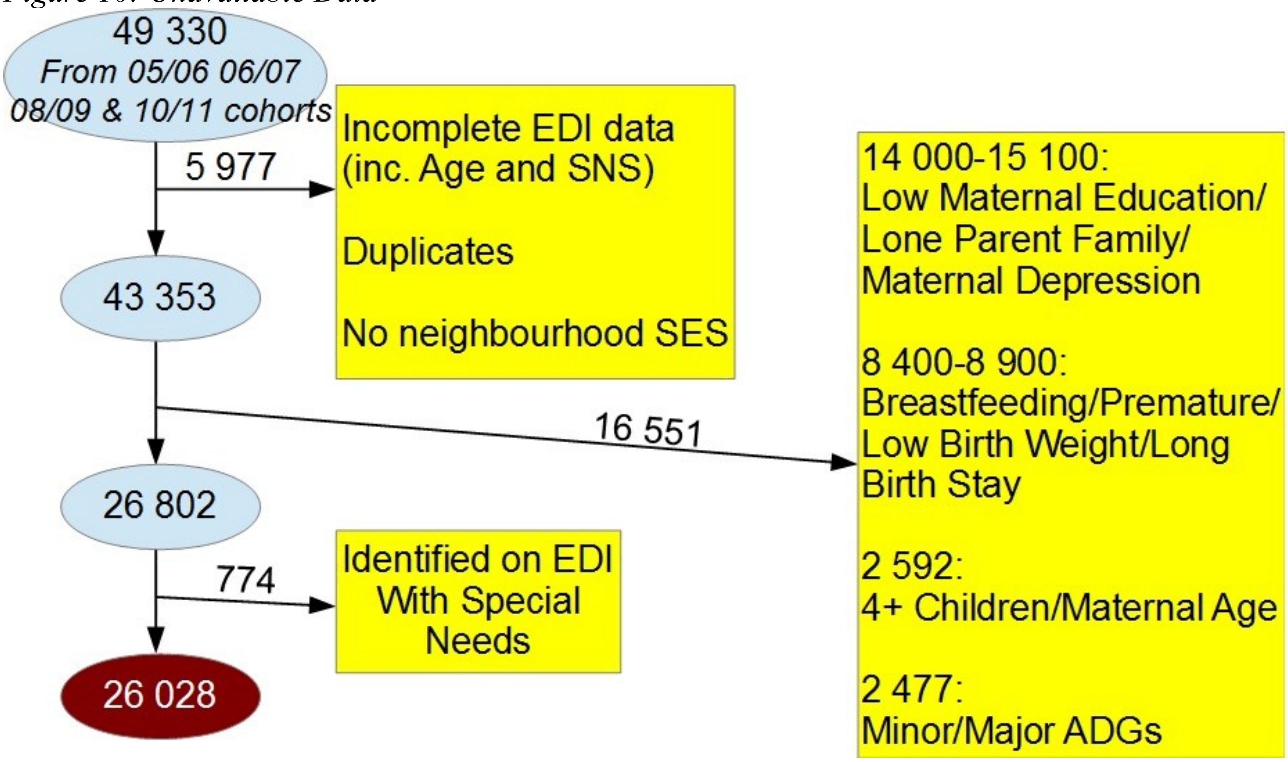
Variable	% Vulnerable in Included sample (n)	% Vulnerable in Excluded sample (n)	χ^2 (sig)
Physical Readiness for School	7.94 (2127)	10.50 (1742)	<0.0001
Physical Independence	11.73 (3143)	12.86 (2134)	0.0004
Gross and Fine Motor	29.26 (7841)	32.20 (5342)	<0.0001
Overall Social Competence	9.50 (2547)	12.95 (2148)	<0.0001
Responsibility and Respect	5.08 (1362)	6.77 (1123)	<0.0001
Approaches to Learning	8.65 (2317)	11.76 (1951)	<0.0001
Readiness to Explore New Things	2.74 (735)	4.01 (665)	<0.0001
Prosocial and Helping Behaviour	37.61 (9929)	42.87 (7000)	<0.0001
Anxious and Fearful Behaviour	2.42 (649)	2.63 (437)	0.1683
Aggressive Behaviour	7.96 (2134)	9.31 (1544)	<0.0001
Hyperactivity and Inattention	13.96 (3741)	16.65 (2762)	<0.0001
Basic Literacy	13.25 (3550)	19.26 (3196)	<0.0001
Interest in Literacy/ Numeracy and Memory	13.46 (3605)	17.06 (2826)	<0.0001
Advanced Literacy	19.50 (5217)	24.37 (4037)	<0.0001
Basic Numeracy	17.84 (4781)	24.51 (4065)	<0.0001
FM/VM Index	21.64 (5799)	26.40 (4381)	<0.0001

Table 15: Excluded vs Included populations – Select Control Variables

Variable	% of Included Sample (n)	% of Excluded Sample (n)	χ^2 (sig)
Low SES	33.86 (9075)	43.11 (7018)	<0.0001
CFS Involvement	2.61 (700)	3.44 (571)	<0.0001
Income Assistance	19.38 (5195)	17.53 (2909)	<0.0001

At this point, a final group of children were excluded from the analysis: those who were identified as having special needs through the Special Needs Status variable. These children were excluded as children who have special needs are already known to be vulnerable across areas of development. The remaining data set included 26028 children. An overview of the process of narrowing the initial data set down to the final data set is found in Figure 10.

Figure 10: Unavailable Data



Descriptive Statistics. Descriptive statistics were computed to see how those who are Vulnerable on the FM/VM Index compared to those who are Not Vulnerable on the FM/VM Index on known risk factors (control variables) as well as EDI scores. Chi-squares were used to determine statistical significance for dichotomous variable risk factors and one-way ANOVAs for continuous variable risk factors. Rates for the entire sample are provided for reference. (See Table 16.)

The comparison between those who are Vulnerable to those who are not on the FM/VM Index shows that those who are Vulnerable are more likely to:

- Have a mother who has not completed high school

- Be in a lone parent family
- Reside in a neighbourhood with a low income quintile
- Have a family with four or more children
- Have a mother who was younger when her first child was born
- Have a mother who has had maternal depression
- Have CFS involvement prior to their fourth birthday
- Have been on income assistance prior to their fourth birthday

These differences were statistically significant at the <0.0001 level. (See Table 16.)

Further, children who were Vulnerable on the FM/VM Index, in comparison to children who were Not Vulnerable were more likely to:

- Be younger
- Have reached the 90% Minor ADG threshold
- Be male
- Have more physician visits
- Have spent 6 or more days in hospital before their fourth birthday (not including birth stay)
- Have had an ICU stay prior to their fourth birthday (not including birth stay)

The <0.0001 level of statistical significance was again achieved for all of these variables, except for ICU where the significance was 0.0005, when comparing those who are Vulnerable and those who aren't on the FM/VM Index. (See Table 16.) Results could not be reported for the 2+ Major ADG variable as the number of children with this risk factor was too small to report as per MCHP guidelines. The comparison between the Vulnerable and Not Vulnerable groups was not significant for this variable.

Within the health at birth variables, statistically significant differences were found once again for all included variables. Therefore, children who were Vulnerable on the FM/VM Index, in comparison to children who were Not Vulnerable were more likely to have:

- Initiated breastfeeding
- Weighed less than 2500 grams at birth
- Had a birth hospital stay longer than the 90th percentile
- Been born before 37 complete weeks of gestation
- Had an ICU Stay of 3 or more Days at Birth

Levels of statistical significance varied and can be found in Table 16.

Table 16: Who is Vulnerable/Not Vulnerable on the FM/VM Index? - Control Variables

Variable	% in Complete Sample (n=24652)	% in those Vulnerable FM/VM Index (n=5234)	% in those Not Vulnerable FM/VM Index (n=19418)	Significance[a]
Environmental Variables				
Low Maternal Education	16.09 (4188)	25.29 (1338)	13.74 (2850)	<0.0001
Lone Parent Family	11.26 (2931)	18.09 (957)	9.52 (1974)	<0.0001
Low SES	33.69 (8770)	41.25 (2182)	31.77 (6588)	<0.0001
4+ Children	15.58 (4080)	20.74 (1097)	14.38 (2983)	<0.0001
Maternal Age at First Birth	24.86[b]	23.55[b]	25.19[b]	<0.0001
Maternal Depression	7.53 (1959)	9.17 (485)	7.11 (1474)	<0.0001
CFS Involvement	2.36 (613)	4.57 (242)	1.79 (371)	<0.0001
Income Assistance	18.95 (4932)	32.95 (1743)	15.38 (3189)	<0.0001
Child Variables				
Age	5.69[b]	5.63[b]	5.71[b]	<0.0001
90%+ Minor ADG	16.42 (4275)	20.11 (1064)	15.48 (3211)	<0.0001
Physician Visits	40.40[c]	42.70[c]	39.81[c]	<0.0001
Male	49.97 (13006)	72.51 (3836)	44.22 (9170)	<0.0001
2+ Major ADGs	Cannot report[d]	Cannot report[d]	Cannot report[d]	--
6+ Days in Hospital	5.87 (1529)	8.83 (467)	5.12 (1062)	<0.0001
ICU	1.31 (341)	1.80 (95)	1.19 (246)	0.0005
Health at Birth Variables				
Breastfeeding Initiation	85.90 (22358)	81.43 (4311)	87.02 (18047)	<0.0001
Long Birth Stay	16.52 (4301)	17.67 (935)	16.23 (3366)	0.0116
Low Birth Weight	4.33 (1126)	4.91 (260)	4.18 (866)	0.0184
Premature	6.63 (1726)	7.56 (400)	6.39 (1326)	0.0023
ICU Stay of 3+ Days at Birth	3.20 (834)	3.82 (202)	3.05 (632)	0.0045

a. Significance is reported between those Vulnerable and those Not Vulnerable. X^2 reported for dichotomous variables and F-stat for continuous variables.; b. Mean Years; c. Mean; d. suppressed

In order to better understand the associations between covariates and being Vulnerable on the

FM/VM Index, a logistic regression was computed using the dichotomized FM/VM Index score as the dependent variable (Vulnerable/Not Vulnerable). The final model had a max-rescaled R-square of 0.1582. In contrast with linear regressions, in logistic regressions, the R-square is not the proportion of the variance explained by the model. R-squares are however valuable as they can be compared across similar models within the same dataset. As will be seen in Results Objective 3&4: Predicting Being Not Ready/Vulnerable and Comparing the G&FM Sub-Domain to the FM/VM Index this regression provided a better fitting model (higher R-square) than any other control variable only analysis. Odds Ratios resulting from this logistic regression are provided in Table 17. Variables are listed in the order in which they were selected for inclusion.

Table 17: Logistic Regression – Predicting being Vulnerable on the FM/VM Index

Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	3.63 (3.39-3.89)	<0.0001
Income Assistance	2.12 (1.93-2.32)	<0.0001
Age	0.35 (0.31-0.39)	<0.0001
Low Maternal Education	1.33 (1.22-1.46)	<0.0001
Maternal age at First Birth	0.99 (0.98-0.99)	<0.0001
6+ days in Hospital	1.28 (1.12-1.45)	0.0002
Low SES	1.15 (1.08-1.24)	<0.0001
4+ Children	1.20 (1.10-1.31)	<0.0001
Breastfeeding Initiation	0.85 (0.78-0.93)	0.0002
Physician Visits	1.00 (1.00-1.00)	0.0021
ICU Stay of 3+ Days at Birth	1.24 (1.04-1.47)	0.0160

The greatest odds of being Vulnerable on the FM/VM Index is associated with being male. Male children had 3.63 times greater odds of being Vulnerable on the FM/VM Index than female children. Income Assistance is also associated with a comparably high odds of being vulnerable (OR

2.12). Santos (2012) found most of these variables were associated with being 'Not Ready in one or more Domains'. The exception was Low Maternal Education, a variable not included in their analysis.

Objectives 3 & 4: Predicting Being Not Ready/Vulnerable and Comparing the G&FM Sub-Domain to the FM/VM Index

At this point, a further 1840 children were removed from the analysis (bringing the total to 24188). These children were removed as their EDI data was incomplete for one or more of the items on the G&FM Sub-Domain and, as a result, a raw score for the G&FM Sub-Domain could not be computed. Data for these 1840 children were assumed to be missing at random so complete case analysis was warranted. The removal of these children allowed for the same sample to be used in all three sets of regressions outlined below.

Multicollinearity. A test for multicollinearity was completed for all the control variables included in the analysis; as can be seen in **Appendix** 1, multicollinearity was not a concern for this set of variables.

Logistic Regressions. For each Domain and Sub-Domain which did not contain FM/VM Index questions, stepwise logistic regressions were completed for three different sets of models. The first includes control variables only. The second set of models replicated the control variable only regression and included the FM/VM Index. Comparison of the first two models allows for comment on whether the addition of the FM/VM Index provides a model that is a better fit for being ready on each domain than the control variable only model.

To determine whether the FM/VM Index contributed additional information when compared to the existing G&FM sub-domain, a third set of models were completed. These replicated the control variable only regressions, but also made the G&FM Sub-Domain available for inclusion. Comparison of the models with the G&FM Sub-Domain to the models with the FM/VM Index allowed for comment on whether including the G&FM Sub-Domain or the FM/VM Index provides a better fitting model for predicting being ready on each domain/sub-domain than the control variable only model.

The results of these regressions are outlined in the following two sections: Logistic Regressions Domains and Logistic Regressions Sub-Domains followed by a discussion of overall trends observed across the logistic regressions (Regression Summary). Control variables made available for the regression analyses are listed in Table 18 with further information on each variable available in Table 2.

Table 18: Control Variables

Environmental Variables	Child Variables	Health at Birth Variables
• Low SES • Income Assistance • Low Maternal Education • CFS Involvement • Maternal Age at First Birth • 4+ Children • Maternal Depression • Lone Parent Family	• Age • Sex • Number of Physician Visits • 2+ Major ADGs • 90% +Minor ADGs • 6+ Days in Hospital • ICU	• Breastfeeding Initiation • Long Birth Stay • Low Birth Weight • Prematurity • ICU Stay of 3+ Days at Birth

Logistic Regressions – Domains. Tables 19-25 include the final models for the EDI domain regressions with control variables only, control variables and the FM/VM Index, and control variables and the G&FM Sub-Domain. Regressions were computed for the Communication and General Knowledge and the Emotional Maturity Domains as these were the only two of the five domains that did not include FM/VM Index Questions.

Communication and General Knowledge Domain. The results of the three regressions for the

Communication and General Knowledge Domain. These are presented in Tables 19-21.

Table 19: Logistic Regression – Predicting Being Not Ready on Communication and General Knowledge Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.70 (1.50-1.93)	<0.0001
4+ Children	1.95 (1.74-2.18)	<0.0001
Age	0.35 (0.29-0.41)	<0.0001
Male	1.85 (1.67-2.04)	<0.0001
Low Maternal Education	1.67 (1.48-1.80)	<0.0001
Low Birth Weight	1.51 (1.22-1.87)	0.0002
Maternal Age at First Birth	0.98 (0.97-0.99)	0.0002
6+ Days in Hospital	1.26 (1.07-1.50)	0.0070
Breastfeeding Initiation	0.85 (0.75-0.97)	0.0115
Long Birth Stay	1.18 (1.03-1.35)	0.0161

Table 20: Logistic Regression –Predicting Being Not Ready on Communication and General Knowledge Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.00 (0.87-1.16)	0.9691
4+ Children	1.91 (1.68-2.17)	<0.0001
Age	0.64 (0.54-0.77)	<0.0001
Male	0.82 (0.73-0.92)	0.0006
Low Maternal Education	1.57 (1.37-1.80)	<0.0001
Low Birth Weight	1.24 (0.97-1.59)	0.0922
Maternal Age at First Birth	0.99 (0.98-1.00)	0.1708
6+ Days in Hospital	1.08 (0.89-1.31)	0.4562
Breastfeeding Initiation	0.90 (0.78-1.03)	0.1356
Long Birth Stay	1.06 (0.91-1.23)	0.4462
FM/VM Index	0.74 (0.73-0.75)	<0.0001

Table 21: Logistic Regression – Predicting Being Not Ready on Communication and General Knowledge Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.28 (1.11-1.50)	0.0004
4+ Children	2.08 (1.84-2.35)	<0.0001
Age	0.53 (0.44-0.63)	<0.0001
Male	1.31 (1.18-1.46)	<0.0001
Low Maternal Education	1.66 (1.46-1.90)	<0.0001
Low Birth Weight	1.23 (0.97-1.55)	0.0859
Maternal Age at First Birth	0.98 (0.97-1.55)	0.0048
6+ Days in Hospital	1.08 (0.90-1.30)	0.4370
Breastfeeding Initiation	0.91 (0.80-1.04)	0.1628
Long Birth Stay	1.10 (0.95-1.26)	0.2218
G&FM Sub-Domain	0.63 (0.61-0.64)	<0.0001

Both the FM/VM Index and the G&FM Sub-Domain were selected to be added to the regression models with a significance level of <0.0001. The addition of either the FM/VM Index or the G&FM Sub-Domain resulted in changes in the significance and direction of the association of control variables within the regression. Four variables were no longer significant with the addition of either the FM/VM Index or the G&FM Sub-Domain: Breastfeeding Initiation, 6+ Days in Hospital, Long Birth Stay and Low Birth Weight. An additional two variables were no longer significant with the addition of the FM/VM Index only: Income Assistance and Maternal Age at First Birth.

The direction of the effect of Sex on the odds of being Not Ready on the Communication and General Knowledge Domain varied across the three regressions. Being Male was associated with an increased odds of being Not Ready in regressions with control variables only as well as control variables and the G&FM Sub-Domain (odds ratio of 1.85 and 1.31 respectively). For the model with control variables and the FM/VM Index, there was an increased odds of being Not Ready associated with being Female (odds ratio of 1.22 or 1/0.82). This result was unexpected and will be discussed further later in this document. (See **Discussion, Objective 3**.)

Emotional Maturity Domain. The results of the three regressions for the Emotional Maturity Domain are found in Tables 22-24 with an overview of variables included in Table 25.

Table 22: Logistic Regression – Predicting Being Not Ready on Emotional Maturity Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	3.41 (3.10-3.77)	<0.0001
Income Assistance	1.81 (1.59-2.07)	<0.0001
Age	0.55 (0.47-0.64)	<0.0001
CFS Involvement	1.75 (1.41-2.17)	<0.0001
Low Maternal Education	1.25 (1.10-1.41)	0.0005
Long Birth Stay	1.27 (1.13-1.42)	<0.0001
Number of Physician Visits	1.00 (1.00-1.01)	0.0004
Maternal Depression	1.27 (1.09-1.47)	0.0015
Maternal Age at First Birth	0.99 (0.98-1.00)	0.0080
Lone Parent Family	1.18 (1.03-1.35)	0.0195

Table 23: Logistic Regression – Predicting Being Not Ready on Emotional Maturity Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	2.10 (1.89-2.33)	<0.0001
Income Assistance	1.25 (1.09-1.44)	0.0019
Age	0.88 (0.75-1.03)	0.1064
CFS Involvement	1.76 (1.40-2.21)	<0.0001
Low Maternal Education	1.12 (0.98-1.28)	0.0879
Long Birth Stay	1.17 (1.04-1.32)	0.0114
Number of Physician Visits	1.00 (1.00-1.00)	0.0130
Maternal Depression	1.21 (1.04-1.42)	0.0164
Maternal Age at First Birth	1.00 (0.99-1.01)	0.6650
Lone Parent Family	1.20 (1.04-1.39)	0.0145
FM/VM Index	0.81 (0.80-0.82)	<0.0001

Table 24: Logistic Regression – Predicting Being Not Ready on Emotional Maturity Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	2.84 (2.57-3.14)	<0.0001
Income Assistance	1.51 (1.32-1.73)	<0.0001
Age	0.74 (0.64-0.86)	0.0001
CFS Involvement	1.76 (1.41-2.20)	<0.0001
Low Maternal Education	1.20 (1.05-1.36)	0.0056
Long Birth Stay	1.19 (1.06-1.34)	0.0038
Number of Physician Visits	1.00 (1.00-1.00)	0.0260
Maternal Depression	1.22 (1.05-1.42)	0.0095
Maternal Age at First Birth	0.99 (0.98-1.00)	0.0539
Lone Parent Family	1.18 (1.03-1.36)	0.0206
G&FM Sub-Domain	0.75 (0.74-0.77)	<0.0001

As is seen in Tables 22-24, both the FM/VM Index and the G&FM Sub-Domain were selected to be added to the regression models with a significance level of <0.0001. The addition of the FM/VM Index or the G&FM Sub-Domain resulted in changes in the significance of control variables within the regression. Maternal Age at First Birth was no longer significant with the addition of either the FM/VM Index or the G&FM Sub-Domain. An additional two variables were no longer significant with the addition of the FM/VM Index only: Low Maternal Education and Age.

Trends Across Domains. While the variables selected for inclusion varied between the two domains, several were included for both sets of models: Low Maternal Education, Male, Age, Income Assistance, Long Birth Stay and Maternal Age at First Birth. Other variables were not selected for inclusion in both of these stepwise logistic regressions. These include: Low SES, 2+ Major ADGs, 90% + Minor ADGs, ICU, Premature, and ICU Stay of 3+ Days at Birth.

Table 25: Logistic Regression – FM/VM Index Predicting Being Not Ready on EDI Domains

Domain	Model	Max R-Square	Odds Ratio (CI)
Communication and General Knowledge	Control Variables only	0.0969	-
	Control Variables and FM/VM Index	0.3177	0.74 (0.73-0.75)
	Control Variables and G&FM Sub-Domain	0.2694	0.63 (0.61-0.64)
Emotional Maturity	Control Variables only	0.1020	-
	Control Variables and FM/VM Index	0.2242	0.81 (0.80-0.82)
	Control Variables and G&FM Sub-Domain	0.1774	0.75 (0.74-0.77)

Note: All regression models had a Chi-Square significant at $p<0.0001$. The FM/VM Index and the G&FM Sub-Domain were re-scaled such that the odds ratios reported represent a change of 5 points.

The inclusion of either the FM/VM Index or the G&FM Sub-Domain increased the quantity of variation explained by the models as shown by the higher Max R-square values over the control variables only models (Table 25). Further, the FM/VM Index models had higher Max R-square values over the G&FM Sub-Domain models suggesting that the addition of the FM/VM Index better fit the outcome data than the addition of the G&FM Sub-Domain.

The odds ratio represented the odds of being 'Not Ready' on the domain in question with each increase in score on the FM/VM Index or G&FM Sub-Domain. Therefore, an odds ratio of less than 1.00 indicates that a decrease in score (worse performance) on the FM/VM Index or G&FM sub-domain increases the odds of being Not Ready on the given domain. As can be seen in Table 25, all odds ratios are in the expected direction (those who are less at risk are less likely to be 'Not Ready' on the given domain). No confidence intervals cross 1.00 indicating these results are statistically significant.

Logistic Regressions – Sub-Domains. The same analysis set was then computed using sub-domains instead of domains as the dependent variable. Results are found in Tables 26-59.

Sub-Domains of the Physical Health and Well-Being Domain. Within the Physical Health and Well-Being Domain, regressions were completed for the Physical Readiness for School Sub-Domain. Items from the other two sub-domains within this Domain were included within the FM/VM Index and as such, logistic regressions for the other two sub-domains were not computed. The results of these regressions can be found in Tables 26-28.

Physical Readiness for School Sub-Domain. As was done for the domains, three regressions were computed for the Physical Readiness for School Sub-Domain. The first included control variables only, the second replicated the first and added the FM/VM Index and the third replicated the first and added the G&FM Sub-Domain.

Table 26: Logistic Regression – Predicting Being Vulnerable on Physical Readiness for School Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	2.63 (2.32-2.99)	<0.0001
Maternal Age at First Birth	0.94 (0.92-0.95)	<0.0001
4+ Children	1.70 (1.52-1.91)	<0.0001
Low Maternal Education	1.41 (1.25-1.59)	<0.0001
Long Birth Stay	1.24 (1.08-1.41)	0.0018
Low SES	1.18 (1.06-1.31)	0.0025
90%+ Minor ADG	1.19 (1.05-1.34)	0.0071
Age	0.82 (0.70-0.98)	0.0239

Table 27: Logistic Regression – Predicting Being Vulnerable on Physical Readiness for School Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	2.21 (1.94-2.51)	<0.0001
Maternal Age at First Birth	0.94 (0.93-0.95)	<0.0001
4+ Children	1.63 (1.45-1.83)	<0.0001
Low Maternal Education	1.35 (1.20-1.53)	<0.0001
Long Birth Stay	1.17 (1.02-1.34)	0.0251
Low SES	1.14 (1.02-1.27)	0.0176
90%+ Minor ADG	1.14 (1.00-1.29)	0.0468
Age	1.08 (0.91-1.29)	0.3574
FM/VM Index	0.89 (0.88-0.90)	<0.0001

Table 28: Logistic Regression – Predicting Being Vulnerable on Physical Readiness for School Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	2.29 (2.02-2.61)	<0.0001
Maternal Age at First Birth	0.94 (0.93-0.95)	<0.0001
4+ Children	1.68 (1.50-1.89)	<0.0001
Low Maternal Education	1.37 (1.21-1.55)	<0.0001
Long Birth Stay	1.16 (1.01-1.33)	0.0332
Low SES	1.16 (1.04-1.29)	0.0069
90%+ Minor ADG	1.12 (0.98-1.27)	0.0893
Age	1.09 (0.91-1.23)	0.3485
G&FM Sub-Domain	0.78 (0.77-0.80)	<0.0001

Income Assistance, Maternal Age at First Birth, 4+ Children, Low Maternal Education, Long Birth Stay and Low SES remained significant with the addition of the FM/VM Index or the G&FM Sub-Domain. Age was significant in the control variable only regression, but is not when either the FM/VM Index or the G&FM Sub-Domain are included. 90%+ Minor ADGs was significant in the control variable only regression and the regression with the FM/VM Index added but are not significant at the 0.05 level once the G&FM Sub-Domain is added.

Both the FM/VM Index and the G&FM Sub-Domain were selected for inclusion with odds ratios that are in the expected direction with a significance of <0.0001.

Table 29: Logistic Regression – FM/VM Index Predicting Being Vulnerable on Physical Health and Well-Being Sub-Domain

Sub-Domain	Model	Max R-Square	Odds Ratio (CI)
Physical Readiness for School	Control Variables only	0.1374	-
	Control Variables and FM/VM Index	0.1756	0.89 (0.88-0.90)
	Control Variables and G&FM Sub-Domain	0.1898	0.78 (0.77-0.80)

Note: All regression models had a Chi-Square significant at $p<0.0001$. The FM/VM Index and the G&FM Sub-Domain were re-scaled such that the odds ratios reported represent a change of 5 points.

The model containing the FM/VM Index and the model containing the G&FM Sub-Domain provided a better fit for readiness on the Physical Readiness for School Domain compared to the control variable only model, as demonstrated by a higher Max R-Square (See Table 29). Atypically for the regressions outlined here, the model with the G&FM Sub-Domain was a better fit than the model with the FM/VM Index. The size of the improvement in the model for this sub-domain was less than what was seen for most domains/sub-domains. Odds ratios for the variables of interest (FM/VM Index and the G&FM Sub-Domain) were again less than 1.00 with confidence intervals that did not cross 1.00. Both were significant with a relationship in the expected direction (lower scores on the FM/VM Index/G&FM Sub-Domain increased the odds of being Vulnerable on the Physical Readiness for School Sub-Domain).

Sub-Domains of the Social Competence Domain. A total of nine models were computed for the sub-domains of the Social Competence Domain, three for each of the three included sub-domains. Regressions for the Overall Social Competence Sub-Domain were not computed, as an item from this sub-domain was included in the FM/VM Index. The results of these regressions can be found in Tables 30-39.

Overall Social Competence. Tables 33-35 provide an overview of the three regressions computed for the Overall Social Competence Sub-Domain.

Table 30: Logistic Regression – Predicting Being Vulnerable on Overall Social Competence Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	2.08 (1.83-2.38)	<0.0001
Male	2.04 (1.86-2.25)	<0.0001
Age	0.59 (0.51-0.69)	<0.0001
Low Maternal Education	1.27 (1.12-1.44)	0.0002
Long Birth Stay	1.26 (1.12-1.43)	0.0002
CFS Involvement	1.46 (1.18-1.81)	0.0006
Lone Parent Family	1.23 (1.07-1.41)	0.0031
Number of Physician Visits	1.00 (1.00-1.00)	0.0231
Maternal Age at First Birth	0.99 (0.98-1.00)	0.0326
Premature	1.21 (1.01-1.44)	0.0388

Table 31: Logistic Regression – Predicting Being Vulnerable on Overall Social Competence Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.34 (1.16-1.55)	<0.0001
Male	1.07 (0.96-1.19)	0.2083
Age	1.07 (0.90-1.26)	0.4566
Low Maternal Education	1.12 (0.98-1.28)	0.0903
Long Birth Stay	1.19 (1.04-1.36)	0.0139
CFS Involvement	1.47 (1.16-1.86)	0.0016
Lone Parent Family	1.28 (1.10-1.48)	0.0014
Number of Physician Visits	1.00 (1.00-1.00)	0.3065
Maternal Age at First Birth	1.00 (0.99-1.01)	0.6397
Premature	1.09 (0.90-1.33)	0.3885
FM/VM Index	0.78 (0.77-0.79)	<0.0001

Table 32: Logistic Regression – Predicting Being Vulnerable on Overall Social Competence Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.12 (1.49-1.98)	<0.0001
Male	1.50 (1.35-1.67)	<0.0001
Age	0.94 (0.79-1.11)	0.4315
Low Maternal Education	1.16 (1.02-1.33)	0.0293
Long Birth Stay	1.18 (1.03-1.35)	0.0192
CFS Involvement	1.49 (1.18-1.89)	0.0009
Lone Parent Family	1.25 (1.07-1.45)	0.0039
Number of Physician Visits	1.00 (1.00-1.00)	0.8128
Maternal Age at First Birth	1.00 (0.99-1.01)	0.3886
Premature	1.08 (0.89-1.32)	0.4317
G&FM Sub-Domain	0.66 (0.64-0.67)	<0.0001

Of the 11 variables in the control variable only regression, only four remained significant when the FM/VM Index or G&FM Sub-Domain were added to the model: Lone Parent Family, CFS Involvement, Income Assistance, and Long Birth Stay. In addition to those four variables, Low Maternal Education and Male also remained significant in the G&FM Sub-Domain model. It should be noted that the control variable only model for the Overall Social Competence Sub-Domain was the only model where premature was selected for inclusion.

Here again, both the FM/VM Index and the G&FM Sub-Domain were selected for inclusion. Both were significant with poorer performance on the FM/VM Index or G&FM Sub-Domain increasing the odds of being Vulnerable on the Overall Social Competence Sub-Domain.

Responsibility and Respect Sub-Domain. Results of the three regressions computed for the Responsibility and Respect Sub-Domain are found in Tables 33-35.

Table 33: Logistic Regression – Predicting Being Vulnerable on Responsibility and Respect Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.35 (1.13-1.63)	<0.0001
Male	2.80 (2.44-3.23)	<0.0001
Long Birth Stay	1.36 (1.16-1.59)	0.0001
CFS Involvement	1.66 (1.26-2.18)	0.0003
Lone Parent Family	1.35 (1.13-1.63)	0.0013
90%+ Minor ADG	1.23 (1.05-1.43)	0.0094
Age	0.77 (0.62-0.96)	0.0187
Maternal Depression	1.23 (1.01-1.51)	0.0443

Table 34: Logistic Regression – Predicting Being Vulnerable on Responsibility and Respect Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.35 (1.14-1.61)	0.0007
Male	1.59 (1.37-1.84)	<0.0001
Long Birth Stay	1.26 (1.07-1.48)	0.0061
CFS Involvement	1.55 (1.15-2.07)	0.0036
Lone Parent Family	1.34 (1.11-1.63)	0.0027
90%+ Minor ADG	1.17 (0.99-1.37)	0.0620
Age	1.31 (1.05-1.63)	0.0168
Maternal Depression	1.15 (0.93-1.43)	0.1896
FM/VM Index	0.81 (0.80-0.82)	<0.0001

Table 35: Logistic Regression – Predicting Being Vulnerable on Responsibility and Respect Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.80 (1.52-2.12)	<0.0001
Male	2.23 (1.94-2.58)	<0.0001
Long Birth Stay	1.27 (1.09-1.50)	0.0030
CFS Involvement	1.60 (1.21-2.12)	0.0011
Lone Parent Family	1.35 (1.12-1.63)	0.0018
90%+ Minor ADGs	1.17 (1.00-1.36)	0.0564
Age	1.07 (0.86-1.33)	0.05343
Maternal Depression	1.19 (0.96-1.46)	0.1062
G&FM Sub-Domain	0.75 (0.73-0.77)	<0.0001

The regressions for the Responsibility and Respect Sub-Domain once again had a set of variables that remained significant even with the addition of the FM/VM Index or the G&FM Sub-Domain: Male, CFS Involvement, Lone Parent Family, Long Birth Stay. Two variables were no longer significant when either the FM/VM Index or the G&FM Sub-Domain were added: Maternal Depression, and 90% Minor ADGs. Age was significant in the control variable only model and the model with the FM/VM Index, but not in the model with the G&FM Sub-Domain. Both the FM/VM Index and the G&FM Sub-Domain were selected to be added into the regression with a significance of <0.0001 and odds ratios below 1.00 as was expected.

Readiness to Explore New Things Sub-Domain. Readiness to Explore New Things was the last sub-domain within the Social Competence Domain. Results of the three regressions computed for this sub-domain are found in Tables 36-38.

Table 36: Logistic Regression – Predicting Being Vulnerable on Readiness to Explore New Things Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.89 (1.53-2.33)	<0.0001
Male	1.70 (1.43-2.02)	<0.0001
Age	0.48 (0.36-0.64)	<0.0001
Maternal Age at First Birth	0.97 (0.95-0.98)	0.0003
6+ Days in Hospital	1.49 (1.12-1.96)	0.0054
4+ Children	1.30 (1.05-1.61)	0.0141

Table 37: Logistic Regression – Predicting Being Vulnerable on Readiness to Explore New Things Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.00 (0.80-1.24)	0.9810
Male	0.76 (0.63-0.92)	0.0048
Age	0.93 (0.69-1.26)	0.6413
Maternal Age at First Birth	0.98 (0.96-1.00)	0.0242
6+ Days in Hospital	1.20 (0.89-1.62)	0.2222
4+ Children	1.10 (0.88-1.37)	0.4214
FM/VM Index	0.77 (0.75-0.78)	<0.0001

Table 38: Logistic Regression – FM/VM Index Predicting Being Vulnerable on Readiness to Explore New Things Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.40 (1.13-1.73)	0.0020
Male	1.23 (1.02-1.47)	0.0262
Age	0.73 (0.54-0.98)	0.0337
Maternal Age at First Birth	0.97 (0.95-0.99)	0.0019
6+ Days in Hospital	1.26 (0.95-1.67)	0.1139
4+ Children	1.26 (1.02-1.56)	0.0352
G&FM Sub-Domain	0.68 (0.66-0.71)	<0.0001

As can be noted in the above tables, both the FM/VM Index and the G&FM Sub-Domain were selected to be added to the regression models with a significance level of <0.0001. The addition of the FM/VM Index or the G&FM Sub-Domain resulted in changes in the significance of control variables within the regression. 6+ Days in Hospital was no longer significant with the addition of either the FM/VM Index or the G&FM Sub-Domain. Additionally, 4+ Children, Income Assistance, and Age were no longer significant with the FM/FM Index included.

The direction of the effect of Sex on the odds of being Vulnerable on the Readiness to Explore New Things Sub-Domain varied across the three regressions. Being Male had an increased odds of being Not Ready in regressions with control variables only as well as control variables and the G&FM Sub-Domain (odds ratio of 1.70 and 1.23 respectively). For the model with control variables and the FM/VM Index, there was an increased odds of being Not Ready associated with being Female (odds ratio of 1.32 or 1/0.76).

Overview of the Sub-Domains of the Social Competence Domain. The variables selected for inclusion varied between the sub-domains, with only three being included for all three sets of models: Income Assistance, Male, and Age. Only one of these variables remained significant at the 0.05 level once the FM/VM Index or the G&FM Sub-Domain was added: Sex (Male), although as discussed above in one instance (Readiness to Explore New Things with the FM/VM Index) the direction of the association changed. Some variables were absent in all three sets of regressions. These include: Low SES, 2+ Major ADGs, ICU, Breastfeeding Initiation, Premature and ICU Stay of 3+ Days at Birth.

Table 39: Logistic Regression – FM/VM Index Predicting Being Vulnerable on Social Competence Sub-Domains

Sub-Domain	Model	Max R-Square	Odds Ratio (CI)
Approaches to Learning	Control Variables only	0.0685	-
	Control Variables and FM/VM Index	0.2333	0.78 (0.77-0.79)
	Control Variables and G&FM Sub-Domain	0.2198	0.66 (0.64-0.67)
Responsibility and Respect	Control Variables only	0.0713	-
	Control Variables and FM/VM Index	0.1842	0.81 (0.80-0.82)
	Control Variables and G&FM Sub-Domain	0.1372	0.75 (0.73-0.77)
Readiness to Explore New Things	Control Variables only	0.0400	-
	Control Variables and FM/VM Index	0.2031	0.77 (0.75-0.78)
	Control Variables and G&FM Sub-Domain	0.1356	0.68 (0.66-0.71)

Note: All regression models had a Chi-Square significant at $p<0.0001$. The FM/VM Index and the G&FM Sub-Domain were re-scaled such that the odds ratios reported represent a change of 5 points.

A total of nine different models run for the sub-domains of the Social Competence Domain. Odds ratios for the variables of interest (FM/VM Index and the G&FM Sub-Domain) were again less than 1.00 with confidence intervals that did not cross 1.00. Both were significant with a relationship in the expected direction (lower scores on the FM/VM Index increased the odds of being Vulnerable on the given sub-domain).

Again, both the models with the FM/VM Index and those with the G&FM Sub-Domain were better fitting models than those with the control variables only for the sub-domains of the Social Competence Domain. The models containing the FM/VM Index provided a better fit for the outcome data than those with the G&FM Sub-Domain (See Table 39.) The improvement in the Max R-square for the Approaches to Learning Sub-Domain was especially noteworthy as it is one of the largest changes seen in this work.

Sub-Domains of the Emotional Maturity Domain. Regressions were computed for all four sub-domains within the Emotional Maturity Domain as no questions from this domain were included in the FM/VM Index. The results of these 12 regressions can be found in Tables 40-52.

Prosocial and Helping Behaviour Sub-Domain. The results of the three regressions computed for the Prosocial and Helping Behaviour Sub-Domain can be found in Tables 40-42.

Table 40: Logistic Regression – Predicting Being Vulnerable on Prosocial and Helping Behaviour Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	1.96 (1.86-2.07)	<0.0001
Income Assistance	1.35 (1.24-1.47)	<0.0001
Age	0.68 (0.62-0.75)	<0.0001
Low Maternal Education	1.16 (1.07-1.26)	0.0003
4+ Children	1.17 (1.09-1.27)	<0.0001
CFS Involvement	1.37 (1.15-1.64)	0.0006
ICU	1.36 (1.08-1.72)	0.0097
Lone Parent Family	1.15 (1.04-1.27)	0.0064
Low Birth Weight	1.19 (1.04-1.35)	0.0112
Number of Physician Visits	1.00 (1.00-1.00)	0.0146

Table 41: Logistic Regression – Predicting Being Vulnerable on Prosocial and Helping Behaviour Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	1.48 (1.40-1.57)	<0.0001
Income Assistance	1.08 (0.99-1.18)	0.0918
Age	0.88 (0.80-0.97)	0.0080
Low Maternal Education	1.07 (0.98-1.17)	0.1131
4+ Children	1.10 (1.02-1.19)	0.0185
CFS Involvement	1.34 (1.11-1.61)	0.0024
ICU	1.31 (1.02-1.66)	0.0315
Lone Parent Family	1.13 (1.02-1.25)	0.0234
Low Birth Weight	1.08 (0.94-1.24)	0.2668
Number of Physician Visits	1.00 (1.00-1.00)	0.1174
FM/VM Index	0.87 (0.87-0.88)	<0.0001

Table 42: Logistic Regression – Predicting Being Vulnerable on Prosocial and Helping Behaviour Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	1.78 (1.68-1.88)	<0.0001
Income Assistance	1.23 (1.12-1.34)	<0.0001
Age	0.79 (0.72-0.87)	<0.0001
Low Maternal Education	1.12 (1.03-1.22)	0.0083
4+ Children	1.15 (1.07-1.24)	0.0003
CFS Involvement	1.36 (1.13-1.63)	0.0010
ICU	1.28 (1.01-1.62)	0.0436
Lone Parent Family	1.13 (1.02-1.25)	0.0173
Low Birth Weight	1.10 (0.96-1.25)	0.1703
Number of Physician Visits	1.00 (1.00-1.00)	0.1307
G&FM Sub-Domain	0.86 (0.85-0.87)	<0.0001

As can be seen in the above tables, both the FM/VM Index and the G&FM Sub-Domain were selected to be added to the regression models with a significance level of $p<0.0001$. The addition of the FM/VM Index or the G&FM Sub-Domain resulted in changes in the significance of control variables within the regression. Two variables were no longer significant with the addition of either the FM/VM Index or the G&FM Sub-Domain: Number of Physician and Visits Low Birth Weight. An additional two variables were no longer significant with the addition of the FM/VM Index only: Income Assistance and Low Maternal Education.

Here, both the FM/VM Index and the G&FM Sub-Domain were selected for inclusion. Both were significant with poorer performance on the FM/VM Index or G&FM Sub-Domain increasing the odds of being Vulnerable on the Prosocial and Helping Behaviour Sub-Domain.

Anxious and Fearful Behaviour Sub-Domain. Tables 43-45 contain an overview of the results of the three regressions computed for the Anxious and Fearful Behaviour Sub-Domain.

Table 43: Logistic Regression – Predicting Being Vulnerable on Anxious and Fearful Behaviour Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.46 (1.20-1.78)	0.0002
Age	0.71 (0.53-0.95)	0.0213
Long Birth Stay	1.28 (1.03-1.59)	0.0255

Table 44: Logistic Regression – FM/VM Index Predicting Being Vulnerable on Anxious and Fearful Behaviour Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.03 (0.83-1.26)	0.8093
Age	0.95 (0.70-1.27)	0.7051
Long Birth Stay	1.20 (0.86-0.90)	0.1046
FM/VM Index	0.88 (0.86-0.90)	<0.0001

Table 45: Logistic Regression – Predicting Being Vulnerable on Anxious and Fearful Behaviour Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.08 (0.88-1.32)	0.4787
Age	0.99 (0.74-1.33)	0.9388
Long Birth Stay	1.15 (0.93-1.43)	0.2071
G&FM Sub-Domain	0.73 (0.71-0.76)	<0.0001

The most notable thing about the Anxious and Fearful Behaviour Sub-Domain was how few variables were included in any of the logistic regressions. Additionally, the included variables (Income Assistance, Age and Long Birth Stay) were no longer significant once either the FM/VM Index or the G&FM Sub-Domain were added to the regression. When included, the FM/VM Index or the G&FM Sub-Domain had significant odds ratios suggesting that better skill on the FM/VM Index/G&FM Sub-Domain improve the odds of being Not Vulnerable on the Anxious and Fearful Behaviour Sub-Domain.

Aggressive Behaviour Sub-Domain. The same three regressions were computed for the Aggressive Behaviour Sub-Domain. Results are found in Tables 46-48.

Table 46: Logistic Regression – Predicting Being Vulnerable on Aggressive Behaviour Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	3.14 (2.82-3.51)	<0.0001
Income Assistance	1.94 (1.70-2.23)	<0.0001
CFS Involvement	1.95 (1.56-2.44)	<0.0001
Low Maternal Education	1.24 (1.09-1.43)	0.0017
Number of Physician Visits	1.00 (1.00-1.01)	0.0014
Age	0.78 (0.66-0.92)	0.0027
Maternal Depression	1.23 (1.04-1.45)	0.0134
Maternal Age at First Birth	0.99 (0.98-1.00)	0.0284

Table 47: Logistic Regression – Predicting Being Vulnerable on Aggressive Behaviour Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	2.39 (2.13-2.68)	<0.0001
Income Assistance	1.58 (1.38-1.82)	<0.0001
CFS Involvement	1.92 (1.53-2.41)	<0.0001
Low Maternal Education	1.17 (1.02-1.35)	0.0232
Number of Physician Visits	1.00 (1.00-1.01)	0.0094
Age	1.00 (0.84-1.18)	0.9945
Maternal Depression	1.20 (1.01-1.41)	0.0347
Maternal Age at First Birth	0.99 (0.98-1.00)	0.2046
FM/VM Index	0.90 (0.89-0.91)	<0.0001

Table 48: Logistic Regression – Predicting Being Vulnerable on Aggressive Behaviour Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	2.90 (2.60-3.24)	<0.0001
Income Assistance	1.80 (1.57-2.07)	<0.0001
CFS Involvement	1.94 (1.55-2.43)	<0.0001
Low Maternal Education	1.22 (1.06-1.40)	0.0043
Number of Physician Visits	1.00 (1.00-1.01)	0.0069
Age	0.87 (0.74-1.03)	0.1121
Maternal Depression	1.21 (1.03-1.42)	0.0229
Maternal Age at First Birth	0.99 (0.99-1.00)	0.0480
G&FM Sub-Domain	0.90 (0.88-0.92)	<0.0001

Inclusion of either the FM/VM Index or the G&FM Sub-Domain made the variable Age no longer significant. All other variables remained significant in both the FM/VM Index and the G&FM Sub-Domain models except for Maternal Age at First Birth which was no longer significant in the FM/VM Index model.

Once again, the FM/VM Index and the G&FM Sub-Domain were selected for inclusion in these models. They were both significant with poorer performance on the FM/VM Index or G&FM Sub-Domain being associated with increased odds of poorer performance on the Aggressive Behaviour Sub-Domain.

Hyperactivity and Inattention Sub-Domain. Hyperactivity and Inattention was the final sub-domain for the Emotional Maturity Domain. Results of the three regressions computed for this sub-domain are found below in Tables 49-51.

Table 49: Logistic Regression – Predicting Being Vulnerable on Hyperactivity and Inattention Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	3.58 (3.28-3.91)	<0.0001
Income Assistance	1.88 (1.68-2.10)	<0.0001
Age	0.53 (0.46-0.61)	<0.0001
CFS Involvement	1.64 (1.34-2.02)	<0.0001
Low Maternal Education	1.29 (1.15-1.44)	<0.0001
Long Birth Stay	1.22 (1.10-1.35)	0.0001
Maternal Depression	1.20 (1.05-1.37)	0.0079
Maternal Age at First Birth	0.99 (0.98-1.00)	0.0101
90%+ Minor ADG	1.13 (1.02-1.25)	0.0181
Low SES	0.91 (0.84-1.00	0.0392

Table 50: Logistic Regression – Predicting Being Vulnerable on Hyperactivity and Inattention Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	2.31 (2.10-2.53)	<0.0001
Income Assistance	1.37 (1.22-1.55)	<0.0001
Age	0.81 (0.70-0.94)	0.0038
CFS Involvement	1.62 (1.30-2.02)	<0.0001
Low Maternal Education	1.17 (1.04-1.32)	0.0078
Long Birth Stay	1.14 (1.02-1.27)	0.0230
Maternal Depression	1.15 (0.99-1.32)	0.0647
Maternal Age at First Birth	1.00 (0.99-1.01)	0.6351
90%+ Minor ADG	1.08 (0.97-1.20)	0.1629
Low SES	0.84 (0.76-0.92)	0.0002
FM/VM Index	0.82 (0.81-0.83)	<0.0001

Table 51: Logistic Regression – Predicting Being Vulnerable on Hyperactivity and Inattention Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Male	3.07 (2.81-3.35)	<0.0001
Income Assistance	1.62 (1.44-1.81)	<0.0001
Age	0.68 (0.59-0.78)	<0.0001
CFS Involvement	1.63 (1.32-2.02)	<0.0001
Low Maternal Education	1.25 (1.11-1.40)	0.0002
Long Birth Stay	1.15 (1.04-1.28)	0.0076
Maternal Depression	1.15 (1.01-1.33)	0.0415
Maternal Age at First Birth	0.99 (0.98-1.00)	0.0515
90%+ Minor ADG	1.08 (0.97-1.20)	0.1431
Low SES	0.884 (0.81-0.97)	0.0068
G&FM Sub-Domain	0.79 (0.77-0.80)	<0.0001

As is seen in Tables 49-51, both the FM/VM Index and the G&FM Sub-Domain were selected to be added to the regression models with a significance level of <0.0001. The addition of the FM/VM Index or the G&FM Sub-Domain resulted in Maternal Age at First Birth and 90%+ Minor ADG's no longer being significant. The addition of the FM/VM Index also made Maternal Depression no longer significant.

Both the FM/VM Index and the G&FM Sub-Domain were selected for inclusion. Both were significant with poorer performance on the FM/VM Index or G&FM Sub-Domain increasing the odds of being Vulnerable on the Basic Numeracy Sub-Domain.

Overview of the Sub-Domains of the Emotional Maturity Domain. As was noted above, the Anxious and Fearful Behaviour regressions contained only three control variables: Income Assistance, Age and Long Birth Stay. Two of these three control variables (Income Assistance and Age) were also included in the regressions for the three other sub-domains within the Emotional Maturity Domain. Male, Low Maternal Education and CFS Involvement were included in the regressions of all three of the other sub-domains.

Again, there were some control variables that were not selected for any of the 4 sub-domains. These were: 2+ Major ADGs, 6+ Days in Hospital, Breastfeeding Initiation, Premature, and an ICU stay of 3+ Days at Birth.

Table 52: Logistic Regression – FM/VM Index Predicting Being Vulnerable on Emotional Maturity Sub-Domains

Sub-Domain	Model	Max R-Square	Odds Ratio (CI)
Prosocial and Helping Behaviour	Control Variables only	0.535	-
	Control Variables and FM/VM Index	0.1209	0.87 (0.87-0.88)
	Control Variables and G&FM Sub-Domain	0.0869	0.86 (0.85-0.87)
Anxious and Fearful Behaviour	Control Variables only	0.0049	-
	Control Variables and FM/VM Index	0.0419	0.88 (0.86-0.90)
	Control Variables and G&FM Sub-Domain	0.0711	0.73 (0.71-0.76)
Aggressive Behaviour	Control Variables only	0.0837	-
	Control Variables and FM/VM Index	0.1166	0.90 (0.89-0.91)
	Control Variables and G&FM Sub-Domain	0.0941	0.90 (0.88-0.92)
Hyperactivity and Inattention	Control Variables only	0.1080	-
	Control Variables and FM/VM Index	0.2236	0.82 (0.81-0.83)
	Control Variables and G&FM Sub-Domain	0.1682	0.79 (0.77-0.80)

Note: All regression models had a Chi-Square significant at $p<0.0001$. The FM/VM Index and the G&FM Sub-Domain were re-scaled such that the odds ratios reported represent a change of 5 points.

In reviewing the sub-domains of the Emotional Maturity Domain, the Anxious and Fearful Behaviour Sub-Domain stood out for its low degrees of freedom as only three variables were selected for inclusion in the control variable only model. The Max R-Squares for all three Anxious and Fearful Behaviour models were also quite low in comparison to the other models run, suggesting that the included variables were not as strongly associated with the outcomes for this sub-domain as they were for the other domains/sub-domains. (See Table 52.) As has been seen for all sub-domains thus far, both the models with the FM/VM Index and those with the G&FM Sub-Domain provided a better fit than those with the control variables only for the sub-domains of the Emotional Maturity Domains, as demonstrated by an increase in the Max R-Square (See Table 52). For three of the sub-domains in the

Emotional Maturity Domain, the models containing the FM/VM Index provided a better fit than those with the G&FM Sub-Domain. The exception is the Anxious and Fearful Behaviour Sub-Domain. This sub-domain was one of two (Physical Readiness for School being the other) where the model with the G&FM Sub-Domain was a better fitting model than that with the FM/VM Index. Odds ratios for the variables of interest (FM/VM Index and the G&FM Sub-Domain) were again less than 1.00 with confidence intervals that did not cross 1.00 across all of the sub-domains. Both were significant with a relationship in the expected direction (lower scores on the FM/VM Index increased the odds of being Vulnerable on the given sub-domain).

Sub-Domains of the Language and Cognitive Development Domain. The last of the Domains is the Language and Cognitive Development Domain. It again has four sub-domains, but two of these, Basic Literacy and Advanced Literacy, contain FM/VM Index questions. As a result, regressions were only computed for two of the sub-domains, Interest in Literacy/Numeracy and Memory and Basic Numeracy. Information of these logistic regressions can be found in Tables 53-59**.**

Interest in Literacy/Numeracy and Memory. Tables 53-55 contain the results of the three regressions where Interest in Literacy/Numeracy and Memory was the dependent variable.

Table 53: Logistic Regression – Predicting Being Vulnerable on interest in Literacy/Numeracy and Memory Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	2.00 (1.80-2.22)	<0.0001
Age	0.42 (0.36-0.48)	<0.0001
Maternal Age at First Birth	0.96 (0.95-0.97)	<0.0001
Male	1.56 (1.44-1.70)	<0.0001
Long Birth Stay	1.20 (1.08-1.34)	0.0011
4+ Children	1.25 (1.13-1.38)	<0.0001
90%+ Minor ADGs	1.19 (1.08-1.32)	0.0008
Breastfeeding Initiation	0.84 (0.75-0.93)	0.0007
Low Maternal Education	1.17 (1.05-1.30)	0.0044
6+ Days in Hospital	1.21 (1.05-1.40)	0.0095
Low Birth Weight	1.28 (1.06-1.54)	0.0109

Table 54: Logistic Regression – Predicting Being Vulnerable on Interest in Literacy/Numeracy and Memory Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.26 (1.11-1.42)	0.0002
Age	0.82 (0.70-0.96)	0.0129
Maternal Age at First Birth	0.97 (0.95-0.98)	<0.0001
Male	0.59 (0.54-0.65)	<0.0001
Long Birth Stay	1.11 (0.97-1.26)	0.1210
4+ Children	1.10 (0.97-1.24)	0.1368
90%+ Minor ADGs	1.15 (1.02-1.30)	0.0204
Breastfeeding Initiation	0.89 (0.79-1.00)	0.0563
Low Maternal Education	1.00 (0.89-1.21)	0.9544
6+ Days in Hospital	1.02 (0.85-1.21)	0.8416
Low Birth Weight	1.03 (0.82-1.29)	0.7948
FM/VM Index	0.70 (0.69-0.71)	<0.0001

Table 55: Logistic Regression – Predicting Being Vulnerable on Interest in Literacy/Numeracy and Memory Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.66 (1.49-1.86)	<0.0001
Age	0.58 (0.51-0.67)	<0.0001
Maternal Age at First Birth	0.96 (0.95-0.97)	<0.0001
Male	1.19 (1.10-1.30)	<0.0001
Long Birth Stay	1.14 (1.01-1.28)	0.0295
4+ Children	1.23 (1.11-1.37)	0.0001
90%+ Minor ADGs	1.14 (1.03-1.27)	0.0149
Breastfeeding Initiation	0.88 (0.79-0.98)	0.0213
Low Maternal Education	1.11 (0.99-1.24)	0.0728
6+ Days in Hospital	1.08 (0.92-1.26)	0.3391
Low Birth Weight	1.09 (0.89-1.33)	0.3909
G&FM Sub-Domain	0.70 (0.69-0.72)	<0.0001

Inclusion of either the FM/VM Index or the G&FM Sub-Domain made the 6+ Days in Hospital, Low Birth Weight and Low Maternal Education variables no longer significant. 4+ Children, Long Birth Stay and Breastfeeding Initiation were also no longer significant in the FM/VM Index regression.

Once again, the direction of the effect of Sex was reversed for the FM/VM Index model of this sub-domain. Being Male was associated with increased odds of being Vulnerable on the Interest in Literacy/Numeracy and Memory Sub-Domain within the control variable only and the G&FM Sub-Domain regressions (increases of 1.56 and 1.19 times respectively). On the FM/VM Index model however there was a 1.69 (1/0.59) times increase in the odds of being Vulnerable associated with being Female.

The FM/VM Index and the G&FM Sub-Domain were selected for inclusion in these models.

They were both significant with poorer performance on the FM/VM Index or G&FM Sub-Domain and increased the odds of being Vulnerable on the Interest in Literacy/Numeracy and Memory Sub-Domain.

Basic Numeracy Sub-Domain. The final three regressions computed were for the Basic Numeracy Sub-Domain. Their results are found in Tables 56-58.

Table 56: Logistic Regression – Predicting Being Vulnerable on Basic Numeracy Sub-Domain, Control Variables Only

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	2.00 (1.82-2.01)	<0.0001
Age	0.31 (0.28-0.35)	<0.0001
Maternal Age at First Birth	0.95 (0.95-0.96)	<0.0001
4+ Children	1.48 (1.36-1.62)	<0.0001
Male	1.33 (1.24-1.43)	<0.0001
Low Maternal Education	1.39 (1.26-1.53)	<0.0001
Low Birth Weight	1.62 (1.39-1.90)	<0.0001
Breastfeeding Initiation	0.82 (0.75-0.90)	<0.0001
6+ Days in Hospital	1.22 (1.07-1.40)	0.0037
Low SES	1.12 (1.03-1.20)	0.0055
90%+ Minor ADG	1.13 (1.03-1.24)	0.0093

Table 57: Logistic Regression – Predicting Being Vulnerable on Basic Numeracy Sub-Domain, Control Variables and FM/VM Index

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.45 (1.30-1.61)	<0.0001
Age	0.50 (0.44-0.57)	<0.0001
Maternal Age at First Birth	0.96 (0.95-0.97)	<0.0001
4+ Children	1.41 (1.27-1.56)	<0.0001
Male	0.60 (0.55-0.65)	<0.0001
Low Maternal Education	1.29 (1.16-1.44)	<0.0001
Low Birth Weight	1.40 (1.17-1.67)	0.0003
Breastfeeding Initiation	0.85 (0.77-0.95)	0.0032
6+ Days in Hospital	1.07 (0.92-1.25)	0.3727
Low SES	1.02 (0.93-1.11)	0.7185
90%+ Minor ADG	1.09 (0.98-1.21)	0.1288
FM/VM Index	0.75 (0.74-0.75)	<0.0001

Table 58: Logistic Regression – Predicting Being Vulnerable on Basic Numeracy Sub-Domain, Control Variables and G&FM Sub-Domain

Included Variable	Odds Ratio (95% Wald Confidence Limits)	Significance
Income Assistance	1.75 (1.58-1.93)	<0.0001
Age	0.40 (0.35-0.46)	<0.0001
Maternal Age at First Birth	0.96 (0.95-0.96)	<0.0001
4+ Children	1.49 (1.36-1.64)	<0.0001
Male	1.06 (0.98-1.14)	0.1268
Low Maternal Education	1.35 (1.22-1.49)	<0.0001
Low Birth Weight	1.42 (1.21-1.68)	<0.0001
Breastfeeding Initiation	0.85 (0.77-0.94)	0.0015
6+ Days in Hospital	1.11 (0.97-1.28)	0.1414
Low SES	1.09 (1.01-1.18)	0.0352
90%+ Minor ADG	1.09 (0.99-1.20)	0.0951
G&FM Sub-Domain	0.75 (0.74-0.76)	<0.0001

Once again, the FM/VM Index and the G&FM Sub-Domain were selected for inclusion in these models. They were both significant with poorer performance on the FM/VM Index or G&FM Sub-Domain increasing the odds of being Vulnerable on the Basic Numeracy Sub-Domain. Inclusion of either the FM/VM Index or the G&FM Sub-Domain made the 90%+ Minor ADGs and 6+ Days in Hospital variables no longer significant. Low SES was also no longer significant in the FM/VM Index regression.

Sex was no longer significant when the G&FM Sub-Domain was included. This instance was the only regression where Sex did not remain a significant variable if it was included in the control variable only model. Once again, the direction of the effect of Sex was reversed for the FM/VM Index model of this sub-domain. Being Male was associated with an increased odds of being Vulnerable within the control variable only regression (OR of 1.33). On the FM/VM Index model, however, there was a 1.66 (1/0.60) times increase in the odds of being Vulnerable associated with being Female.

Overview of the Sub-Domains of the Language and Cognitive Development Domain.

Within the control variable regressions for the two sub-domains considered here, there was consistency in how the Sex variable behaved. For both sub-domains, Females had higher odds compared to Males of being Vulnerable when the FM/VM Index is included in the model.

Once again there were some control variables that were not selected for either of the sub-domains. These were: CFS Involvement, Maternal Depression, Lone Parent Family, Number of Physician Visits, 2+ Major ADGs, ICU, ICU Stay of 3+ Days at Birth and Premature.

Table 59: Logistic Regression – FM/VM Index Predicting Being Vulnerable on Language and Cognitive Development Sub-Domains

Sub-Domain	Model	Max R-Square	Odds Ratio (CI)
Interest in Literacy/ Numeracy and Memory	Control Variables only	0.0872	-
	Control Variables and FM/VM Index	0.3795	0.70 (0.69-0.71)
	Control Variables and G&FM Sub-Domain	0.2101	0.70 (0.69-0.72)
Basic Numeracy	Control Variables only	0.1273	-
	Control Variables and FM/VM Index	0.3425	0.75 (0.74-0.75)
	Control Variables and G&FM Sub-Domain	0.2139	0.75 (0.74-0.76)

Note: All regression models had a Chi-Square significant at $p<0.0001$. The FM/VM Index and the G&FM Sub-Domain were re-scaled such that the odds ratios reported represent a change of 5 points.

Across the considered sub-domains of the Language and Cognitive Development Domain, models with the FM/VM Index or the G&FM Sub-Domain once again provided a better fit than those with control variables only (See Table 59). The improvements observed in the Max R-Square for the Basic Numeracy and the Interest in Literacy/Numeracy and Memory when the FM/VM Index was added, were amongst the largest of the sub-domain models. Further, the models containing the FM/VM Index once again provided a better fitting model than those with the G&FM Sub-Domain as demonstrated by a larger Max R-Square.

For both these sub-domains, odds ratios for the variables of interest (FM/VM Index and the G&FM Sub-Domain) were again less than 1.00 with confidence intervals that did not cross one. Both were significant with a relationship in the expected direction (lower scores on the FM/VM Index increases the odds of being Vulnerable on the given sub-domain).

Summary of Results

The first objective of this thesis was to create a FM/VM Index with strong face validity and internal consistency using a Delphi method with the help of 10 occupational therapists (nine in later rounds). Through three survey rounds, they identified 11 of the 58 EDI questions to be included on a FM/VM Index. Internal consistency was then established as the index was found to have a Cronbach's alpha that was comparable to both the published and the study-specific Cronbach's alphas for the established sub-domains. To complete this first objective, a cutoff score was established of <80 using the ROC curves for the domains/sub-domains with >25% overlap with the FM/VM Index. Below that cutoff score, children are considered Vulnerable, with skills that do not meet the minimum needed for school.

The second study objective was to describe the population of children considered Vulnerable on the FM/VM Index. Descriptive statistics were computed showing that children who were Vulnerable on the FM/VM Index were statistically different than those who were not Vulnerable for all the environmental, child, and health variables (except for 2+Major ADGs where results could not be reported).

Logistic regression analysis showed that child variables (Sex, Age, and 6+ Days in Hospital), environmental variables (Income Assistance, Low Maternal Education, Maternal Age at First Birth, Low SES, Physician Visits and 4+ Children), and Health at Birth Variables (Breastfeeding Initiation, and ICU Stay of 3+ Days at Birth) all impact the odds of being Vulnerable on the FM/VM Index.

The third objective of this study was to determine if lower scores on the FM/VM Index were related to being Not Ready/Vulnerable in other areas of readiness. Two sets of logistic regressions were computed using each domain, then each sub-domain, as the dependent variable so long as there was no question overlap between the domain/sub-domain and the FM/VM Index. Comparison of logistic regressions determined that for each domain/sub-domain the model was improved by the addition of the FM/VM Index as seen through an increase in the Max R-square. Further, the odds ratios computed suggested the expected direction of the relationship between scores on the FM/VM Index and readiness/vulnerability with a decrease in FM/VM Index score increasing the odds of being Not Ready or Vulnerable.

The final objective of this study determined whether the FM/VM Index provided additional information to what could be provided by the G&FM Sub-Domain. The ability to provide information that is improved or different than what the G&FM Sub-Domain can provide is necessary to justify use of the FM/VM Index in further research. Towards this end, a third logistic regression was computed for each of the existing sets of logistic regressions. This third set of logistic regressions added the G&FM Sub-Domain as an independent variable to the regressions with control variables. These regressions were then compared to the previously run regressions with the control variables and the FM/VM Index. Results suggested that in all but two instances the FM/VM Index provided a better fitting model than the G&FM Sub-Domain. The regressions with the FM/VM Index accounted for more of the variability than the regressions with the G&FM Sub-Domain when the outcome of interest is school readiness as measured on the EDI.

Discussion

The theory and practice of occupational therapy recognizes that functional participation in daily activities generally requires the simultaneous use of fine motor and visual skills. The connection between these two skill areas is sufficiently frequent that the terms 'fine motor' and 'visual motor' are often used to describe activities with both a fine motor and visual motor component in reporting and assessment (Beery & Beery, 2004; Miller, 2006; Folio & Fewell, 2000). Further, occupational therapy has demonstrated the importance of FM/VM skills for participation in daily life in general (Case-Smith, 2005) and school in particular (Bruni, 2006; McMaster & Roberts, 2016). There is, however, currently a lack of information available on the FM/VM school readiness of Manitoba's children. This lack of information available compelled this research. The implications of the findings will be discussed for each of the four study objectives. As well, potential implications of this work and suggestions for future research will be explored.

Objective 1: Creation of a FM/VM Index

Currently, individual children whose FM/VM skills are not adequate for the demands of school might be identified in the preschool years by parents or childcare providers. They might also be identified in school by teachers, parents or occupational therapists. In 2016, the Canadian Task Force on Preventative Health Care published a guideline focused on the effectiveness of routine use of child-level standardized screening tools to identify children with developmental delays. They recommend against universal individual screening of children 1-4 years old for developmental delay (Canadian Task Force on Preventative Health Care [CTFPHC], 2016). While individual level assessment is used for diagnostic purposes and the implementation of individualized intervention, population level assessment is different in that it can influence policy and suggest need for community level programming and resources. CTFPHC (2016) made no recommendations on the use of population level tools. The widespread adoption of the EDI across Canada and internationally (Early Development Instrument, 2016-a) suggests policy makers find population level data to be useful when exploring school readiness. Without universal screening, population level data on FM/VM skills are not available unless a population-level tool, such as the FM/VM Index, is implemented.

For a tool measuring FM/VM readiness to be used in an ongoing manner, data collection must not be burdensome. Use of the FM/VM Index does not increase demand of data collection and as such, incorporation of the variable into school readiness analyses is relatively simple. Use of EDI data increases the likelihood that FM/VM Index scores will be available for those children included in existing school readiness analysis in the province.

Delphi. A Delphi process showed that the EDI contains items reflecting FM/VM skills across three different domains and five different sub-domains making it difficult to comment on FM/VM readiness within the current reporting structure of EDI. Given the findings of Grissmer et al. (2010) and Pagani et al. (2010), which suggested that FM/VM skills are an important predictor of school achievement separate from gross motor skills, attempting to fill in this information gap seemed warranted. The population level measure of FM/VM school readiness created through the Delphi process had an internal consistency comparable to that of existing EDI sub-domains.

ROC Curves. When determining the cutoff for a tool using ROC curves, the researcher determines a cutoff point based on the ROC curve analysis results. A cutoff of <80 was chosen. For three of the domains/sub-domains used as comparisons, this selection resulted in reasonably low false negative rates (2.04% for the Literacy and Cognitive Development Domain, 3.78% for the Basic Literacy Sub-Domain) and 4.41% for the Advanced Literacy Sub-Domain) with somewhat higher false positive rates

(12.27% for the Literacy and Cognitive Development Domain, 11.36% for the Basic Literacy Sub-Domain and 6.46% for the Advanced Literacy Sub-Domain. This finding would suggest, that a small number of children are being categorized as Not Vulnerable on the FM/VM Index when they are in fact Vulnerable, and a larger number are being categorized as Vulnerable when they are in fact Not Vulnerable. Given that this is a population level tool, it was determined that misidentifying children as Vulnerable was preferable to misidentifying children as Not Vulnerable. The fourth domain/sub-domain used as a comparison for the ROC curves was the G&FM Sub-Domain. The false positive (7.15%) and false negative (13.6%) rates for this sub-domain were different from those of the other three domains/sub-domains in that false negatives were more prevalent than false positives. For a screening tool, misidentifying 13.6% of the population as being Not Vulnerable when they are in fact Vulnerable is concerning. However, a cutoff that would have reduced this false negative to 9.01% (which is still somewhat high) would result in a misidentification of over 20% of the population as being Vulnerable as measured by the Language and Cognitive Development Domain and the Basic Literacy Sub-Domain, which was thought to be unacceptable.

Objective 2: Who is Vulnerable?

Excluded subjects. The initial EDI data contained 49,330 potential subjects. This pool decreased to 43,353 after excluding those with incomplete or invalid EDI entries. Substantial subject were lost due to control variable information. Many of these excluded subjects are likely to be those for whom a birth record was not available (i.e. those born out of province or not in hospital in Manitoba). This loss of 45.67% of the subjects from the initial EDI dataset, is one of the more unfortunate consequences when interpreting the outcomes. The statistically significant difference found between the included and excluded sample on EDI domain/sub-domain scores, FM/VM Index scores and select control variables

(Neighbourhood Socioeconomic Status, CFS Involvement and Income Assistance) suggested these groups had meaningful differences. The included sample was, overall, more likely to be ready for school, as included subjects did better on all EDI related variables; the FM/VM Index results likely underestimated the size of the population who have Vulnerable FM/VM skills. The in the included sample was less likely to have CFS Involvement or have come from a Low Income Neighbourhood, but they were more likely to have been on Income Assistance.

In her study, deRocquigny (2014) compared those in her sample who were born in Manitoba (included in her sample) to those born outside Manitoba (excluded from her sample). She found those born outside of Manitoba were more likely to be Ready on the Physical Health and Well-Being Domain and less likely to be Ready on all other domains. This is consistent with some of the results found here but not for the Physical Health and Well-Being Domain. deRocquigny (2014) also found that children born in Manitoba (and therefore included) were more likely to have CFS Involvement and less likely to have been on Income Assistance. The reverse was found here. Taken together, the comparison done by deRocquigny (2014) would suggest that the differences between the sample included and the sample excluded sample in this study is not simply explained by differences between those born inside and outside Manitoba.

It is logical that the Family First/Baby First surveys would also be missing for those with unavailable birth records due to the timing of their completion shortly after birth for babies in Manitoba. However, with roughly14,000 and 15,100 missing entries for the variables taken from the Family First/Baby First surveys and roughly 8,400-8,900 missing entries for the variables taken from the hospital birth record there must be substantial Family First/Baby First survey data missing beyond those with an unavailable birth record.

Santos et al. (2012) looked at school readiness within specific groups including those with CFS Involvement and families who have had Income Assistance. They found that these groups tended to have statistically significantly poorer EDI outcomes. Statistically significant differences between included and excluded samples would suggest that some caution is needed when generalizing the results to the population in general; however in instances where the included and excluded sample are statistically different on variables shown to impact the outcome of interest, this caution is especially warranted.

Descriptive statistics. Just over 21% of those in the included sample have vulnerable FM/VM skills. Table 16, highlighted the difference in known risk factors (control variables) among those who are Vulnerable and Not Vulnerable. Santos et al. (2012) and Brownell et al. (2012) also found these factors contributed to school readiness as measured by other EDI constructs.

The logistic regression in Table 17 identified which control variables were associated with readiness on the FM/VM Index. The factors that affect FM/VM readiness are similar to those that affect other types of school readiness. Sex (Male) and Income Assistance were the variables with the highest odds ratios. The effect of Sex and income on FM/VM skills had been identified in the literature with girls being found to outperform boys and children from higher socioeconomic households outperforming children from low or middle income households (Comuk-Balci, Bayoglu, Tekindal, Kerem-Gunel, & Anlar, 2016; Gottschling-Lang, Franze, & Hoffmann, 2013; Morley, Till, Ogilvie, & Turner, 2015). The prominence of Sex and Income Assistance was consistent with results of regressions for other areas of readiness found here and with the odds ratios (for being Not Ready on domains) computed by Santos et al. (2012). FM/VM readiness was associated with a factor that is not prominent for other areas of school readiness. The selection of ICU Stay of 3+ Days in the regression was relatively unique having not been included in any other control variable model and found to be not significant in Santos et al. (2012). Potential limitations resulting from the use of logistic regressions to analyze the data will be further explored.

The Max R-square for the regression predicting vulnerability on the FM/VM Index (0.1582) was higher than the Max R-square for any of the other control variable domain/sub-domain regressions computed. The closest were the Physical Readiness for School Sub-Domain (0.1374) and the Basic Numeracy Sub-Domain (0.1273). Further, the regression predicting vulnerability on the FM/VM Index had some of the highest control variable odds ratios. Only one sub-domain (Physical Readiness for School) had a higher odds ratio for the variable Income Assistance and only one sub-domain (Basic Numeracy) had a higher odds ratio for the variable Age. (The Communication & General Knowledge Domain and the Approaches to Learning had the same odds ratio for the variable Age.) The most notable of the control variables, however, was Sex. The odds ratio of 3.63 in the regression predicting vulnerability on the FM/VM Index was the highest seen in any control variable regression. (The next closest was the Hyperactivity and Inattention Sub-Domain at OR=3.58.) The comparatively high max R-squares would suggests that the control variables available for analysis were more strongly associated with vulnerability on the FM/VM Index than they were with readiness/vulnerability on the other analyzed domains/sub-domains. Odds ratios suggested that some specific control variables (including Sex, Income Assistance, Age, ICU Stay of 3+ Days) were more strongly associated with FM/VM skill performance than they were with other areas of school readiness.

Being Indigenous was more likely to be associated with poverty, being in the care of CFS, poor housing conditions, discrimination, cultural devaluation and the legacy of residential schools, thereby increasing Indigenous children's risk for poor outcomes, including school readiness (UNICEF Canada, 2009). The decision not to consider Indigenous identity in the study was made due to the difficulties in acquiring permissions to use this information. Also, many children who attended school on reserves were not included in the EDI data, resulting in a group of Manitoba children that are completely missing from the analysis. Should access become more readily available, separate analysis of children as belonging to First Nations, Inuit or Métis groups is encouraged for future research. Understanding the barriers to success among Indigenous children could help encourage policy makers to work with these communities in developing resources that address readiness for school.

Objective 3: Predicting Being Not Ready/Vulnerable

Overall, the addition of the FM/VM Index to the regression models resulted in a better model fit. Poorer performance on the FM/VM Index was associated with an increase in the odds of being Not Ready/Vulnerable for school (as measured by the EDI domains and sub-domains). Previous work suggested that FM/VM readiness had an impact on school performance in grade 2 (Pagani et al., 2010) and grade 5 (Grissmer et al., 2010). This study suggested that the impact is measurable not only in grades 2 and 5, but also at school entry.

In examining the odds ratios for the FM/VM Index, a few instances were particularly interesting. At the domain level, the odds ratios for the FM/VM Index, when predicting Not Ready on the Communication and General Knowledge Domain, was 0.74. This odds ratio of less than 1 indicates that for every 5-point increase in score on the FM/VM Index, the odds of being Not Ready on that given domain decreased 26%. At the sub-domain level, three sub-domains stood out as having comparatively large odds ratios: Readiness to Explore New Things (FM/VM Index odds ratio = 0.77), Basic Numeracy (FM/VM Index odds ratio = 0.75) and Interest in Literacy/Numeracy and Memory (FM/VM Index odds ratio = 0.70). For every 5-point increase in score on the FM/VM Index, the odds of being Vulnerable on the above sub-domains decreased 23% (Readiness to Explore New Things), 25% (Basic Numeracy), and 30% (Interest in Literacy/Numeracy and Memory). The link between FM/VM readiness and many other areas of school readiness was supported in other literature (Skelton & Leclair, 2013).

Previous research found that the presence or absence of a relationship between social and emotional skills and FM/VM skills was inconclusive (Skelton & Leclair, 2013) but this relationahip was supported by this study. The addition of the FM/VM Index to the model resulted in an improvement in the max R-square for all the analyzed domains and sub-domains in this area (Emotional Maturity Domain, Responsibility and Respect Sub-Domain, Approaches to Learning Sub-Domain, Readiness to Explore New Things Sub-Domain, Prosocial and Helping Behaviour Sub-Domain, Anxious and Fearful Behaviour Sub-Domain, Aggressive Behaviour Sub-Domain, and Hyperactivity and Inattention Sub-Domain). The skills that comprise social and emotional development are complex and varied. Given the tendency of the studies included in the literature review to focus on one or two different social or emotional skills, it is possible that inconclusive results found in the literature review may reflect varied relationships between specific skills and FM/VM skills. The max R-squares for the EDI sub-domains related to social and emotional skills supported this variation of the impact of FM/VM skills on sub-sets of emotional/social skills. The Overall Social Competence Sub-Domain had an improvement in the max R-square of 0.1648 while in contrast, Aggressive Behaviour Sub-Domain had an improvement in the max R-square of 0.0329, with the improvements in the max R-square for the other sub-domains of the Social Competency and Emotional Maturity Domains falling between the two.

When analyzing model fit for the logistic regressions, the highest max R-squares (and therefore the best model fit) were found within the FM/VM Index models for the Communication and General Knowledge Domain (0.3177), Interest in Literacy/Numeracy and Memory Sub-Domain (0.3795), and Basic Numeracy Sub-Domain (0.3425). The control variable only models for these domains/sub-domains were: Communication and General Knowledge Domain (0.0969), Interest in Literacy/Numeracy and Memory (0.0872), and Basic Numeracy (0.1273). The improvement in max R-square between these control variable only models and these control variable with FM/VM Index models were the largest observed in this study. The strong relationship between FM/VM skills and components of language and cognitive development, especially numeracy, is consistent with previous research (Pitchford, Papini, Outhwaite, & Gulliford, 2016).

In total, 12 different sets of regression models were computed. Income Assistance and Age were the most frequently included variables included in all 12 sets of regressions. Sex was included in all but two sets of the regressions and Maternal Age at First Birth, and Low Maternal Education was included in all but three sets of regressions. These control variables had the widest reaching impact on school readiness as measured by the EDI. Other EDI research supports their importance. Santos et al., 2012 found that Income Assistance, Age, Sex and Maternal Age at First Birth all had significant coefficients when predicting domain scores using structural-equation modelling. In the same study, Age, Income Assistance and Sex were significant in all the regression analyses for being Not Ready on one or more Domains. Maternal Education was not included in that study.

As noted above, Sex was selected in 10 of the sets of models run. Generally, boys demonstrated increased odds of being Not Ready/Vulnerable compared to girls. However, in some models with control variables and the FM/VM Index, girls had an increased risk of being Not Ready/Vulnerable (Communication and General Knowledge Domain, Readiness to Explore New Things Sub-Domain, Interest in Literacy/Numeracy and Memory Sub-Domain, and Basic Numeracy Sub-Domain). Being Male had a higher odds ratio (3.63) in the regression where the FM/VM Index was the dependent variable than it did in any other control variable regression. Further, in the four model sets where Sex reversed direction (Communication and General Knowledge Domain, Readiness to Explore New Things Sub-Domain, Literacy/Numeracy and Memory Sub-Domain, and Basic Numeracy Sub-Domain) the odds ratios for Sex were the lowest seen in control variable only regressions (OR between 1.33 and 1.85) where Sex was selected. This finding was possibly an example of a Simpson's Paradox (Julious & Mullee, 1994) where the association between two variables (sex and readiness) was reversed when a third variable (FM skill) is controlled. Boys had a 3.6 times increased odds of having vulnerable FM skills and disproportionately lower scores on the FM/VM Index in comparison to girls. This uneven distribution of one variable (sex) within another (FM skill) can cause a reversal in the direction of the association of one variable (sex) with another (readiness on the domains/sub-domains) creating a paradoxical result.

Some variables were infrequently selected in these analyses: 2+ Major ADGs, ICU Stay of 3+ Days at Birth and Premature. They were not selected in any of the 12 sets of regressions. ICU was selected for only one set of models and Breastfeeding Initiation and Low SES for three. Overall, these variables were not particularly influential on school readiness in this context. However, Santos et al. (2012) found, in multi-level regressions, that 2+ Major ADGs and Low SES had statistically significant differences for Not Ready on all five EDI Domains. Structural equation modelling has, however, suggested that all of these variables contribute to different constructs which in turn directly or indirectly impact school readiness as measured by the EDI domains in a Manitoba sample (Santos et al., 2012). Given the statistical methods employed in this research were unable to incorporate latent constructs or indirect effects, they may not have captured the complex relationship between control variables and school readiness.

In this study, two different variables measured the impact of income on vulnerability/readiness. One of these (Income Assistance) was frequently included, the other (Low SES) was generally excluded from analysis. The level of multicollinearity between these two variables was low enough to justify inclusion of both variables; however, the regression results clearly suggested that Income Assistance had a stronger association. These findings would suggest that neighbourhood income levels (Low SES) have less of an impact than family income levels (Income Assistance). An interaction variable may provide a more accurate picture of the effect of income on school readiness.

Objective 4: Comparing the FM/VM Index to the G&FM Sub-Domain

The works of Grissmer et al. (2010) and Pagani et al. (2010) showed that kindergarten fine motor skills and gross motor skills have differing abilities to predict later outcomes in school. Both Duncan et al. (2010) and Pagani et al. (2010) found that while fine motor skills were a consistent significant predictor of later achievement (defined in each study as a combination of some of reading, math, general achievement and classroom engagement), gross motor skills were not. Further, Carlson, Rowe and Curby (2013) completed a study focused on determining which parts of fine motor skills were associated with academic achievement. They concluded visual motor skills and not fine motor coordination were associated with math and written expression. Grouping fine motor skills with visual motor skills, as was done in this study, allows for the visual motor dependent sub-set of fine motor skills to be incorporated into the measure and better capture the risk factor as identified by Carlson et al. (2013).

As with the inclusion of the FM/VM Index, Max R-square values increased with the inclusion of the G&FM Sub-Domain over the control variables only models regardless of which domain or sub-domain was the dependent variable. For all the domains/sub-domains, except for the Anxious and Fearful Behaviour and Physical Readiness for School Sub-Domains, the models containing FM/VM Index provided a better fit for the outcome than did the models containing G&FM Sub-Domain. Overall, the additional construct of the FM/VM Index appeared to provide an improved understanding of the contributors to school readiness over the G&FM Sub-Domain construct. Grissmer et al. (2010) and Pagani et al. (2010), both found that kindergarten fine motor skills were better predictors of school performance than kindergarten gross motor skills. Carlson et al. (2013) stressed that the visual motor component of fine motor skills was more important than motor coordination. This work provided further support that grouping and analyzing fine motor skills with visual motor skills was preferable to grouping fine motor skills with gross motor skills when the outcomes of interest are areas of school readiness.

Future Research

Occupational Therapy Research. As FM/VM skill is fundamental to the practice of occupational therapy in the preschool and early school years, results of this work will be of particular interest to this profession. Occupational Therapy would benefit from more current research on the importance of FM skill in school.

The use of secondary data analysis to create and analyze the FM/VM Index contributes to an emerging type of research for the field of occupational therapy. Freburger and Konrad (2002) concluded that secondary data analysis is a useful, cost-effective, and efficient research strategy for occupational therapy. There is, however, limited published research using this type of data. In undertaking a study that utilizes secondary data analysis, this research provides an example of the potential of secondary data analysis for occupational therapy research and will hopefully encourage increased implementation of this research strategy.

Looking forward. This study has provided an important first step in allowing for the identification of populations of children who are not ready for school with respect to their FM/VM skills. However, it did not look forward – towards the ability of FM/VM readiness at kindergarten to predict later school achievement. Given the results, which suggested that FM/VM skills are associated with school readiness in other areas, and the work of Pagani et al. (2010) and Grissmer et al. (2010) which suggested fine motor skills are predictive of school performance, future research linking readiness on the FM/VM Index to school performance in later grades would add substantially to the understanding of the importance of FM/VM readiness. With the data available in the Population Research Data Repository in Manitoba, FM/VM Index scores could be linked to other education data such as grade three assessments or high school completion. These analyses would add greatly to the discussion of the importance of FM/VM skills in school.

In the course of this research, two studies were found that focused on predicting school achievement using secondary data analysis and variables specific to FM/VM readiness (Grissmer, 2010; Pagani, 2010). Neither of these studies, however, included variables that would be available in a Manitoba sample making it impractical to replicate their models with the available Manitoba data. As the FM/VM Index draws from already collected EDI data, this variable is more accessible for future research in Manitoba focusing on the ability of kindergarten FM/VM skill to predict school performance.

Another direction for future research would be research focused on sub-domains. Most if not all of the research in Manitoba to date, using the EDI as a predictor of later school performance, has focused on the use of Domain scores. Many domains encompass a fairly wide range of skills and important knowledge can be gained from looking at more specific skill sets to help inform programming and policy to support the development of specific skills.

Statistical methods. School readiness research that included the EDI often employed more complex statistical models than were used in this sutdy. De Rocquigny (2014) used multilevel modelling to help address concerns of dependence within the data and more appropriately incorporated both individual level and area level data. Previous work (Santos et al., 2012) used logistic regressions with best subset selection as none of the hypothesized predictor variables had, at that time, been previously linked to EDI scores. With little research to date considering the effects of control variables on sub-domains scores, the control variables used here have never been linked to many of the outcomes used. Therefore a similar strategy could have been beneficial. Also, both Santos et al. (2012) and Brownell et al. (2012) used structural equation modelling in their work. Structural equation modelling has the advantage of being able to incorporate latent variables and accommodate indirect effects between the variables (Nachtigall, Kroehne, Funke & Steyer, 2003). In this work, employing structural equation modelling would have allowed for the inclusion of other EDI outcomes as predictors and therefore control for the effect of school readiness in one area on school readiness in another area. (e.g. Incorporate the Language and Cognitive Development, Emotional Maturity, Physical Health & Well-Being, and Social Competence Domains as the independent variable when the outcome of interest (dependent variable) is the Communication and General Knowledge Domain). Controlling for readiness in other skill areas could not be included within the logistic regression models due to the high levels of multicollinearity between the EDI variables. Use of more complex statistical methods may also shed some light onto the presentation discussed above of control variables that presented differently than in previous research (Sex, Maternal Depression, 4+ Children, Neighbourhood Socioeconomic Status and ICU).

The problem of question overlap. The decision to create a FM/VM Index comprised of existing questions from the EDI makes the score available anywhere the EDI is administered. This strategy, however, also presents some limitations. In this work, the most noticeable limitation derives from the substantial overlap that was present between the FM/VM Index and some of the EDI Domains/Sub-Domains which resulted in difficulties assessing the impact of FM/VM readiness on readiness in those areas. For the Physical Health and Well-Being, Social Competence, and Language and Cognitive Development Domains as well as the Physical Independence, G&FM, Overall Social Competence, Basic Literacy, and Advanced Literacy Sub-Domains, question overlap existed. The overlap with literacy related domains/sub-domains was perhaps the most unfortunate. Previous research has suggested a relationship between FM/VM skill and literacy skill (e.g. James, 2010; Longcamp et al., 2008) and the extent of the question overlap is perhaps indicative of this relationship. This overlap limits this study's ability to provide meaningful comment on this relationship.

While question overlap will not eliminate the ability of the FM/VM Index to be used in regressions focused on future academic achievement, the interconnectedness of the FM/VM Index with existing EDI constructs will have to be considered carefully in the statistical design of future work. For example, the question overlap could prove problematic if multiple EDI markers of readiness (e.g. the FM/VM Index and the Basic Literacy Sub-Domain) were to be included in the same analysis. Much of the work done in Manitoba has focused on performance on particular EDI domains/sub-domains or the effects of a particular domain on later school performance. The FM/VM Index could easily be considered alongside the domains and sub-domains as a category for analysis within this type of work.

Other outcomes used, such as the Multiple Challenge Index (which is used to represent children at risk in multiple areas) or 'not ready on 1+ Domain' (which has been used to identify children who have at least one area of need) would require more careful consideration.

There are, however, potential advantages to the question overlap. Examination of the of the degree of overlap in children who are vulnerable on sub-domains (e.g. Basic and Advanced Literacy) and the FM/VM Index could lead to hypotheses as to what aspects of the given skills set (e.g. the visual motor dependent aspects of literacy or the visual motor independent ones) are contributing to the vulnerability. Likewise, which aspects of FM/VM readiness are contributing to vulnerability could be explored.

The EDI allows for the identification of children who have multiple challenges if they are Vulnerable on one or more sub-domains. These children can be considered especially unprepared to meet the demands of kindergarten given their vulnerability in a wide range of areas. Incorporating FM/VM readiness into this construct would be ideal, but at present may not be possible.

Implications for Services

While the EDI is used to identify readiness at a population level, the results of this research should also have implications for direct service provision. Firstly, results supported the identification of individual children with FM delay as over 20% of children in this sample did not have the FM skills required for school. The question of how best identify these children remains as we move away from universal screening; there is no best practice strategy to ensure children aren't falling through the cracks. Occupational therapists are well established as experts on fine motor skill development and are equipped to provide screening, assessments of fine motor skills (Henderson & Pehoski, 2006). Further, studies have shown that occupational therapy intervention for preschool children effectively improved

FM/VM skills in children with FM/VM delays (Case-Smith, 2013) or for children with specific diagnoses such as DCD (Smits-Engelman et al., 2012). Also, occupational therapy for early school children can improve handwriting skills (Hoy, Egan & Feder, 2011). While it is hopeful that services can address the skill gap that places children at risk for inadequate FM/VM skills at school entry, the problem cannot be addressed unless a mechanism exists to identify those children who are at risk in this area. In addition, this study highlighted many environmental factors that occupational therapists may not be currently addressing as part of their interventions or when identifying who would benefit from early occupational therapy services.

Continuing education has been found to have positive effects on early years classroom programming focused on behaviour (Conroy, Sutherland, Vo, Carr & Ogston, 2014) and play (Vu, Han & Buel, 2015), that it could also be effective for programming focused on FM/VM skills. One of the logistic regressions computed here helps identify which populations have an increased odds of being not ready (see Table 17) such as those in lower income households/neighbourhoods, males, etc. While we would expect some populations with higher odds of having vulnerable FM/VM skills to be spread across the province (e.g. males, those who are younger) other populations with a higher odds of having vulnerable FM/VM skills often cluster in particular neighbourhoods or types of programming (e.g. lower socioeconomic status) making them comparatively easier to target. Professional development focused on implementing programming rich in FM/VM skill building activities would help those entrusted with caring for children, especially those working with populations who have an increased odds of being not ready, to promote the FM/VM skills needed to be ready for school.

Implications for Policy

Measurement of FM/VM readiness as explored in this research allows policy makers and educators to determine whether current programming targeting the development of FM/VM skills is adequate, or if further strategies are required. Research focusing on this developmental area is particularly important in light of the fact that motor skills proficiency has largely been lost on the policy and research agenda (Pagani, 2010) and that early years interventions are currently largely focused on changing the way math and reading are taught (Grissmer, 2010). Both Pagani et al. (2010) and Grissmer et al. (2010) concluded that an increased emphasis needs to be placed on the importance of fine motor skills in the preschool and early school years. Manitoba EDI results also suggest a need to focus on motor readiness at the population level. Between 23.9% and 26.8% of children did not have the required skill on the G&FM Sub-Domain each year the EDI has been completed (Healthy Child Manitoba, n.d.-a). As shown above, this thesis work suggested that 21.1% of children did not have the FM/VM skills required for kindergarten. Regardless of the grouping (FM/VM or G&FM), with high percentages of children lacking the required fine motor skills, re-evaluating the emphasis placed on these skills in early years program development and evaluation as well as their prominence in related research seems warranted.

Education targeted at, for example, early childhood educators, primary school teachers, pediatricians and parents on how to identify children with vulnerable FM/VM skills would provide these key persons with a stronger knowledge base from which to identify children whose skills are at risk and provide children with the opportunities they need to develop the required skills. Policy and funding to support this type of professional and public education, as well as the availability of opportunity for FM/VM skill development in the community, would be a positive response to the identification of a substantial portion of kindergarten children not having the FM/VM skills required for school.

Evaluation is an important part of policy change and resource allocation. Current EDI reports in Manitoba are released every two years in response to kindergarten classroom teachers bi-annual completion of the EDI. These reports not only seek to identify how different populations of Manitoba's children are performing on various markers of school readiness, they also comment on how scores are trending (improving, worsening or stable) since the start of EDI collection (Healthy Child Manitoba, n.d.-a). Separate reporting of the FM/VM Index within these bi-annual reports would, over time, allow for at least one form of evaluation of the effectiveness of policy designed to improve FM/VM school readiness by comparing different cohorts of children.

Conclusion

Previous research as outlined in the introduction, suggested that there is a role for FM/VM skills in the discussion of what contributes to school readiness. This research demonstrated that the development of a FM/VM Index with strong face validity and internal consistency is possible. Through a Delphi method using expert occupational therapists, a FM/VM Index comprising 11 EDI questions was created and a vulnerability cutoff established through AUC analysis. The resulting FM/VM Index was then used to characterize children whose FM/VM school readiness was vulnerable.

Descriptive statistics showed that children who were Vulnerable on the FM/VM Index were statistically different from children who were Not Vulnerable for a wide variety of environmental and child variables as well as some health at birth variables. Children who are Vulnerable on the FM/VM Index also tend to do poorer on other markers of school readiness (EDI domains and sub-domains). Further, logistic regression analyses showed that child variables (Male, Age, and 6+ Days in Hospital), environmental variables (Income Assistance, Low Maternal Education, Maternal Age at First Birth, Low SES, CFS Involvement, and 4+ Children), and health at birth variables (Breastfeeding Initiation, and ICU Stay of 3+ Days at Birth) were all associated with the odds of being Vulnerable on the FM/VM Index.

The addition of the FM/VM Index or the G&FM Sub-Domain improved how well the model fits its outcome data: Ready/Not Ready for each domain or Not Vulnerable/Vulnerable for each sub-domain. Odds ratios computed suggested a relationship in the expected direction between scores on the FM/VM Index or G&FM Sub-Domain and readiness/vulnerability with a decrease in FM/VM Index/G&FM Sub-Domain score increasing the odds of being Not Ready/Vulnerable. In most instances the FM/VM Index provided a better fitting model than the G&FM Sub-Domain suggesting that the FM/VM Index has the ability to account for more of the variability than the G&FM Sub-Domain when the outcome of interest is school readiness as measured on the EDI. Overall, this study suggested that the inclusion of a marker of FM/VM readiness is warranted if we are to more fully understand what puts school readiness at risk.

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Appendix 1: Studies Included in Scoping Review

Appendix Table 60: Studies Included in Scoping Review

Study	Developmental area(s)	Study type	Measures before and/or after school entry	Supports relationship
Aram DM (1983)	Speech	Cross-Sectional	Before and After	No
Badian NA (1982)	Literacy	Longitudinal	Before and After	No
Banes MA (2011)	Numeracy	Longitudinal	Before	Yes
Bart O (2007)	Behaviour	Longitudinal	After	Yes
Bishop DV (2002)	Speech Language	Cross-Sectional	After	Yes
Bishop DMV (1987)	Language	Longitudinal	Before	Mixed
Bloch MH (2006)	Psychosocial	Longitudinal	After	Yes
Bradford A (1994)	Speech Language	Cross-Sectional	Before and After	Mixed
Bradford A (1996)	Speech	Cross-Sectional	Before and After	Mixed
Butler SR (1982)	Literacy	Longitudinal	Before and After	Yes
Butler SR (1985)	Literacy	Longitudinal	Before and After	Yes
Carte ET (1996)	Attention	Cross-Sectional	After	Yes
Cermak SA (1986)	Speech	Cross-Sectional	After	Yes
Chuang YC (2011)	Language	Cross-Sectional	Before	Yes
Davis EE (2010)	Cognition	Cross-Sectional	Before and After	Yes
Davis EE (2011)	Cognition	Cross-Sectional	Before and After	Yes
Dellatolas G (2003)	Cognition	Longitudinal	Before and After	Yes
Dyck M (2009)	Language Cognition Emotional	Cross-Sectional	Before and After	Yes
Dyck M (2009)	Language Cognition Emotional	Cross-Sectional	Before and After	Yes
Estil LB(2003)	Language	Cross-Sectional	After	Yes
Fowler MG (1986)	Literacy Numeracy	Cross-Sectional	Before	Yes

Study	Developmental area(s)	Study type	Measures before and/or after school entry	Supports relationship
Gernsbacher MA(2008)	Speech	Retrospective	Before and After	Yes
Godin-Meadow S (2009)	Numeracy	Cross-Sectional	After	Yes
Goldstein DJ (1994)	Litearcy Numeracy	Cross-Sectional	After	Yes
Gottesman RL (1984)	Literacy	Longitudinal	After	Mixed
Grissmer D(2010)	Literacy Numeracy	Longitudinal	Before and After	Yes
Haines C (2003)	Language Literacy	Longitudinal	Before and After	Mixed
Hill EL (1998)	Language Speech	Cross-Sectional	After	Yes
Hill EL (2001)	Language	Review		Yes
Horn WF (1985)	Literacy	Review		Yes
Hsu H-C (2004)	Social	Cross-Sectional	Before	Yes
Iversen S (2005)	Literacy	Cross-Sectional	After	Yes
Iverson JM (2011)	Language	Cross-Sectional	Before	Yes
Jäncke L (2007)	Speech Language	Cross-Sectional	Before and After	Yes
Judge S (2005)	Literacy Numeracy	Cross-Sectional	Before	Yes
Katz WF (1992)	Speech Language	Longitudinal	Before and After	Yes
Klimkeit EI (2004)	Attention	Cross-Sectional	After	Yes
Knoff HM (1986)	Literacy Numeracy	Cross-Sectional	After	No
Korkman M (1994)	Attention	Cross-Sectional	After	Yes
Kristensen H (2008)	Anxiety	Cross-Sectional	After	No
Kulp MT (1999)	Literacy Numeracy	Cross-Sectional	After	Mixed
Lesiak J (1984)	Literacy	Review		No
Lindquist GT (1982)	Literacy	Cross-Sectional	After	Yes

Study	Developmental area(s)	Study type	Measures before and/or after school entry	Supports relationship
Losse A (1991)	Literacy Numeracy Socialization Behaviour	Longitudinal	After	Yes
Luo Z (2007)	Numeracy	Longitudinal	Before and After	Yes
Marcotte AC (1997)	Attention	Cross-Sectional	After	Mixed
Massoth NA (1982)	Literacy	Longitudinal	Before and After	Yes
McCormack J (2009)	Speech	Review		Yes
McKay MF (1985)	Literacy	Longitudinal	Before and After	Yes
Michel E (2011)	Cognition	Longitudinal	After	Yes
Missiuna C (2007)	Social Emotional	Qualitative	After	Yes
Newmeyer AJ (2007)	Speech	Cross-Sectional	Before	Yes
Nielson S (1991)	Literacy Numeracy	Cross-Sectional	After	No (literacy) Mixed (numeracy)
Noterdaeme M (2002)	Language	Cross-Sectional	After	Yes
O'Hare A (2002)	Literacy	Cross-Sectional	After	No
Owen SE (1997)	Speech Language	Cross-Sectional	Before and After	Yes
Ozcebe E (2009)	Speech	Cross-Sectional	After	Yes
Pagani LS (2010)	Literacy Numeracy	Longitudinal	Before and After	Yes
Perez JM (1993)	Behaviour Language	Longitudinal	After	No
Pianta RC (1991)	Behaviour Academic	Longitudinal	Before and After	Mixed
Piek JP (1999)	Attention	Cross-Sectional	After	Yes
Piek JP (2008)	Cognition	Longitudinal	Before and After	No
Piek JP (2010)	Emotional	Longitudinal	Before and After	No
Pitcher TM (2003)	Attention	Cross-Sectional	After	Yes

Study	Developmental area(s)	Study type	Measures before and/or after school entry	Supports relationship
Powell RP (1992)	Speech Language	Cross-Sectional	After	Yes
Preis S (1997)	Language	Cross-Sectional	Before and After	Yes
Qu X (2008)	Cognition	Cross-Sectional	Before	Yes
Rechetrnikov RP (2009)	Speech Language	Review		Yes
Rhemtulla M (2011)	Literacy Numeracy Language	Longitudinal	Before and After	Yes
Riou EM (2009)	Cognition	Cross-Sectional	Before	Yes
Roebers CM (2009)	Cognition	Cross-Sectional	After	Yes
Savage RS (2006)	Literacy	Cross-Sectional	After	No
Schmidt S (1985)	Literacy Numeracy	Longitudinal	Before and After	Yes
Seitz J (2006)	Cognition	Cross-Sectional	After	Yes
Sigurdsson E (2002)	Anxiety	Historic Cohort	After	Mixed
Silva PA (1984)	Speech	Cross-Sectional	After	No
Simner ML (1982)	Literacy Numeracy	Longitudinal	Before and After	Yes
Sipes M (2011)	Social	Cross-Sectional	Before	Mixed
Smimi P (1989)	Language	Cross-Sectional	Before and After	Mixed
Solan HA (1985)	Literacy	Cross-Sectional	Before	Yes
Sommers RK (1988)	Speech Language	Cross-Sectional	After	Yes
Sommers RK (1991)	Language Cognition	Cross-Sectional	After	Yes
Son S-H (2006)	Literacy Numeracy	Longitudinal	Before and After	Yes
Sortor JM (2003)	Literacy Numeracy	Longitudinal	After	Yes
Stone WL (2001)	Language	Longitudinal	Before	Yes

Study	Developmental area(s)	Study type	Measures before and/or after school entry	Supports relationship
Teverovsky EG (2009)	Speech	Survey	Before and After	Yes
Tramontana MG(1988)	Litearcy Numeracy	Review	Before and After	Yes
Trauner D (2000)	Language	Cross-Sectional	After	Yes
Tseng M-H (2007)	Attention Literacy Psychological Adjustment	Cross-Sectional	After	Yes
Uhrich TA (2007)	Litearcy	Cross-Sectional	After	Yes
Valtonen R (2004)	Language Attention Behaviour	Cross-Sectional	Before	Yes
Vance B (1986)	Cognition Literacy Numeracy	Cross-Sectional	After	Yes (Cognition, numeracy) No (Literacy)
VanRooijen M (2012)	Numeracy	Cross-Sectional	After	Yes
Viholainen H (2002)	Langauge	Longitudinal	Before	Yes
Viholainen H (2006)	Language Literacy	Longitudinal	Before	Yes
Vinck A (2010)	Cognition	Cross-Sectional	After	No
Visscher C (2007)	Speech Language	Cross-Sectional	After	Yes
Wallace IF (1982)	Literacy Cognition	Cross-Sectional	After	Yes
Wassenberg R (2005)	Cognition	Cross-Sectional	After	Yes
Webster RI (2005)	Language Cognition	Cross-Sectional	After	Yes
White S (2006)	Literacy	Cross-Sectional	After	No
Wolff PH (1985)	Literacy	Longitudinal	Before and After	No
Wright D (1982)	Literacy Numeracy	Cross-Sectional	After	Yes
Wuang Y-P (2008)	Cognition	Cross-Sectional	After	Yes

Study	Developmental area(s)	Study type	Measures before and/or after school entry	Supports relationship
Zelaznik HN (2010)	Language	Cross-Sectional	After	Yes

(Skelton & Leclair, 2013)

Appendix 2: Multicollinearity

Appendix Table 61: Multicollinearity – Communication and General Knowledge Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.69683
Lone Parent Family	0.68523
Low SES	0.87120
4+ Children	0.85220
Maternal Age at First Birth	0.61131
Maternal Depression	0.97819
CFS Involvement	0.88369
Income Assistance	0.50294
Age	0.99492
90%+ Minor ADG	0.59900
2+ Major ADG	1.0000
Number of Physician Visits	0.56230
Sex	0.99005
Breastfeeding Initiation	0.92839
Long Birth Stay	0.72287
Low Birth Weight	0.59294
Premature	0.54386
ICU Stay of 3+ Days at Birth	0.65637
ICU	0.91263
6+ Days in Hospital	0.86476

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 62: Multicollinearity – Emotional Maturity Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.68852
Lone Parent Family	0.67065
Low SES	0.87006
4+ Children	0.86446
Maternal Age at First Birth	0.62077
Maternal Depression	0.97886
CFS Involvement	0.87006
Income Assistance	0.49576
Age	0.99581
90%+ Minor ADG	0.60591
2+ Major ADG	0.99999
Number of Physician Visits	0.56886
Sex	0.99066
Breastfeeding Initiation	0.93522
Long Birth Stay	0.77857
Low Birth Weight	0.63930
Premature	0.59785
ICU Stay of 3+ Days at Birth	0.71778
ICU	0.91276
6+ Days in Hospital	0.86161

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 63: Multicollinearity – Physical Readiness for School Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.72408
Lone Parent Family	0.71183
Low SES	0.87552
4+ Children	0.87033
Maternal Age at First Birth	0.61840
Maternal Depression	0.97716
CFS Involvement	0.89577
Income Assistance	0.52636
Age	0.99704
90%+ Minor ADG	0.58563
2+ Major ADG	0.99999
Number of Physician Visits	0.54959
Sex	0.99382
Breastfeeding Initiation	0.93137
Long Birth Stay	0.76543
Low Birth Weight	0.63767
Premature	0.58805
ICU Stay of 3+ Days at Birth	0.71739
ICU	0.91682
6+ Days in Hospital	0.87063

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 64: Multicollinearity – Responsibility and Respect Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.68338
Lone Parent Family	0.65787
Low SES	0.86419
4+ Children	0.86335
Maternal Age at First Birth	0.60134
Maternal Depression	0.97585
CFS Involvement	0.86171
Income Assistance	0.47903
Age	0.99711
90%+ Minor ADG	0.59340
2+ Major ADG	0.99999
Number of Physician Visits	0.55699
Sex	0.99452
Breastfeeding Initiation	0.93433
Long Birth Stay	0.78764
Low Birth Weight	0.65902
Premature	0.61489
ICU Stay of 3+ Days at Birth	0.74157
ICU	0.90987
6+ Days in Hospital	0.85631

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 65: Multicollinearity – Overall Social Competence Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.69275
Lone Parent Family	0.67184
Low SES	0.87086
4+ Children	0.86578
Maternal Age at First Birth	0.61551
Maternal Depression	0.97811
CFS Involvement	0.88101
Income Assistance	0.49567
Age	0.99476
90%+ Minor ADG	0.60248
2+ Major ADG	0.99999
Number of Physician Visits	0.56493
Sex	0.99099
Breastfeeding Initiation	0.93447
Long Birth Stay	0.76285
Low Birth Weight	0.60686
Premature	0.56369
ICU Stay of 3+ Days at Birth	0.69098
ICU	0.90462
6+ Days in Hospital	0.85558

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 66: Multicollinearity – Readiness to Explore New Things Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.70546
Lone Parent Family	0.68452
Low SES	0.86681
4+ Children	0.85477
Maternal Age at First Birth	0.61252
Maternal Depression	0.98156
CFS Involvement	0.89774
Income Assistance	0.50196
Age	0.99756
90%+ Minor ADG	0.59374
2+ Major ADG	0.99999
Number of Physician Visits	0.54967
Sex	0.99356
Breastfeeding Initiation	0.93423
Long Birth Stay	0.75862
Low Birth Weight	0.63755
Premature	0.58954
ICU Stay of 3+ Days at Birth	0.68937
ICU	0.88119
6+ Days in Hospital	0.83269

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 67: Multicollinearity – Prosocial and Helping Behaviour Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.72553
Lone Parent Family	0.69379
Low SES	0.88986
4+ Children	0.87557
Maternal Age at First Birth	0.67154
Maternal Depression	0.98271
CFS Involvement	0.89777
Income Assistance	0.54141
Age	0.99730
90%+ Minor ADG	0.62300
2+ Major ADG	0.99999
Number of Physician Visits	0.58667
Sex	0.99117
Breastfeeding Initiation	0.94519
Long Birth Stay	0.77168
Low Birth Weight	0.64758
Premature	0.60276
ICU Stay of 3+ Days at Birth	0.69950
ICU	0.91337
6+ Days in Hospital	0.86892

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 68: Multicollinearity – Anxious and Fearful Behaviour Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.70273
Lone Parent Family	0.67513
Low SES	0.87824
4+ Children	0.86103
Maternal Age at First Birth	0.63718
Maternal Depression	0.98060
CFS Involvement	0.90891
Income Assistance	0.51185
Age	0.99849
90%+ Minor ADG	0.62141
2+ Major ADG	1.00000
Number of Physician Visits	0.58897
Sex	0.99342
Breastfeeding Initiation	0.93930
Long Birth Stay	0.78535
Low Birth Weight	0.63841
Premature	0.60216
ICU Stay of 3+ Days at Birth	0.74888
ICU	0.90909
6+ Days in Hospital	0.86801

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 69: Multicollinearity – Aggressive Behaviour Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.68467
Lone Parent Family	0.67487
Low SES	0.87103
4+ Children	0.86258
Maternal Age at First Birth	0.61355
Maternal Depression	0.97774
CFS Involvement	0.85899
Income Assistance	0.49209
Age	0.99698
90%+ Minor ADG	0.60267
2+ Major ADG	0.99999
Number of Physician Visits	0.56467
Sex	0.99266
Breastfeeding Initiation	0.93551
Long Birth Stay	0.79437
Low Birth Weight	0.65670
Premature	0.61373
ICU Stay of 3+ Days at Birth	0.73652
ICU	0.91184
6+ Days in Hospital	0.85976

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 70: Multicollinearity – Hyperactivity and Inattention Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.69310
Lone Parent Family	0.67792
Low SES	0.87370
4+ Children	0.86909
Maternal Age at First Birth	0.63300
Maternal Depression	0.97984
CFS Involvement	0.87586
Income Assistance	0.50616
Age	0.99580
90%+ Minor ADG	0.60775
2+ Major ADG	1.00000
Number of Physician Visits	0.57348
Sex	0.98937
Breastfeeding Initiation	0.93800
Long Birth Stay	0.76942
Low Birth Weight	0.64398
Premature	0.59916
ICU Stay of 3+ Days at Birth	0.69953
ICU	0.92415
6+ Days in Hospital	0.87270

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 71: Multicollinearity – Interest in Literacy/Numeracy and Memory Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.71153
Lone Parent Family	0.69034
Low SES	0.87592
4+ Children	0.86824
Maternal Age at First Birth	0.63366
Maternal Depression	0.97966
CFS Involvement	0.89538
Income Assistance	0.51845
Age	0.99515
90%+ Minor ADG	0.60022
2+ Major ADG	0.99999
Number of Physician Visits	0.56146
Sex	0.99140
Breastfeeding Initiation	0.93766
Long Birth Stay	0.74767
Low Birth Weight	0.62105
Premature	0.57372
ICU Stay of 3+ Days at Birth	0.68280
ICU	0.90448
6+ Days in Hospital	0.85839

Note: **Bold** indicates multicollinearity is of concern.

Appendix Table 72: Multicollinearity – Basic Numeracy Sub-Domain

Variable (Raw Score)	Tolerance
Low Maternal Education	0.72353
Lone Parent Family	0.69358
Low SES	0.88240
4+ Children	0.87714
Maternal Age at First Birth	0.64598
Maternal Depression	0.97883
CFS Involvement	0.89634
Income Assistance	0.53138
Age	0.99029
90%+ Minor ADG	0.60576
2+ Major ADG	0.96290
Number of Physician Visits	0.55508
Sex	0.99101
Breastfeeding Initiation	0.94275
Long Birth Stay	0.73686
Low Birth Weight	0.61514
Premature	0.56673
ICU Stay of 3+ Days at Birth	0.67321
ICU	0.90211
6+ Days in Hospital	0.86466

Note: **Bold** indicates multicollinearity is of concern.