The Breastfeeding Triangle: Crawling as a Mediator of Breastfeeding Duration and Cognitive Development at 2 Years of Age

By

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Table of Abbreviations

Abbreviation	Term
AA	Arachidonic Acid
AIMS	Alberta Infant Motor Scale
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BCC	Breastfeeding Committee for Canada
BF	Breastfed
BSID	Bayley Scales of Infant Development
BSID-MDI	Bayley Scales of Infant Development - Mental Development Index
BSID-PDI	Bayley Scales of Infant Development - Psychomotor Development Index
CI	Confidence Interval
DDST	Denver II Developmental Screening Test
DHA	Docosahexaenoic Acid
FF	Formula Fed
HDQ	Health and Demographics Questionnaire
ICC	Intraclass Correlation
IMS	Infant Milestones Study
LCPUFA	Long-Chain Polyunsaturated Fatty Acids
MCDI	MacArthur Communicative Development Inventory

Abbreviation	Term *(continued)*
MHRC	Manitoba Health Research Council
MSCA	McCarthy Scales of Children’s Abilities
PARCA	Parent Report of Children’s Abilities
PDMS	Peabody Developmental Motor Scales
PPVT	Peabody Picture Vocabulary Test
RDLS	Reynell Developmental Language Scales
SEM	Structural Equation Modeling
SES	Socioeconomic Status

Abstract

Longer breastfeeding durations may enhance cognition and accelerate motor development; motor development, and in particular, crawling, may lead to dramatic changes in cognition. Based on these empirical relations, the hypothesis that crawling mediates breastfeeding duration and cognitive outcome was tested. Specifically, it was hypothesized that longer breastfeeding durations would significantly predict both earlier crawling and higher cognitive scores at 2 years of age, that earlier crawling would also predict higher cognitive scores, and that earlier crawling would account for part of the relationship between longer breastfeeding durations and higher cognitive scores. A sample of 44 full term infants from Winnipeg, Manitoba was followed longitudinally between birth and 2 years of age. Data on breastfeeding duration and crawling were collected through daily parent checklists, with supplemental breastfeeding information obtained via questionnaires. Near the toddlers' 2nd birthdays, cognitive abilities were assessed with the *MacArthur Communicative Development Inventory: Words and Sentences* (Fenson et al., 1993) and the *Parent Report of Children's Abilities* (Saudino et al., 1998). All 3 key variables were measured on continuous scales, and a mediational analysis based on Baron and Kenny's (1986) classic approach of 3 regressions was used. Several covariates were considered for inclusion in the regressions, but none reached significance in preliminary tests and thus, were not included. In the first 2 regression analyses, exclusive and partial breastfeeding durations significantly predicted neither cognitive scores (p = .59) nor age of crawling attainment (p = .41). The 3rd regression

analysis showed a significant, small-to-medium effect size for earlier crawling attainment predicting higher cognitive scores ($p < .05$, adjusted $R^2 = .09$). However, crawling onset had no effect on the breastfeeding-cognition link. The overall test of the mediation was inconclusive, due to low power. The significant finding between age of crawling onset and cognitive outcomes at 2 years of age may be due to earlier crawling altering the course of development, to reverse causation whereby more cognitively advanced infants are motivated to crawl sooner, or to a 3rd variable affecting both crawling and cognition. Future research should continue to explore motor and cognitive connections in infant development.

Chapter 1: Introduction

Improving early child development is a national and provincial priority (e.g., Healthy Child Manitoba, 2002a, 2002b, 2003; Human Resources Development Canada & Health Canada, 2002, 2003), and rightly so. Improved development in the first 5 to 6 years of life can mean improved outcomes for a lifetime, and the more we can learn about early child development, the more we can do to improve it. However, learning about development is not an easy task. It is complicated by the fact that development is not linear, nor does it proceed in exactly the same way for all children. Furthermore, even if these complications were mitigated, it remains that a single study cannot possibly answer an expansive research question like how to improve early child development. Rather, several studies are needed that act as "single data points" (Schmidt, 1992, p. 1179), and the current study can be considered one of these important data points.

The current research focuses on 3 of the 16 indicators of child well-being used by the Government of Canada to monitor early child development: breastfeeding duration, cognitive and language development, and motor development (Human Resources Development Canada & Health Canada, 2002, 2003). By bringing together these three domains of infant development, this research heads in a new direction in psychology; that is, it takes physiological considerations, such as breast milk's ongoing effect on infants, into account in the study of behavioural development (Michel & Moore, 1995). Such consideration is important because nutrition is an element woven throughout the development of an infant, likely affecting the infant in ways we have yet to understand.

To help bridge this gap in understanding, the current study approached development from the perspective of dynamic systems theory, which “is more a way of thinking about development than a specific theory” (Thelen & Smith, 1998, p. 601). This approach to development uses the idea that dynamic systems, such as developing infants, are formed from complex webs of myriad related processes that affect, and are affected by, each other. This web of processes, or, in other words, the *complexity* of the system, is one of the five main principles of dynamic systems theory (Michel & Moore, 1995; Thelen & Smith, 1994, 1998). This principle stresses the interrelatedness and dependence among various aspects of development, as well as the possibility that relationships among processes may not always be obvious. For example, “the development of reading ability may not require practice with books; rather it may depend on the development of certain forms of neural processing derived from motor skills acquired quite a long time before reading begins” (Michel & Moore, 1995, p. 21). The development of these neural processes may have depended on several bioactive compounds that the infant received throughout the duration of breastfeeding (Cockburn, 2003; Newburg, 2001). Thus, a link between breastfeeding duration, motor skills, and cognition seems plausible according to this theory, but has not yet been specifically explored.

The relationship between two of these variables, breastfeeding duration and cognition, *has* been thoroughly explored over several decades, and within the framework of dynamic systems theory, this past research provides important information about the system of the developing infant. Additional processes, such as motor development, are best studied in the context of this system; therefore, the current research considered

Burgard's (2003) model of the web of processes linking nutrition and cognitive outcomes. His model included the physiological variables of the nervous system and the hormones prolactin and oxytocin, as well as the behavioural and social interaction variables of type of feeding, mother-child contact, and parenting. The current study proposed that the additional intervening variable of motor development could be added to such a model (Figure 1.1).

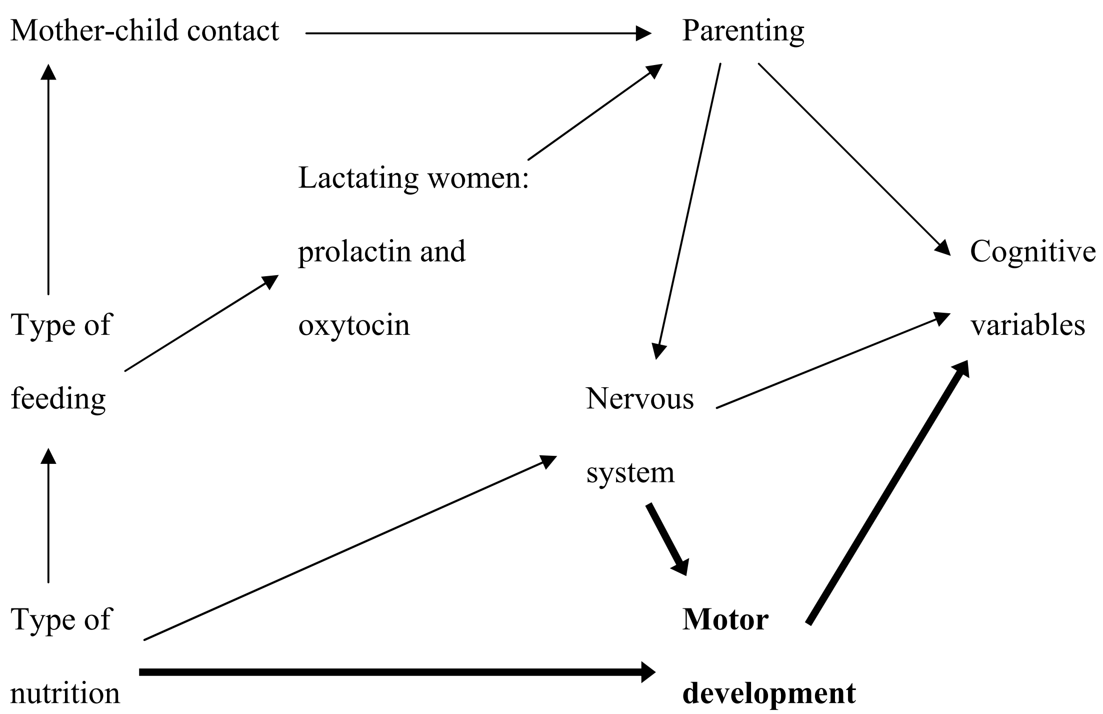

Figure 1.1. Conceptual model of the pathways from nutrition to cognitive development with proposed additions in bold type. *Note.* From "Critical evaluation of the methodology employed in cognitive development trials," by P. Burgard, 2003, *Acta Pædiatrica, 92* (Suppl.), p. 7. Copyright 2003 by Taylor & Francis. Adapted with permission.

The addition of motor development as an intervening variable between nutrition and cognitive outcomes is not a new idea (e.g., Pollitt, Gorman, Engle, Martorell, & Rivera, 1993); Pollitt and colleagues (Pollitt, 2000; Pollitt, Jahari, & Walka, 2000; Walka & Pollitt, 2000) used a model containing motor development to explore how undernutrition during early life may have related to cognitive delay at 12 and 18 months of age (Figure 1.2). Pollitt's (2000) model included different variables than Burgard's (2003), supporting the idea that different variables may be important in the relation between nutrition and various outcomes for different groups of children (e.g., Pollitt, 2000; Pollitt et al., 1993; Scrimshaw, 1993; Wachs, 1993). For example, undernourished children, more so than well-nourished children, may suffer from iron deficiency anemia, which has been associated with poor motor and cognitive development (Grantham-McGregor & Ani, 1999, 2001; Harahap, Jahari, Husaini, Saco-Pollitt, & Pollitt, 2000; Moffatt, Longstaffe, Besant, & Dureski, 1994; Pollitt, 1993). In contrast, for infants and children replete with iron, a relation between iron status and cognitive and motor development is not present (Sherriff, Emond, Bell, Golding, & the ALSPAC Study Team, 2001; Stoltzfus et al., 2001). Thus, if a relation exists between nutritional status and these outcomes for well-nourished children, the effect likely acts through different pathways than those for undernourished children.

Given Burgard's (2003) and Pollitt's (2000) models, it may be possible to construct a more complete model of the system of the developing infant by combining these models and adding variables, such as iron status, to better account for each pathway through which an infant may develop. Such a complex model may approach the ideal of

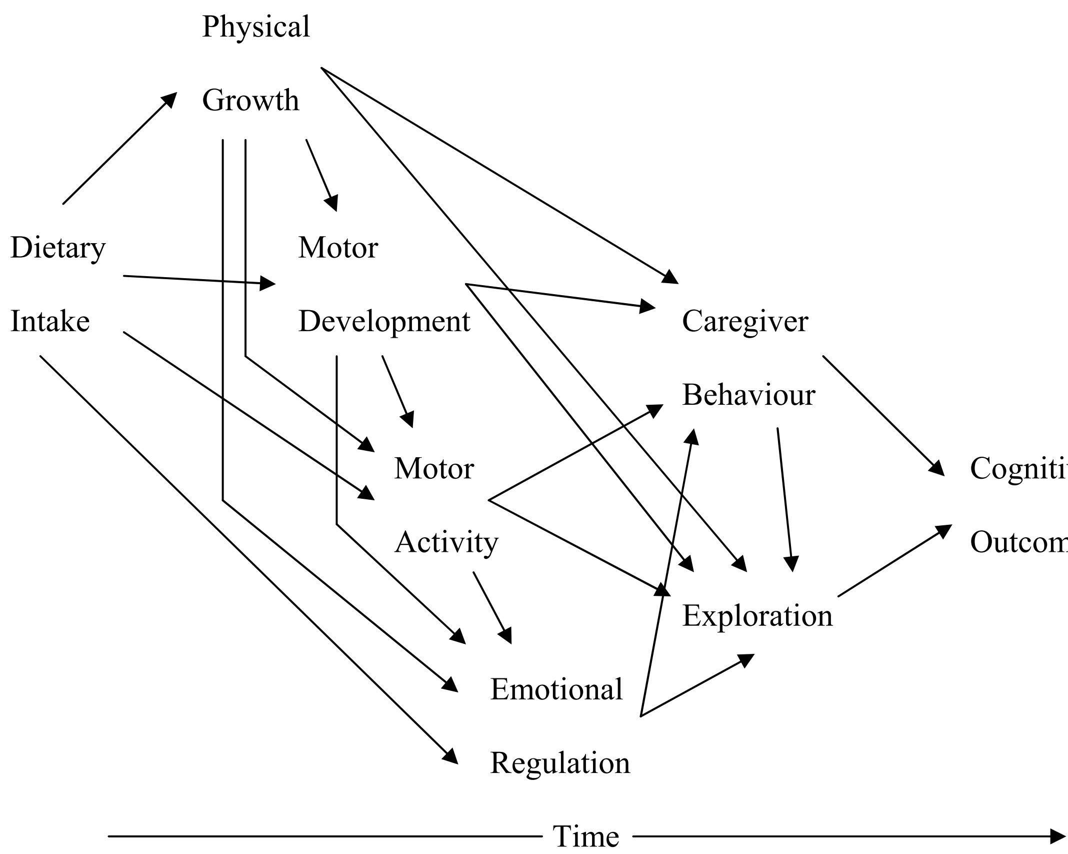

Figure 1.2. Conceptual model of undernutrition and development. *Note.* From "A developmental view of the undernourished child: Background and purpose of the study in Pangalengan, Indonesia," by E. Pollitt, 2000, *European Journal of Clinical Nutrition, 54* (Suppl. 2), p. S3. Copyright 2000 by Nature Publishing Group. Adapted with permission.

the dynamic systems model, which would include *all* variables in the web of related processes (Michel & Moore, 1995; Miller, 2002; Thelen & Smith, 1994, 1998). However, testing such a model would be difficult to accomplish, because it would be near impossible to determine whether the model captured all relevant variables and then to measure all the variables that had been identified. Even if these steps could be performed, it is important to consider that the more variables included in one study, the less clearly the results can be attributed to each variable (Cohen, 1990). Furthermore, because dynamic systems theory was originally used to describe physical systems, its application to development is relatively new, and a guiding methodology is not in place (Lewis, 2000). Therefore, although dynamic systems theory emphasizes the importance of considering the whole web of related processes, and overall the research community is best off to do so, other factors limit the scope of single research studies. Consequently, the current study acknowledges the multitude of influences in the web of infant development, but does not specifically study every one. Rather, the study focused on a subset of variables from the theoretically more complete model and looked at motor development as an intervening variable between breastfeeding and cognitive development. The current study used Figures 1.1 and 1.2 to support conceptually a simplified model containing only the three key variables (Figure 1.3).

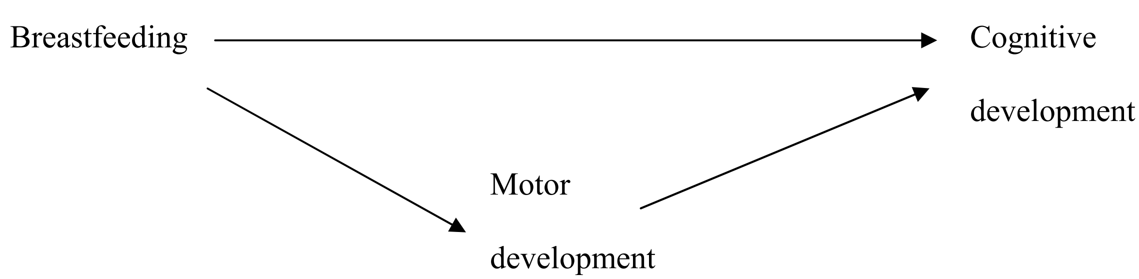

Figure 1.3. Simplified model explored in the current study.

The model in Figure 1.3 could be tested in a variety of ways. The current study tested it by operationally defining breastfeeding as the duration of both exclusive and partial breastfeeding, motor development as the age of crawling onset, and cognitive development as the score on standard verbal (MacArthur Communicative Development Inventory: Words and Sentences; MCDI; Fenson et al., 1993) and nonverbal (Parent Report of Children's Abilities; PARCA; Saudino et al., 1998) assessment tools at 2 years of age. The choice of these definitions was based on the method of longitudinal parent diaries used in this study, as well as on a literature review that explored each side of the triangle in Figure 1.3. This chapter describes that literature review and presents the case for why studying the mediator of crawling onset may elucidate the relationship between longer durations of breastfeeding and enhanced cognitive development.

The chapter first explores the impact that breastfeeding has on several aspects of infant development and describes existing studies that have looked at dose-response type relationships between breastfeeding duration and cognitive development. Next, the evolution of cognitive abilities in the second year of life is examined, providing context to understand the cognitive outcome measures. Then the chapter returns to the topic of breastfeeding, this time exploring its dose-response type influence on motor development, and specifically, on the development of crawling. Modern research on crawling development is discussed next, and then evidence is presented for the relation between earlier crawling attainment and enhanced cognitive outcomes. Finally, studies that have assessed all three key variables are reviewed, the introduction is summarized, and the hypotheses are explicitly stated.

1.1 Breastfeeding: Many Paths of Influence on Infant Development

"Breast milk can quite readily be described as broad-spectrum medicine as well as nutrition" (Fredrickson, 1995, p. 411), and it and the act of breastfeeding have been designed through evolutionary history to provide optimal outcomes for the developing infant, as well as for the mother (Stuart-Macadam & Dettwyler, 1995). Modern science has not yet designed an infant formula that can rival this system, and infants who do not receive breast milk or experience breastfeeding have, in general, worse outcomes than infants who do. Thus, several countries and the World Health Organization have policies in place that support and recommend breastfeeding (e.g., American Academy of Pediatrics Section on Breastfeeding, 2005; Health Canada, 2004; World Health Organization, 1989).

While breastfeeding's health benefits to mothers may in general allow them to better care for their infants, this section will cover some of the health and developmental benefits of breastfeeding for infants. Specific aspects of health and development have been selected because of their relevance to the current study. That is, breastfeeding's influence on these aspects (the micronutrient iron, ear infections, growth, communication, and long-chain polyunsaturated fatty acids [LCPUFA]) may lead to differential outcomes in motor and cognitive development, and although differences between breastfed (BF) and formula fed (FF) infants are presented, in most of these examples, longer durations of breastfeeding may likely provide more of the benefits.

1.1.1 Iron

Researchers have suggested for many years that iron is linked to healthy cognitive and motor development in infants and children (Grantham-McGregor & Ani, 1999, 2001; Pollitt, 1993). Much of this research has been based on general developmental tests, but more recently, researchers are going beyond these general tests to assess specific aspects of development that may be affected by iron status. For example, Friel et al. (2003) tested visual acuity in 1-year-old infants and Metallinos-Katsaras et al. (2004) tested speed of processing and discrimination, as well as rate of conceptual learning in 3- to 4-year-old children. These researchers found that better iron status predicted better visual acuity and better discrimination speed. Further, scattered studies have examined specific motor outcomes; Lozoff et al. (2003) found that infants supplemented with iron crawled earlier than unsupplemented infants.

Opportunities to acquire iron early in life differ for BF and FF infants. Exclusively BF infants can obtain adequate amounts of iron for the first 4 to 6 months of life from breast milk, which contains a low concentration of highly bioavailable iron (Calvo, Galindo, & Aspres, 1992; Canadian Paediatric Society , Dieticians of Canada, & Health Canada, 1998; Krebs, 2000; Stuart-Macadam & Dettwyler, 1995). In contrast, infants fed with a cow's milk formula may not be able to obtain iron as readily; the iron in cow's milk is not as bioavailable to the human infant, and further, the high calcium content of cow's milk depresses the absorption of iron.

Both BF and FF infants may require iron-fortified foods or iron supplementation after about 4 to 6 months of age to meet their iron needs (Calvo et al., 1992; Canadian

Paediatric Society et al., 1998; Godel, 2000; Krebs, 2000); iron status during the latter half of infancy varies depending on such supplementation. Some studies report that BF infants have higher hemoglobin levels and suffer less iron-deficiency anemia in the late-first and early-second year of life compared to FF infants (Pisacane et al., 1995; Stuart-Macadam & Dettwyler, 1995; Willows, Dewailly, & Gray-Donald, 2000), while other studies report the reverse (Calvo et al., 1992; Hokama, 1993a, 1993b). Thus, iron's effect on developmental outcomes may differ between BF and FF infants, but the direction of the difference cannot be clearly predicted.

1.1.2 Ear Infections

Breastfeeding strengthens young infants' immune systems (e.g., Stuart-Macadam & Dettwyler, 1995), protecting against many infections, including ear infections (Aniansson et al., 1994; Duncan et al., 1993; Engel, Anteunis, Volovics, Hendriks, & Marres, 1999). Protection from ear infections is important to a developing infant because it may prevent adverse effects on hearing and later language development (Duncan et al., 1993). Several studies suggest a dose-response type relationship may exist between breastfeeding and ear infections. Aniansson et al. (1994) found that age at the first acute otitis media episode was inversely related to the duration of breastfeeding, and for infants BF longer than 10 months, no episode occurred. Similarly, Duncan et al. (1993) found that the number of episodes of acute otitis media decreased significantly with increasing duration and exclusivity of breastfeeding, and in fact, the relationship was independent of the other risk factors such as male gender, day care, and maternal smoking. Supporting this evidence, Engel et al. (1999) found a significant breastfeeding by time interaction and suggested that it was due to longer durations of breastfeeding decreasing risk; however, they also pointed out that the more time elapsed since the complete cessation of breastfeeding, the greater the risk, up to 24 months of age. One caution in reviewing this research is that while longer durations of breastfeeding may be beneficial, the reduced episodes of ear infection at older ages may simply reflect that fact that if episodes are prevented early in life, they will be less likely to occur later on (Duncan et al., 1993).

1.1.3 Growth

BF infants tend to follow a different growth pattern in the first year of life compared to FF infants (Butte, Wong, Hopkinson, Smith, & Ellis, 2000; Cole, Paul, & Whitehead, 2002; de Onis & Onyango, 2003; Dewey, 1998; Dewey et al., 1995; Dewey, Heinig, Nommsen, Peerson, & Lönnerdal, 1993; Heinig, Nommsen, Peerson, Lonnerdal, & Dewey, 1993a; Kramer et al., 2004; Williams, 2002). BF infants generally grow rapidly in the first few months of life and then their growth rate slows, and they have a lower weight-for-length index from approximately 6 to 12 months of age compared to published growth norms. This growth pattern is relevant in terms of the present study because in developed countries, chubbier babies tend to crawl later than slimmer ones (Adolph, 1997; Adolph, Vereijken, & Denny, 1998; Hopkinson, 2003; Pollitt et al., 1994; Shirley, 1931), and crawling usually begins during this period when BF infants show slower growth (e.g., Piper & Darrah, 1994).

The conclusions about infant growth have all been drawn from observational studies because breastfeeding cannot be randomly assigned to infants in a controlled trial. Thus, it is possible that uncontrolled confounding variables or bias are responsible for the differences observed in growth trajectories (Kramer et al., 2002; Williams, 2002). For example, mothers in developed countries who breastfeed tend to be of higher socioeconomic status (SES), and it is possible that these mothers have different views of nutrition than mothers who formula feed their infants. This potential bias was shown when Baughcum et al. (2001) controlled for family income: they found that the significant relationship between breastfeeding and child overweight status in the second year of life disappeared. Although the differences in growth trajectories may be due to this or other potential confounders, the differences remain robust (O'Brien, 2003), and thus should be considered as a potential source of differential outcomes for BF and FF infants in the first year of life.

1.1.4 Communication

An additional realm of development that appears to be facilitated by breastfeeding is that of communication. The human infant's communication skills develop during all experiences where the infant interacts with others, and the feeding experience is one of the earliest regular interactions that the infant has with other people. During feeding, mothers and infants learn to communicate with each other through turn-taking led by the infant's bursts and pauses during suckling (Field, 1977; Kaye, 1977). It is "speculated that a possible adaptive function of the pauses might be their one most striking effect: to elicit a response from the mother" (Kaye, 1977, p. 93), and indeed, mothers often "jiggle" their infants during pauses, after which the infants resume suckling. This turn taking has been hypothesized to be necessary for language acquisition because it helps infants to understand the same kind of turn taking that occurs during conversations (Kaye, 1977). Interestingly, Lavelli and Poli (1998) found differences in the burst-pause behaviour of BF and FF infants. FF infants spent less total time sucking, and their pauses were shorter or almost did not occur at all. Thus, bottle-feeding may lead to reduced opportunities for communication between mother and infant (Lavelli & Poli, 1998), especially since feeding may be one of the few times when a busy mother can sit and interact intimately with her baby (Buckley, 1992; Epstein, 1993). Furthermore, breastfeeding mothers in Lavelli and Poli's (1998) study provided more tactile stimulation and shared more gazes with their infants compared to the bottle-feeding mothers, and touch and shared attention are two important communicative tools in infancy that aid in the acquisition of language, as well as in social and emotional development (Epstein, 1993; Hertenstein, 2002).

1.1.5 Long-Chain Polyunsaturated Fatty Acids

A final breastfeeding advantage briefly presented here is the presence of some bioactive components that have received much attention recently: LCPUFAs, mainly docosahexaenoic acid (DHA) and arachidonic acid (AA), and their polyunsaturated fatty acid precursors, α-linolenic acid and linoleic acid, respectively (e.g., Cockburn, 2003; Farquharson et al., 1995). These LCPUFAs are important for retinal and neural development and may be so for cognitive and motor development as well (e.g., Bouwstra et al., 2003; Cockburn, 2003; Columbo et al., 2004; Newburg, 2001).

Newborn infants may not be able to effectively convert the precursor fatty acids to their LCPUFA counterparts (Farquharson et al., 1995), so the availability of the LCPUFAs in infant nutrition is important. BF infants receive both DHA and AA throughout the duration of breastfeeding (Agostoni et al., 2001; Cockburn, 2003), and numerous research studies have explored the results of adding LCPUFA to formula (e.g., Dobbing, 1997), although not all modern formulas contain these compounds (e.g., Cockburn, 2003; Giovannini, 2001; Rey, 2003). For both BF and FF infants, LCPUFAs are transported from the mother prenatally through the placenta (Dutta-Roy, 2000), and maternal DHA levels have been shown to affect cognitive outcomes in infants throughout the first and second years of life (Columbo et al., 2004).

While several lines of research are pointing to the importance of LCPUFA, it is also important to point out that “clear attribution … to some components of breast milk (long-chain polyunsaturated fatty acids) is precluded since human milk contains many other substances not present in formulae (e.g. hormones) that may theoretically influence neurodevelopment” (Rey, 2003, p. 11). Furthermore, “the presence of a factor in breast milk does not necessarily imply essentiality” (Lucas, 1997, p. 8). Thus, while BF babies tend to have higher concentrations of LCPUFAs than FF babies, and BF babies are assumed to have better retinal and neural development, it is not clear that the LCPUFAs cause such development.

In conclusion, this section has presented reasons why we might expect BF babies to differ from their FF counterparts, and further, why we may expect differences depending on the duration of breastfeeding. However, the "arguments are irrelevant unless a beneficial behavioural outcome is demonstrated" (Rey, 2003, p. 17). Thus, in subsequent sections evidence for breastfeeding's impact on the behavioural outcomes of cognitive and motor development is presented, along with supporting evidence for dose-response type relationships.

1.2 Breastfeeding and Cognitive Development: A Literature Review

Breastfeeding's relation to cognitive development has been studied since the early decades of the twentieth century (e.g., Hoefer & Hardy, 1929), and although higher intelligence is often reported as a verified benefit of breastfeeding (e.g., Riordan & Auerbach, 1999), recent efforts have been made to take a critical look at the amassed information regarding the relationship (Anderson, Johnstone, & Remley, 1999; Drane & Logemann, 2000; Jain, Concato, & Leventhal, 2002; Rey, 2003; Uauy & Peirano, 1999). This increased scrutiny has shown that methodological flaws plague the research, and conclusions drawn from these inadequate procedures should be interpreted cautiously. Thus, first some of the key methodological problems likely responsible for inconsistency in the research conclusions are covered, and then selected studies are presented.

1.2.1 Methodological Problems

1.2.1.1 Random Assignment. The main methodological problem faced in breastfeeding research is the ethical preclusion of randomly assigning babies to a BF condition. Inability to do so means observational studies must be used, which “no matter how well controlled, restrict the validity of comparisons by potential inherent biases” (Uauy & Periano, 1999, p. 433). Thus, a key goal is to disentangle, either methodologically or analytically, the effects of numerous variables that correlate with initiating and continuing breastfeeding (see Table 1.1; Breastfeeding Promotion Steering Committee of Manitoba, 1998; Cernadas, Noceda, Barrera, Martinez, & Garsd, 2003; Dennis, 2002; Dubois & Girard, 2003). This goal has been achieved to some extent in studies that matched BF and FF infants (e.g., Silva, Buckfield, & Spears, 1978), or that included confounding variables in an analysis of covariance (ANCOVA; e.g., Morrow-Tlucak, Haude, & Ernhart, 1988) or regression analysis (e.g., Rogan & Gladen, 1993).

Researchers disagree about whether only a few very important factors should be considered as covariates (Jain et al., 2002; Uauy & Peirano, 1999), or whether studies should control as many as possible (Anderson et al., 1999). The hesitation with including several covariates is that many of the variables in Table 1.1 are related to each other in a complex web and may not explain unique variance in the outcome. Thus, if researchers decide to use several of these variables, they should take care to ensure that the predictor variables are not too highly correlated (i.e., no multicollinearity is present; Drane & Logemann, 2000; Paine, Makrides, & Gibson, 1999).

Table 1.1

Some Characteristics Associated with the Decision to Initiate and Continue Breastfeeding

Maternal Characteristics		
	Age at delivery	Marital status or cohabitation
	Alcohol use	Parenting skills, style, and attitudes
	Educational level	Parity
	Ethnicity	Prenatal class attendance
	Health	Smoking status
	Intelligence	Working status or occupation
Infant Characteristics		
	Birth order	Health
	Birth weight	Ethnicity
	Gestational age	Sex
Family Characteristics		
	Home environment	Social class or socioeconomic status (SES)

1.2.1.2 Definition of Breastfeeding. The factors listed in Table 1.1 contribute to differences between mother-infant pairs who breastfeed and those who do not, as well as between those who breastfeed for longer versus shorter durations. Breastfeeding durations are more highly variable today than they once were: up to the early 1900s, if an infant was BF at all, he or she was BF for a "reasonably long duration" (Fredrickson, 1995, p. 407). In contrast, recent breastfeeding duration estimates show great variability. For example, in 1996, 92% of Manitoba mothers initiated breastfeeding in hospital, 82% were still breastfeeding at 2 weeks (Breastfeeding Promotion Steering Committee of Manitoba, 1998), 57% (± 7%) continued to breastfeed at 3 months, 36% (± 7%) continued until 6 months, and 15% (± 6%) BF to 1 year (Martens, Derksen, Mayer, & Walld, 2002). With each passing month, fewer mothers breastfeed, and because of this variability in breastfeeding duration, dichotomous transformations in recent studies discard large amounts of data, causing loss of statistical power (Fredrickson, 1995; MacCallum, Zhang, Preacher, & Rucker, 2002) and potential misclassification bias (Drane & Logemann, 2000). Misclassification occurs when infants with different feeding histories are included in the same category, for example, when infants with short durations of breastfeeding and FF infants are grouped (e.g., Wigg et al., 1998), or when both exclusively and partially BF infants are grouped (e.g, Aarts et al., 2000). Such misclassification likely masks differences between exclusively and partially BF infants, and in fact, Drane and Logemann (2000) found larger differences, or effect sizes in studies that differentiated between the two groups.

Although a simple dichotomy is not the answer, a useful alternative is also difficult to define. At the very least, multiple categories should be used, and while this seems simple enough, in practice it has led to almost as many different category splits as there are studies (Burgard, 2003). Beyond the various age categories available, there are also several labels for the same feeding pattern. For example, an infant fed breast milk and one bottle of formula in a day could have a “partial-high” (Labbok & Krasovec, 1990) or a “predominant” (Breastfeeding Committee for Canada [BCC], 2004; World Health Organization, 1996) breastfeeding pattern. Because of this long-standing inconsistency in definitions, Labbok and colleagues (Labbok & Krasovec, 1990; Labbok & Coffin, 1997; Labbok, Belsey, & Coffin, 1997) have made calls to researchers to define breastfeeding in uniform terms to allow comparisons across studies, and more recently the BCC (2004) developed guidelines for use in Canada. Even though these documents outline straightforward classification schemes, Labbok and Krasovec’s (1990) original plea has remained largely ignored (Labbok & Coffin, 1997; Labbok et al., 1997), and it is too early to know whether the BCC’s guidelines will be useful. Part of the difficulty in using these schemes may be that they are designed for use at one point in time (e.g., *at three months* the infant was exclusively BF; Martens, 2000). Thus, these schemes are not directly applicable over time because we cannot label a 2-year-old toddler as exclusively BF when he or she was exclusively BF up to 4 months of age.

One solution to the problem of categorization, of course, is to measure breastfeeding as a continuous variable. This can be accomplished by asking mothers to retrospectively provide the age at which their infants were no longer BF or exclusively BF (Arbon & Byrne, 2001). Again, this seems simple enough at the outset. However, once researchers consider that breastfeeding does not always follow a uniform progression from exclusive to partial to none (Marquis, Diaz, Bartolini, De Kanashiro, & Rasmussen, 1998; Martens, 2000; Piwoz, De Kanashiro, De Romana, Black, & Brown, 1995; Zohoori, Popkin, & Fernandez, 1993) the picture becomes more complicated. The reversibility of feeding patterns makes it difficult to specifically define at what point exclusive or partial breastfeeding ended. For example, if a strict definition of exclusive breastfeeding were used, that is, it ends the day any other liquid or solid is given, then most infants would not be exclusively BF beyond their hospital stay after delivery (Blomquist, Jonsbo, Serenius, & Persson, 1994; Kurinij & Shiono, 1991; Saarinen et al., 1999). While such supplementation in the hospital may affect later breastfeeding and health and developmental outcomes (Blomquist et al., 1994; de-Rooy & Hawdon, 2002; Nylander, Lindemann, Helsing, & Bendvold, 1991; Perez-Escamilla, Pollitt, Lonnerdal, & Dewey, 1994; Saarinen et al., 1999), a different definition that accounts for continued breastfeeding behavior over time may be useful for some researchers.

Bodnarchuk, Eaton, and Martens (2005) proposed a strategy that can be used to define breastfeeding over time. Using daily parent checklists, Bodnarchuk et al. showed that the transition from exclusive to partial breastfeeding (i.e., the beginning of supplementation) takes up to 7 days for approximately 95% of mother-infant pairs and that the transition from partial to no breastfeeding (i.e., weaning) takes only 1 day for 95% of pairs. Thus, Bodnarchuk et al. proposed that an “age of breastfeeding duration” variable could be calculated by subtracting an infant’s birth date from the first day of the week in which the transition to partial breastfeeding was made, or the week or day in which the transition to no breastfeeding was made. Doing so creates a continuous variable on the age metric, which is then comparable across studies, countries, and time (Wohlwill, 1973). However, this definition of breastfeeding has not yet been tested in an independent sample and some caution may be required in its application.

1.2.1.3 Measurement of Cognitive Abilities. Just as inconsistencies in the definitions of breastfeeding make comparisons difficult, so, too, do the numerous tools used to define cognitive development. For example, cognitive development in the second year of life can be measured by observing infants perform any number of specific activities, such as reproducing a previously witnessed action or recognizing themselves in a mirror (Courage & Howe, 2002). Mental development can also be measured more broadly using standardized assessments, and as shown in the review of selected studies later, a highly popular assessment in infancy is the Bayley Scales of Infant Development (BSID; Bayley 1969, 1993). While consistent use of this tool makes comparisons across studies feasible (e.g., Grantham-McGregor & Ani, 2001), use of the BSID is not without problems (Campbell, Siegel, Parr, & Ramey, 1986; Fenson et al., 1994; McCall, 1979; Pollitt, 1978, 2000; Pollitt & Triana, 1999; Saudino et al., 1998). For example, it may not be sensitive to important cognitive changes that occur before approximately 18 to 24 months of age (Pollitt, 2000; Pollitt & Triana, 1999; Roberts, Bornstein, Slater, & Barrett, 1999; Willatts & Forsyth, 2000). Thus, researchers must consider the options when choosing the best measure of cognitive development for their own studies.

In summary, the three main methodological problems faced by researchers looking at the relationship between breastfeeding and cognitive development are the inability to randomly assign babies to a BF condition, the unclear definitions of breastfeeding, and the pros and cons of available cognitive measurement tools. However, one additional problem faced by researchers in many disciplines is that of having enough power to detect real effects. Power calculations, which require an indication of the size of the effect in the population, are essential for interpreting the significance of results (Cohen, 1988, 1990). However, they remain rare in research, and while only one of the studies presented in the next section performed its own power calculation, effect sizes were estimated here from the diverse analyses in these selected studies and were used in a power calculation for the current study (see *Section 2.1 Participants*).

1.2.2 Selected Studies

The literature on breastfeeding and cognitive development is sizeable and has been summarized almost annually in recent years (Anderson et al., 1999; Drane & Logemann, 2000; Golding, Rogers, & Emmett, 1997; Jain et al., 2002; Rey, 2003; Reynolds, 2001). These reviews have guided selection of the most relevant articles for the present study based on three criteria. First, although studies have been conducted from early infancy (Agostoni, Trojan, Bellù, Riva, & Giovannini, 1995) to old age (Gale & Martyn, 1996), the studies presented here are those looking at cognitive outcomes in children up to 3 years of age. This age range was selected to gain an overview from the existing literature that encompassed the age of 2 years, which was the age of interest in the current study. Second, because the current sample was composed of term infants, studies of small-for-gestational-age (e.g., Rao, Hediger, Levine, Naficy, & Vik, 2002) and preterm or low birth weight infants (e.g., Bier, Oliver, Ferguson, & Vohr, 2002) were not included, even though the effects from breastfeeding have been more pronounced for these babies (Golding et al., 1997; Rey, 2003; Reynolds, 2001). Third, because the present study used duration of breastfeeding as a continuous variable, only those studies that grouped BF infants into at least two categories were included; these studies were able to show whether differing lengths of breastfeeding duration were important, for example, in a dose-response type relationship (see Table 1.2).

As can be seen from Table 1.2, while *significant* differences in cognitive abilities have generally not been found until 1 year of age and even after that are not consistently reported, effect sizes show a more consistent pattern through the whole age range. In general, there appears to be a small-to-medium, with an occasional medium-to-large, effect. The medium-to-large effect usually occurred in studies where breastfeeding was measured as a continuous variable (Bauer, Ewald, Hoffman, & Dubanoski, 1991; Paine et al., 1999) and this shift in effect size may have been due to more precise measurement (Cohen, 1988). In sum, these results suggest a potential true effect in the population.

Two studies presented in Table 1.2 assessed infants longitudinally. First, Morrow-Tlucak et al.'s (1988) study exemplified the trend in significance tests and effect sizes; their study appeared to have adequate power to detect a small-to-medium effect at 1 and 2 years, while accurately accepting the null hypothesis at 6 months. They summarized their regression analyses by suggesting that the "amount of explainable variance contributed by breastfeeding" (p. 638) was 11.7% at 1 year and 5.6% at 2 years. Second, Rogan and Gladen (1993) claimed a "small effect size" (p. 191) overall, but did not report statistics that allowed specific calculations at each age. Rogan and Gladen did not find significant effects until 2 years of age, and results at both 2 and 3 years showed a gradient from the low scores of FF infants to the high scores of infants BF for more than 50 weeks, suggesting a dose-response relationship. The differences in adjusted scores on

Table 1.2

Studies of the Relationship Between Breastfeeding and Cognitive Development in Children up to 3 Years of Age

Age in Months at Cognitive Testing	First Author (Year)	*N*	Covariates Used[a]	Feeding Variable Categories[b]	Cognitive Development Test(s) Used[c]	Significant Results?	ES[d]	ES Level[e]
6	Morrow-Tlucak (1988)	229	Maternal age, education, race, intelligence, marital status, child-rearing attitudes, smoking; infant age at time of testing; home environment	(1) FF (2) BF >1 week, but <4 months (3) BF 4+ months	BSID-MDI	No	f = 0.07	zero-to-small
	Rogan (1993)	788	Maternal age, alcohol use, education, race, smoking, occupation; infant birth order, birth weight, sex, age at testing, prenatal exposure to polychlorinated biphenyls and dichlorodiphenyl dichloroethene; identity of the examiner	(1) FF (2) BF < 9 weeks (3) BF 9-19 weeks (4) BF 19-49 weeks (5) BF > 50 weeks	BSID-MDI	No	–	

Table 1.2 *(continued)*

Age in Months at Cognitive Testing	First Author (Year)	*N*	Covariates Used[a]	Feeding Variable Categories[b]	Cognitive Development Test(s) Used[c]	Significant Results?	ES[d]	ES Level[e]
9	Innis (1996)	433	None	(1) never BF (2) BF <1 month (3) BF 1-3 months (4) BF 3-6 months (5) BF 6-8 months (6) BF 8-9 months (7) BF & FF	Teller Acuity Cards, Fagan Test of Infant Intelligence	No	f = 0.77 f = 0.14	very large small-to-medium
12	Agostoni (2001)	44	Maternal age, education, parity, smoking	(1) BF 3-6 months (2) BF 6+ months	BSID-MDI	No	f = 0.11	small-to-medium
	Morrow-Tlucak (1988)	229	*See listing for 6 month entry by same author.*		BSID-MDI	Yes	f = 0.21	small-to-medium
	Paine (1999)	96	Maternal age; infant sex	*Continuous*	BSID-MDI	Yes	f^2 = 0.18	medium-to-large

Table 1.2 *(continued)*

Age in Months at Cognitive Testing	First Author (Year)	*N*	Covariates Used[a]	Feeding Variable Categories[b]	Cognitive Development Test(s) Used[c]	Significant Results?	ES[d]	ES Level[e]
12	Rogan (1993)	720	*See listing for 6 month entry by same author.*		BSID-MDI	No	–	
13	Angelsen (2001)	345	Maternal age, education, intelligence, smoking	(1) BF <3 months (2) BF 3-6 months (3) BF 6+ months	BSID-MDI	Yes	f = 0.25	medium
18	Gómez-Sanchiz (2003)	249	Maternal education, intelligence, smoking, urban or rural background; family social class; paternal education, intelligence	(1) FF (2) BF <4 months (3) BF 4+ months	BSID-MDI	Yes	r = 0.42 f = 0.47	medium-to-large large
	Rogan (1993)	676	*See listing for 6 month entry by same author.*		BSID-MDI	No	–	
24	Morrow-Tlucak (1988)	229	*See listing for 6 month entry by same author.*		BSID-MDI	Yes	f = 0.15	small-to-medium
	Rogan (1993)	670	*See listing for 6 month entry by same author.*		BSID-MDI	Yes	–	

Table 1.2 *(continued)*

Age in Months at Cognitive Testing	First Author (Year)	*N*	Covariates Used[a]	Feeding Variable Categories[b]	Cognitive Development Test(s) Used[c]	Significant Results?	ES[d]	ES Level[e]
24	Gómez-Sanchiz (2004)	238	Maternal education, intelligence, smoking, work status; infant number of siblings; urban or rural background; family social class; paternal education, intelligence	(1) FF (2) BF ≤4 months (3) BF >4 months	BSID-MDI	Yes	r = 0.37	medium-to-large
	Wigg (1998)	601	Maternal age, IQ, cohabitation status, smoking; infant birth rank, birth weight, sex, blood lead concentration; home environment; family SES	(1) FF (2) BF (3) Mixed	BSID-MDI	No	f = 0.20	small-to-medium
36	Bauer (1991)	50	Infant sex, pesticide exposure; family SES	*Continuous*	MSCA	Yes	r = 0.39	medium-to-large

Table 1.2 *(continued)*

Age in Months at Cognitive Testing	First Author (Year)	*N*	Covariates Used[a]	Feeding Variable Categories[b]	Cognitive Develop-ment Test(s) Used[c]	Signif-icant Results?	ES[d]	ES Level[e]
36	Fergusson (1982)	1037	Maternal education, intelligence, training in child rearing; infant birth weight, gestational age, experiences; family SES	(1) FF (2) BF >4 months (3) BF 4+ months	PPVT RDLS	Yes	–	
	Silva (1978)	1037	Maternal education, mental ability; infant experiences; family SES	(1) BF <1 week (2) BF 1-4 weeks (3) BF 5-12 weeks (4) BF 13-24 weeks (5) BF 25-36 weeks (6) BF 37-51 weeks (7) BF >51 weeks	PPVT RDLS	No	–	
	Johnson (1996)	204	Maternal intelligence, smoking; infant birth order, sex; home environment; family SES	(1) BF / not-BF (2) Partially BF (3) Exclusively BF	Stanford-Binet IV, PPVT-Revised	Yes	$f^2 = 0.03$	small-to-medium

Table 1.2 *(continued)*

Age in Months at Cognitive Testing	First Author (Year)	*N*	Covariates Used[a]	Feeding Variable Categories[b]	Cognitive Development Test(s) Used[c]	Significant Results?	ES[d]	ES Level[e]
36	Rogan (1993)	645	*See listing for 6 month entry by same author.*		MSCA	Yes	–	

[a]SES = Socioeconomic status. [b]FF = Formula fed; BF = Breastfed. [c]BSID-MDI = Bayley Scales of Infant Development – Mental Development Index (Bayley, 1969, 1993); MSCA = McCarthy Scales of Children's Abilities (Kaufman & Kaufman, 1977; McCarthy, 1972); PPVT = Peabody Picture Vocabulary Test (Dunn, 1965; Revised: Dunn & Dunn, 1981); RDLS = Reynell Developmental Language Scales (McGeorge, 1960; Reynell, 1969); Stanford-Binet IV (Thorndike, Hagen, & Sattler, 1986). [d]ES = Effect size; Standardized effect sizes: dashes indicate no effect size calculation was possible, see Appendix A for formulas. [e]Conventional levels, see Appendix A for cut-off values.

the Mental Development Index of the BSID (BSID-MDI; Bayley, 1969) between the FF infants and infants BF for 19 to 49 weeks were estimated to be 5.6 points (95% confidence interval [CI]: 0.2, 11.0) at 24 months and 4.7 points (95% CI: 0.6, 8.7) at 36 months.

The remaining 11 studies in Table 1.2 assessed infants at only one age each, with approximately half studying infants less than 2 years of age. Innis, Nelson, Lwanga, Rioux, and Waslen (1996) studied both preferential looking acuity and novelty preference in 9-month-old infants. No statistically significant relationships between breastfeeding and cognitive outcomes were found. However, effect size calculations showed a small-to-medium effect for the novelty preference task and a very large effect for the visual acuity task, where the difference between the largest and smallest means was 1.3 and the pooled standard deviation was 0.44. This lack of a significant finding for the visual acuity task is perplexing, but may be due to a skewed distribution.

Agostoni et al. (2001) also did not report significant findings with a small-to-medium effect based on unadjusted means. They originally recruited 95 infants at birth, but their focus was on infants BF at least 3 months, which reduced their sample to 44. A nonsignificant difference was found, which may have been due to the small sample size in comparison to most of the other studies; however, as evidenced by Paine et al. (1999), a small sample size was not necessarily the limiting factor. Paine et al. successfully recruited ninety-six 1-year-old infants. A sex by duration-of-breastfeeding interaction explained the largest portion of variance, and separate regressions showed that while both maternal age and breastfeeding remained significant for males (n = 47), neither was significant for females (*n* = 49). Thus, with a sample size similar to the previous study, a medium-to-large effect was evident for males, possibly due to measuring breastfeeding more precisely as a continuous variable (Cohen, 1988).

The final two studies that measured cognitive outcomes before 2 years of age were those of Angelsen, Vik, Jacobsen, and Bakketeig (2001) and Gómez-Sanchiz, Cañete, Rodero, Baeza, and Ávila (2003). Angelson et al. were the only authors to present evidence of knowledge regarding power: "with a power of 80% ($\beta = 0.20$) and $\alpha = 0.05$, this study may detect a 4.8 point difference in MDI" (p. 185). Results showed a medium effect, where infants BF for less than 3 months scored 7.8 points (95% CI: 3.7, 11.9) lower than infants BF for more than 6 months. Gómez-Sanchiz et al. found a medium-to-large effect for a correlation between duration of breastfeeding and cognitive outcomes. Further, a large effect was found based on unadjusted means in a regression and after adding covariates, a significant relationship remained.

Gómez-Sanchiz, Cañete, Rodero, Baeza, and Ávila (2004) followed their sample to 2 years of age, and again found a medium-to-large effect correlation between duration of breastfeeding and cognitive outcomes. The difference in cognitive outcome for infants BF 4 months or less compared to infants BF more than 4 months was significant after covariate adjustment (4.3 point difference). Wigg et al. (1998) conducted an additional study assessing infants at 2 years of age. They found significant differences using unadjusted means, on which the effect size calculation was based; however, after adjustment for several covariates, the relationship between feeding and cognitive outcome became nonsignificant. After adjustment, the BF infants had a 3.4 point (95%

CI: -0.1, 6.9) advantage over the FF infants, but the authors point out that infants who were BF for less than 6 months would have been classified as FF and such a misclassification bias may have limited their results.

Finally, four studies assessed 3-year-old children. First, Bauer et al. (1991) showed that duration of breastfeeding both significantly correlated with and, after adjusting for covariates, significantly predicted cognitive outcomes. Although the statistical information from this study was limited, the significant correlation suggested a medium-to-large effect. Second, Fergusson, Beautrais, and Silva's (1982) multivariate ANCOVA showed significant results for breastfeeding and sex, but there was not a breastfeeding-by-sex interaction. Children BF for more than 4 months scored 2.4, 2.7, and 1.9 points higher than FF children on intelligence, comprehension, and expression, respectively, but no standard deviations were available for effect size calculations. Third, Silva et al. (1978), in a study very similar to Fergusson et al.'s, did not find significant results and, consequently, did not publish any statistics related to cognitive differences among the infants. Fourth, Johnson, Swank, Howie, Baldwin, and Owen (1996) conducted a unique study as far as their measurement of breastfeeding: three variables were created. First, a dichotomous variable indicated whether the infant was BF at all. Second, a continuous variable represented duration of any breastfeeding, and third, another continuous variable indicated length of exclusive breastfeeding. Prediction of the cognitive outcomes after covariate control was significantly improved when the first breastfeeding variable was added, suggesting a small-to-medium effect size for breastfeeding. BF infants scored 5.0 points (95% CI: 0.3, 9.5) and 4.6 points (95% CI:

0.7, 8.5) higher than FF infants on the Stanford-Binet (Thorndike et al., 1986) and PPVT-Revised (Dunn & Dunn, 1981), respectively. When the next two breastfeeding variables were added to the model, they did not add significant predictive power until a quadratic term was added, showing "that as the duration of breast feeding increases, the magnitude of the relation decreases…, after 18 months or so of breast feeding, further increases in duration have little additional relation" (Johnson et al., 1996, p. 1184).

Thus, in sum, while some authors doubt that breastfeeding indisputably affects cognitive development (Anderson et al., 1999; Drane & Logemann, 2000; Jain et al., 2002; Rey, 2003; Uauy & Peirano, 1999), the evidence presented here for the first few years of life is rather persuasive as evaluated in terms of the Bradford Hill criteria, a set of nine viewpoints often used in epidemiological research to determine potential causality (Bradford Hill, 1965; Phillips & Goodman, 2004). The first criterion is the consistency of findings. The relationship between breastfeeding and cognition meets this criterion because similar findings have been found throughout several countries and many years (Golding et al., 1997). Second is the strength of association, which can be measured by effect size. The review in this section provided evidence for a small-to-medium, and potentially a medium-to-large effect, depending on the specific measures used and the ages of assessment. The third and fourth criteria of temporal sequence and biological gradient, respectively, can be considered together in the present context. Breastfeeding begins at birth, and cognitive abilities begin developing prenatally (e.g., Michel & Moore, 1995); thus, there is not a temporal pattern in the same sense as in many epidemiological studies. Rather, the temporal pattern is evident in relation to the recurring dose-response relationships: cognitive differences were not present as early as 6 months of age, but later assessments showed that for those infants BF for longer durations, cognitive outcomes also climbed higher (e.g., Morrow-Tlucak et al., 1988; Rogan & Gladen, 1993). Thus, in some sense, breastfeeding preceded the outcome of better cognitive development.

The fifth criterion, specificity, is difficult to study because although breastfeeding can be isolated statistically to some degree, it cannot be isolated in the environment of a developing infant. Thus, we cannot show that breastfeeding by itself causes differences in cognitive outcome, and further, some of breastfeeding's predictive power may be due to persistently uncontrolled confounding variables (Fergusson et al., 1982). Sixth, the relation must be coherent; that is, it must fit related facts. This criterion is supported by the facts presented in *Section 1.1 Breastfeeding: Many Paths of Influence on Infant Development* and by the absence of any findings showing that FF infants scored higher than BF infants. However, this latter evidence could be hidden in unpublished research. Criterion 7 is that the relationship should be biologically and theoretically plausible, again supported by the information presented in *Section 1.1*. Eighth is the presence of analogous evidence, such as animal studies, and while available, these were not reviewed for the present study. Finally, the last criterion, experimental evidence, is difficult to evaluate because, as mentioned in *Section 1.2.1.1 Random Assignment*, breastfeeding cannot be randomly assigned to mothers and infants. Further, breastfeeding cannot be removed to see if cognitive development is lessened, and then reintroduced to test whether cognitive development returns.

In conclusion, the six Bradford Hill criteria of consistency, strength of association, temporal sequence, biological gradient, coherent relation, and being biologically and theoretically plausible (Bradford Hill, 1965) are supported for the relationship between breastfeeding and cognitive development. The criteria of specificity and experimental evidence cannot be easily tested, and the criterion of analogous evidence was not reviewed here. Thus, as two-thirds of the criteria were supported, and the other one-third was not refuted, sufficient evidence exists to justify continued research regarding this relationship, and having explored the topic of breastfeeding at one side of the relationship, next some aspects of cognitive development are covered, specifically those prominent in the second year of life.

1.3 Cognitive Development in the Second Year of Life

"The second year of human life is characterized by dramatic transitions in all domains of psychological development, but there is broad consensus that psychologists know less about the second year than any other phase of the life span" (Reznick, Corley, & Robinson, 1997, p. 1). What psychologists do seem to know is that language development is a large piece of the mental activities of children by the time they reach their second birthday (e.g., Kagan, 1981; Saudino et al., 1998). In fact, some researchers suggest that two of the three major components of cognitive development in the second year of life relate to language, that is, receptive and expressive language abilities; the third is a catchall category labeled "nonverbal abilities" (Reznick et al., 1997). This section begins with a discussion on the development of language and then covers examples of toddlers' various nonverbal abilities.

1.3.1 Language Development

Language development is one of the key cognitive transitions in the first 2 years of life (Courage & Howe, 2002), and it may be "the most impressive intellectual accomplishment of individual humans" (Bloom, 1994, p. 5). Because of this extraordinary status, the study of language development has captured the interest of countless researchers across history and the amassed knowledge is immense. Thus, this section is, by necessity, a rudimentary overview.

Language consists of receptive and expressive abilities (e.g., Reznick et al., 1997), but only the latter is reviewed here. Development of expressive language begins around a child's first birthday, and during the second year, usually around the age of 18 months, many children undergo a dramatic increase in the number of words they can produce, sometimes referred to as the *naming explosion* or *vocabulary spurt* (e.g., Bloom, 1994; Courage & Howe, 2002). These names suggest this transition is a sudden change; however, the growth of vocabulary may follow a steadier, yet still remarkable, course, with a tenfold increase from 16 to 30 months of age (Fenson et al., 1994).

After children have acquired several words, usually in the second half of the second year, they begin to produce two-word combinations. These combinations typically fall into semantic relation categories such as agent-action, agent-object, object-location, possessor-object, or recurring object or event (Kelly & Dale, 1989; Michel & Moore, 1995). While children can only *produce* two words at this stage, it is possible that they are able to *think* of more (Pinker, 1990), and interestingly, no general three-word stage follows. Rather, the length and complexity of children's sentences steadily increase from the two-word phase on, suggesting that perhaps children's production capabilities catch up to their cognitive abilities (Fenson et al., 1993, 1994).

During the process of learning multi-word speech, children also begin to learn that certain kinds of words can have different endings, or suffixes, and children under 2 years of age learning the English language tend to acquire common grammatical suffixes in the same order, for example, from *–s* to *–ing* to *–ed* (Fenson et al., 1994). This learning is accomplished by a majority of children by their second birthday, but the use of irregular nouns and verbs in the English language comes more slowly. In learning these irregular words, children first use correct forms of the words, but once they learn the "rules" of the English language, tend to use incorrect forms such as "sitted" and "goed" (Michel & Moore, 1995). Children subsequently regain the correct forms of the irregular words, but this occurs well into the third year of life for most children (Fenson et al., 1994).

While the above series of language phenomena seem to appear regularly in a group of children, individual toddlers show much greater variability in their language development (Epstein, 1986; Fenson et al., 1994). Furthermore, while the links between language and cognition are readily apparent at an aggregate level (Oliver et al., 2002), for individual children, the connections between specific cognitive functions and specific language developments are much less obvious (Gopnik & Meltzoff, 1987; Kagan, 1981;

Kelly & Dale, 1989). Nonetheless, researchers have conducted numerous studies to explore the relationship between language and other cognitive abilities. For example, the naming explosion has been linked to the cognitive developments of categorization, means-end understanding, deferred imitation, and sense of self (Courage & Howe, 2002; Gopnik & Meltzoff, 1987; Kelly & Dale, 1989). Further, a general cognitive shift may occur around 18 months of age (Karmiloff-Smith, 1992; Meltzoff, 1990), possibly suggesting an underlying reason for all of these cognitive developments. The next section explores more examples of changes in children's cognition occurring in the second year of life.

1.3.2 Nonverbal Cognitive Development

While researchers have conducted numerous studies of language development and "every [cognitive] theoretical perspective has had the burden of explaining language acquisition" (Bloom, 1994, p. 5), the nonverbal abilities in infancy and early childhood have been almost ignored by comparison (Kagan, 1981). This paucity reflects both the theoretical lack of interest as well as the difficulty working with children nearing the "terrible two's" (Kagan, 1981; Reznick et al., 1997). Nonetheless, a select group of abilities characterize the second year of life, and because many tasks designed to test the cognitive abilities of children near their second birthdays are based on Piaget's classical theory of cognitive development, portions of his theory relevant to the second year of life are presented, along with discussion of more recent research into his ideas.

In Piaget's theory, Stages 5 and 6 of the sensorimotor period cover the second year of life (Baldwin, 1980; Crain, 2000; Miller, 2002; Piaget 1954). Piaget said that in the latter half of the first year infants gain the understanding of *object permanence* (Miller, 2002; Piaget 1954; Schmuckler, 1993), but it is not until Stage 5 that infants can use this concept to correctly search for hidden objects. During Stage 5 children are first able to follow visible displacements of objects; that is, they can follow the path of a moving object as long as they can see it move from one location to the next, but if the object disappears, for example, under a couch or behind someone's back, the infant will look in the last place the object was seen. In contrast to this theory, more recent research has found that infants as young as 4.5 months of age are able to correctly search for hidden objects if they are tested in ways that do not require specific motor abilities to conduct their "search" (Baillergeon, 1986, 1987; Baillergeon, Spelke, & Wasserman, 1985). Thus, according to Piaget's theory, Stage 5 may be the last stage "that does not involve actual mental representation of the external world, imagery, anticipation, and so on…[representing] the peak of the purely sensorimotor adaptations" (Baldwin, 1980, p. 178). However, "in a very real sense, there may be no such thing as an exclusively sensorimotor period in the normal human infant" (Meltzoff, 1990, p. 20). Rather, it may be that the tests used to draw some of the conclusions regarding infants' abilities simply may not have been adequate.

Cognitive representations, according to Piaget, first occur in Stage 6 of the sensorimotor period, usually around 18 months of age (Baldwin, 1980; Crain, 2000; Miller, 2002; Piaget, 1954). In this stage children "can discover solutions to problems without overt trial and error and can imitate actions after the model has disappeared—deferred imitation. They can also fill in invisible portions of an object's trajectory and, thus, anticipate its final location" (Baldwin, 1980, p. 178). In all these examples, children are able to replace their overt actions with thoughts, they can imagine different outcomes without having to actually execute a prescribed behaviour, and by the child's second birthday, thinking typically becomes solely a mental activity (Courage & Howe, 2002).

As with Stage 5, much research has examined Stage 6 abilities and found that Piaget's classic theory erred on some accounts (Courage & Howe, 2002; Meltzoff, 1999). Research on deferred imitation has shown that Piaget may have been wrong about when it emerges; some deferred imitation abilities have been found in infants as young as 6 months of age, while according to Piaget's theory, this does not happen until much later (Barr, Dowden, & Hayne, 1996; Courage & Howe, 2002; Meltzoff & Moore, 1994). Research on deferred imitation has also led to more studies of infant memory. Memory has been tested in infants of varying ages, and although recognition memory has been useful for infants under 1 year of age (e.g., Rovee-Collier, 1990), recall memory seems to be a better differential test of abilities in the second year of life (Kagan, 1981). Kagan (1981) found "major improvements in memory score between 17 and 23 months" (p. 75), and by 2 years of age, most children in his studies could successfully find an object hidden in one of eight containers after a 10 s delay.

Research on Piaget's concept of object permanence and its correlates has also been robust; in one line of research, an infant's understanding that he or she is an independent object, just like all other objects, has been studied through self-awareness and mirror self-recognition (Courage & Howe, 2002; Crain, 2000; Kagan, 1981). Further studies with children in the second half of their second year have shown that many children this age can draw their first circle. While drawing lines and scribbling occurs earlier, drawing a circle requires slightly more skill and is likely linked to experience with colouring and drawing, as well as to the child's fine motor abilities (Kagan, 1981). A final example of the cognitive changes occurring in the second year is the appearance of symbolic play (Kagan, 1981; Kelly & Dale, 1989). In the first year of life, infants play with toys in sensorimotor ways: they are interested in feeling the various textures of objects, exploring them visually, and listening to the sounds they make. In contrast, older infants and toddlers tend to engage in symbolic play; they pretend to talk to their grandparents on toy phones and they pretend that their dolls drink from cups and bottles. Thus, in summary, the second year of life is a time of great change in the cognitive world of the developing infant.

In review of the chapter thus far, this brief discussion of cognition in the second year of life has completed the traverse across the top of Figure 1.3, that is, from breastfeeding to cognitive development. Many emerging cognitive abilities discussed in this section were assessed in the studies in Table 1.2; thus, this connection has been fairly well studied, but now the chapter ventures to less charted territory represented in the lower half of Figure 1.3. Returning to breastfeeding's influence on infant development, the chapter next moves to show evidence for breastfeeding's relation to motor development, and then follows with sections on crawling and its relation to cognition.

1.4 Breastfeeding and Crawling: Accelerating Onset

In one breastfeeding review mentioned above, the authors proclaimed that besides one 50-year-old study (Douglas, 1950), "no other studies have specifically reported either fine or gross motor abilities" (Golding et al., 1997, p. S182). Motor development may not seem to be as easily linked to breastfeeding as cognitive development, but a potential relationship does exist. For example, as mentioned previously, BF infants have different growth trajectories; they are less chubby and therefore more likely to crawl at an earlier age (Adolph, 1997; Adolph et al., 1998; Hopkinson, 2003; Shirley, 1931). Furthermore, it is possible that advanced neural development of BF infants may increase muscle response and synchrony among limbs (Forssberg, 1980, 1985).

While breastfeeding's relationship to motor development has not been studied as intensely as its relationship to cognition, the entire lack of reports suggested by Golding et al. (1997) is simply not the case. For example, even the often-cited first study of breastfeeding and cognition also looked at the motor milestone of walking (Hoefer & Hardy, 1929). More recently, several studies have assessed breastfeeding's potential influence on motor development, often as a by-product in studies employing general developmental tests for the purposes of studying cognitive development; thus, a few studies from Table 1.2 are also represented in Table 1.3. The criteria used for inclusion in Table 1.3 were similar to those used in Table 1.2: (a) assessment by 18 months of age to encompass the age of interest for motor development in the current study, (b) studies of term infants, and (c) at least two breastfeeding categories.

Table 1.3

Studies of the Relationship Between Breastfeeding and Motor Development in Children up to 1.5 Years of Age

Age in Months at Motor Testing	First Author (Year)	*n*	Covariates Used	Feeding Variable Categories[a]	General Motor Development Test Used[b]	Signif-icant Results?	ES[c]	ES Level[d]
6	Rogan (1993)	788	Maternal age, alcohol use, education, race, smoking, occupation; infant birth order, birth weight, sex, age at testing, prenatal exposure to polychlorinated bi-phenyls and dichloro-diphenyl dichloroethene; identity of the examiner	(1) FF (2) BF < 9 weeks (3) BF 9-19 weeks (4) BF 19-49 weeks (5) BF > 50 weeks	BSID-PDI	No	–	
12	Agostoni (2001)	44	Maternal age, education, parity, smoking	(1) BF 3-6 months (2) BF 6+ months	BSID-PDI	Yes	f = 0.30	medium -to-large
	Barros (1997)	401	Maternal education, parity, smoking; infant birth weight, gestational age, morbidity, pacifier use at 6 months of age	BF: (1) < 1 month (2) 1-3.9 months (3) 4-8.9 months (4) 9+ months	DDST	Yes	–	
	Paine (1999)	96	Maternal age; infant sex	*Continuous*	BSID-PDI	No	–	

Table 1.3 *(continued)*

Age in Months at Motor Testing	First Author (Year)	*N*	Covariates Used	Feeding Variable Categories[a]	General Motor Development Test Used[b]	Signif-icant Results?	ES[c]	ES Level[d]
12	Rogan (1993)	720	*See listing for 6 month entry by same author.*		BSID-PDI	No	–	
13	Angelsen (2001)	345	Maternal age, education, intelligence, smoking	(1) BF <3 months (2) BF 3 - 6 months (3) BF 6+ months	BSID-PDI	No	f = 0.12	small-to-medium
18	Gómez-Sanchiz (2003)	249	Maternal education, intelligence, smoking, urban or rural background; family social class; paternal education, intelligence	(1) FF (2) BF <4 months (3) BF 4+ months	BSID-PDI	No	r = 0.03 f = 0.18	zero-to-small small-to-medium
	Rogan (1993)	676	*See listing for 6 month entry by same author.*		BSID-PDI	No	–	

[a]FF = Formula fed; BF = Breastfed. [b]BSID-PDI = Bayley Scales of Infant Development – Psychomotor Development Index (Bayley, 1969, 1993); DDST = Denver II Developmental Screening Test (Frankenburg & Dodds, 1992). [c]ES = Effect size; Standardized ES: dashes indicate no ES calculation was possible, see Appendix A for formulas. [d]Conventional levels, see Appendix A for cut-off values.

To briefly review the studies in Table 1.3 duplicated from Table 1.2, first, Rogan and Gladen (1993) found significant results on the Psychomotor Development Index of the BSID (BSID-PDI; Bayley, 1969) only at 24 months of age, just as on the BSID-MDI (Bayley, 1969). Thus, all results presented in Table 1.3 are negative, and again no statistics were given to allow effect size calculations, although Rogan and Gladen (1993) claimed a “small effect size” (p. 191). Second, Agostoni et al.’s (2001) unadjusted results on the BSID-PDI showed a medium-to-large effect for motor development, when only a small-to-medium effect was present for cognitive development; breastfeeding for 6 months or more showed a 6.6-point (95% CI: -0.6, 13.8) advantage. Third, in Paine et al.’s (1999) study, breastfeeding did not enter the regression as a significant predictor of the BSID-PDI, and fourth, Angelsen et al.’s (2001) ANOVA was not significant, but they did find a significant trend for longer durations of breastfeeding leading to higher motor scores, with a small-to-medium effect size. Finally, Gómez-Sanchiz et al. (2003) reported unadjusted results suggesting a small-to-medium effect and their adjusted results showed a mean motor difference of 3.6 points (95% CI: -1.4, 8.7) between FF infants and infants BF up to 4 months. In addition to these repeated studies, the Barros et al. (1997) study was included because the Denver II Developmental Screening Test (DDST; Frankenburg & Dodds, 1992) contains many specific gross motor items. Breastfeeding showed a dose-response type relationship with developmental outcome, even when adjusted; infants BF for less than 1 month had twice the odds (95% CI: 1.25, 3.18) of infants BF 9 months or more of scoring low on the DDST, but no statistics were given to allow effect size calculations.

Barros et al. (1997) concluded their study with an important remark: “if the test was more specific the effects of breast feeding would probably have been more pronounced” (p. 448). Indeed, while it may be hard to draw the general conclusion that breastfeeding accelerates the onset of motor development from the studies in Table 1.3, when specific motor milestone criteria are used to investigate the relationship the conclusion is strengthened. For example, three studies have looked at the motor milestone of interest in the current study: crawling (see Table 1.4).

Vestergaard et al. (1999) noticed that the majority of studies on breastfeeding’s impact on infant development utilized standardized tests; therefore, they set out to assess three specific developmental milestones, one of which was hands-and-knees crawling. Results showed a small-to-medium effect size and a dose-response type relationship: 35% of infants BF 0-1 months, 34% of infants BF 2-3 months, 40% of infants BF 4-5 months, and 45% of infants BF 6 or more months were crawling by 8 months of age. The authors also assessed crawling in 101 infants who were partially BF and found a similar relationship: the percentage of infants who attained crawling by 8 months was 20% for those not BF, 22% for those BF 1 month, 36% for those BF 2 months, and 40% of infants BF 3 or more months. After correction for covariates, results still confirmed this trend. Infants BF for 6 months or more were 1.3 (95% CI: 1.0, 1.6) times more likely to crawl by 8 months of age compared to infants BF for 0-1 months.

The second study from Table 1.4 to assess breastfeeding’s effect on infant motor milestones was that by Dewey, Cohen, Brown, and Rivera (2001), who performed a randomized trial in Honduras. All infants were exclusively BF until 4 months of age,

Table 1.4

Studies of the Relationship Between Breastfeeding and Crawling

Age in Months at Assessment	First Author (Year)	*N*	Covariates Used	Feeding Variable Categories[a]	Significant Results?	ES[b]	ES Level[c]
8	Vestergaard (1999)	1656	Maternal age, education, cohabitation status, smoking; infant birth weight, gestational age, corrected examination age, number of illnesses; family social standing	Exclusively BF: (1) 0 - 1 months (2) 2 - 3 months (3) 4 - 5 months (4) 6+ months	Yes	h = 0.22	small-to-medium
Longitudinal	Dewey (2001)	140	Maternal education; infant birth weight, sex	Exclusively BF: (1) 4 months (2) 6 months	Yes	f = 0.28	medium-to-large
Longitudinal	Heinig (1993b)	105	Infant sex, energy intake, protein ingestion	(1) BF with solid foods before 6 months (2) BF with solid foods after 6 months (3) FF or BF < 3 months	Yes	f = 0.50	large

[a]FF = Formula fed; BF = Breastfed. [b]ES = Effect size; Standardized ES: dashes indicate no ES calculation was possible, see Appendix A for formulas. [c]Conventional levels, see Appendix A for cut-off values.

when they were randomly assigned to continue to be exclusively BF or to be supplemented with solid foods. Infants were followed longitudinally for the first year of life and mothers were asked to report at each of several home visits whether specific motor milestones had been attained. Results showed that infants exclusively BF for 6 months crawled sooner than infants introduced to solid foods at 4 months. Infants and mothers were not significantly different at the beginning of the randomized trial, but later comparisons showed some differences. Results were re-analyzed controlling for these differences, but the results did not change. Note that continuous measurement of crawling onset in this study resulted in a larger effect size than that in the Vestergaard et al. (1999) study where crawling was a dichotomous variable assessed at 8 months of age.

The third study also treated crawling as a continuous variable (Heinig, Nommsen, Peerson, Lonnerdal, & Dewey, 1993b), and after covariate control, BF infants who received solid foods after 6 months crawled an average of 8 weeks later than the other two groups, yielding a large effect size. In contrast to Dewey et al.'s (2001) study, infants in this study were not randomly assigned, thus group differences prohibited attribution of these effects only to duration of exclusive breastfeeding. For example, although one would expect that infants fed exclusively breast milk would be slimmer (Butte et al., 2000; Dewey, 1998; Dewey et al., 1995; Dewey et al., 1993; Heinig et al., 1993a), the infants supplemented after 6 months of age were chubbier than infants in the early solids group, which may have delayed their crawling onset. Furthermore, the authors suggested that a likely explanation was that "infants showing interest and developmental readiness may have been more likely to receive solids earlier and thus the most developmentally precocious infants were likely to have been in the [early solids] group" (Heinig et al., 1993b, p. 1005). Thus, while this study showed a large effect size, the results were not entirely attributable to feeding status.

In sum, these three studies provided more evidence that longer durations of breastfeeding can affect motor development, and specifically the age of attainment for crawling, with the strongest support provided by Dewey et al.'s (2001) randomized trial. Thus, longer breastfeeding durations might lead to both earlier crawling attainment and higher cognitive scores in the first few years of life. However, to consider the possibility that these three domains of infant development are related, one more piece of the triangle remains to be explored: whether earlier crawling onset can alter cognitive outcomes. That final piece will be covered in a subsequent section, but first, a more detailed coverage of the development of crawling is presented.

1.5 Crawling: The Development of a Motor Milestone

The research on crawling and other gross motor milestones has gone through major transitions in the past century (Adolph, 1997; Bushnell & Boudreau, 1993; Piper & Darrah, 1994; Thelen, 1995, 2000; Thelen & Smith, 1994). In the first half of the 20th century, several prominent researchers theorized that motor development was governed by neural maturation (e.g., Gesell, 1934; McGraw, 1945), and recent scholars have suggested that it was these proclamations that caused research to lay dormant for subsequent decades (e.g., Thelen 2000; Thelen & Smith, 1994). It was as if researchers believed that exploring any potential causes of differences in motor development was useless; some babies were simply programmed to develop faster than others, and all babies would inevitably develop through the same progression (Crain, 2000). However, maturational theories have now begun to be challenged as recent research has returned in earnest to the study of infant motor development (Bushnell & Boudreau, 1993).

In the recent resurgence, crawling has been one of the milestones of interest (e.g., Adolph, 1997; Adolph et al., 1998; Campos et al., 2000) and while some new discoveries have been made, some things remain the same. For example, the onset of hands-and-knees crawling still occurs sometime between 6 and 13 months of age for most infants, with a median age of onset of 8.5 months (e.g., Pikler, 1968; Piper & Darrah, 1994). Further, while most infants crawl on their hands and knees, some infants get around by other means or progress straight to walking (e.g., Adolph, 1997; Adolph et al., 1998; Dewey et al., 2001). Better understanding of the variability in motor development and how atypical patterns in crawling can emerge has been the goal of recent research, which has used new technologies to study transitions in finer detail (Adolph, 1997; Bushnell & Boudreau, 1993).

Freedland and Bertenthal (1994) used detailed kinematic data produced by a motion analysis system that tracked reflective markers attached to six infants' wrists and legs to study the transition to hands-and-knees crawling. They found that approximately a week after their first hands-and-knees crawling attempt, infants had settled into routine use of a diagonal pattern of crawling, that is, the movement of their right arm and left leg coincided. Furthermore, from the onset of hands-and-knees crawling to 4 weeks later, the time required for the infants to go through one cycle of movements of all four limbs was cut in half, while the distance covered by each stride remained the same.

Adolph et al. (1998) expanded on Freedland and Bertenthal's (1994) results in several ways: Their sample was larger; the infants were followed until they began walking; and the impacts of age, body dimensions, and crawling experience were assessed. Twenty-eight infants were recruited shortly before or just after they began crawling. Parents recorded progress on daily checklists, and home visits were made every 2 or 3 days during the crucial transition period to hands-and-knees crawling. Half of the infants were then tested in the lab every 3 weeks from the date of crawling onset, and the other half were tested in their 1st and 10th weeks of crawling. Videotaped crawling sessions were analyzed frame-by-frame for crawling proficiency and interlimb coordination. Results showed that "development of prone progression did not follow a strict stage-like progression" (Adolph et al., 1998, p. 1303). However, all infants showed at least "one clumsy precursor" (Adolph et al., 1998, p. 1303) before attaining mature crawling. These precursors included pivoting, rocking, occasional steps, or shifting from a sitting to a prone position.

Once crawling onset had occurred, infants used a variety of body parts both for propulsion and balance and even used different crawling patterns from cycle to cycle, for example, switching from an "army" crawl to an "inchworm" crawl (Adolph et al., 1998). However, after at least 4 weeks of hands-and-knees crawling, the variability was reduced and infants tended to use only the hands-and-knees pattern. The interlimb coordination of their hands-and-knees crawling did not significantly improve from the 1st week of crawling to the 10th, which, when considered with the results of Freedland and Bertenthal (1994), suggests that once infants discover the diagonal pattern, they tend to stick with it even if their timing is not perfect (Bertenthal, Campos, & Kermoian, 1994). Adolph also verified Freedland and Bertenthal's (1994) results by showing that the speed aspect of crawling proficiency improved over time, but contradicted Freedland and Bertenthal (1994) by showing that infants' movements within crawling cycles became larger. Additionally, Adolph et al. (1998) showed that infants who had previously belly crawled were more proficient at first attempts at hands-and-knees crawling than those who had not, and these results were not due to differences in age or body dimensions.

Because researchers now believe that the variability in the fine detail of infant motor development is not due entirely to neural maturation as suggested by early theories (Adolph et al., 1998; Darrah, Redfern, Maguire, Beaulne, & Watt, 1998), they have gone in search of other factors that may affect the onset of crawling. Researchers have found, for example, that prone placement for sleep or play can accelerate crawling onset (Davis, Moon, Sachs, & Ottolini, 1998; Holt, 1960). Davis et al. (1998) gave parents a daily diary to record both (a) infant sleep and play placement in the first 5 months of life and (b) the attainment of gross motor milestones through the first year. They found that prone sleepers spent much more *play* time in the prone position as well and crawled an average of 23 days earlier than supine sleepers. Furthermore, supine sleepers who spent more play time in the prone position also attained crawling earlier, and Davis et al. went as far as to suggest that "prone playtime … may be the primary factor that influences motor development" (p. 1139) because of its effect on upper body strength.

A second factor shown to affect the timing of crawling onset is season of birth (Bartlett, 1998; Benson, 1993, 1996; Eaton & Bodnarchuk, 2004; Hayashi, 1990, 1992). Benson (1993) asked parents of 414 infants in Denver, Colorado to recall the age when their infant first crawled a distance of 4 feet in 1 min. Month of birth was the only significant predictor in an ANCOVA, and when the months were grouped by season Benson (1993) found that infants born in the winter or spring crawled approximately 21 days earlier than infants born in the summer or fall. Benson (1993) suggested that the study be replicated in a more extreme climate, and Bartlett (1998) did just that. Bartlett assessed 145 7-month-old infants in Edmonton, Alberta using the Alberta Infant Motor Scale (AIMS; Piper & Darrah, 1994). To assess the onset of crawling, she looked at four specific prone subscale items: pivoting, four-point kneeling, reciprocal crawling, and reciprocal creeping. Bartlett found no significant differences, but reported that reciprocal crawling was "the only item that even approached statistical significance" (p. 598), with 21, 24, 11, and 6% of winter, spring, summer, and fall born infants, respectively, achieving this posture. Thus, while it was not statistically significant, the trend certainly supported the results of Benson (1993), with winter and spring born infants showing accelerated crawling development. Furthermore, such low percentages suggest that 7 months of age may have been too early to assess crawling adequately in a cross-sectional study.

While this section has explored factors that affect variability in crawling, such as experience in the prone position and season of birth, the next section presents research showing the effects that crawling can have on cognitive development.

1.6 Crawling and Cognitive Development: A Connection

Campos et al. (2000) suggest that the onset of independent locomotion may be *the* event that triggers a cascade of transformations in the first year of life: "locomotion is a setting event, a control parameter, and a mobilizer that changes the intrapsychic states of the infant, the social and nonsocial world around the infant, and the interaction of the infant with that world" (p. 151). For most infants, the first form of independent locomotion is crawling (Adolph et al., 1998), which gives infants a new tool with which to understand their world. For example, "infants 'know' space by crawling in it and reaching for objects, whereas older children know space by manipulating mental symbols in particular ways" (Miller, 2002, p. 32). The new knowledge about space and about the relationships among objects within space gained by crawling may be a catalyst in the evolution of cognitive abilities for the infant (Bertenthal et al., 1984; Bertenthal & Campos, 1990; Thelen, 2000), and this idea has been alluded to several times. For example, the proposal that locomotion can influence thought can be traced as far back as Rousseau (1762/1962), who wrote that "it is only when we move that we learn that there are things other than ourselves" (p. 23). Indeed, self-produced locomotion may be important in the differentiation of the self from the surrounding environment, a discovery which is important to a child's developing sense of self (Bertenthal et al., 1984).

Self-produced locomotion has also been cited in the development of several other abilities. Bertenthal, Campos, and colleagues (e.g., Bertenthal et al., 1984, 1994; Campos et al., 2000) have been some of the most prominent researchers looking at how crawling changes infants' mental environments. Through multiple research studies, they have provided convincing evidence that locomotor experience in early infancy cannot be ignored as an important ingredient in development, and this section briefly reviews some of their most interesting work related to the present study.

1.6.1 Referential Communication and Language

Before an infant begins to crawl, references to distant objects are not of much use; however, once able to crawl, the infant becomes interested in and able to obtain toys or other objects across a room. Thus, at this point, distal references from a parent or other caregiver become much more ubiquitous in an infant's daily life and may affect the infant's developing communication skills (Campos et al., 2000; Bertenthal & Campos, 1990). To investigate this idea, Chen, Kermoian, and Campos (1991; as cited in Campos, Kermoian, Witherington, Chen, & Dong, 1997) assessed infants' responses to a pointing gesture of an adult. They found a dramatic shift in responses between 6- and 8-month-old groups of infants. Because this is approximately the age-range when crawling begins, and because the authors had reason to suspect that crawling may be at least partly responsible for the shift, Kermoian, Campos, and Chen (1992; as cited in Campos et al., 1997) tested infants with and without crawling experience on the same task. The results showed that as locomotor experience increased, so did the behaviour of looking toward the correct target area; prelocomotor infants followed the pointing gesture 29% of the time, infants with 5 or more weeks of walker experience did so 50% of the time, and infants with 5 or more weeks of crawling experience did so 54% of the time. The difference in proportion between the prelocomotor group and the crawling group showed a medium effect (h =

.51; see Appendix A), and the similarity between the results for the crawling and walker-using infants suggested that it was the ability to move around the room that correlated with the change in response to gestural communication. Further, studies of infants with spina bifida (Telzrow, Campos, Shepherd, Bertenthal, & Atwater, 1987) and infants in China (Tao & Dong, 1997; as cited in Campos et al., 2000) also showed a relation between locomotion and ability to follow a gaze, even though both of these groups of infants showed delayed crawling onset. Thus, “locomotor experience greatly facilitates the development of the child’s social cognition and lays the basis for the future development of skills crucial for social referencing, emotional development, and language acquisition” (Campos et al., 2000, p. 167).

Campos et al.’s (2000) conclusion and the preceding research suggest that infants who crawl sooner may have more advanced language development, and two recent studies have examined this issue. Darrah, Hodge, Magill-Evans, and Kembhavi (2003) assessed 102 infants’ gross motor and general communication abilities at 13, 16, and 21 months of age, and claimed to have found “virtually no relationship between gross motor and communication scores” (p. 106) even though a small effect existed at 16 and 21 months ($r = -0.13$ and $r = 0.09$, respectively; see Appendix A). A larger effect may have been found if they had used different tools to assess motor and language development; their motor and communication scales were designed to identify delayed development, which may not be suitable for ascertaining individual differences (e.g., Palisano, Kolobe, Haley, Lowes, & Jones, 1995).

The second study used tools that were more appropriate for assessing the relationship between crawling and language in infants from the same population as that for the current study (Bazylewski, 2003). The age of attainment for crawling was calculated based on parent-completed checklists and correlated with a total score from the parent-completed MCDI (Fenson et al., 1993) at 20 months of age. The results from 22 infants showed a nonsignificant correlation ($r = -.05$) between motor and language development; this was a very small effect (see Appendix A) with extremely low power to test it. Cohen (1988) suggests that "an analysis which finds that the power was low should lead one to regard the negative results as ambiguous" (p. 4); thus, a relationship between crawling and language development remains plausible despite these conclusions to the contrary.

1.6.2 Perception and Action

The development of crawling also has an intimate link with vision. Aspects of vision that have been tested in relation to crawling include peripheral optic flow and spatial search abilities (Bertenthal & Campos, 1990; Campos et al., 2000). Peripheral optic flow research has tested infants of varying ages, as well as infants with varying levels of self-produced locomotion experience, in a "moving room" paradigm (Bertenthal & Bai, 1989; Higgins, Campos, & Kermoian, 1996). In this test, infants were placed within an apparatus where the front and side walls moved separately from the floor. This allowed movement in the peripheral field of vision to be simulated separately from all other sensory information that usually accompanies body displacement. The goal was to determine whether infants of different ages or levels of locomotor experience differentially used this peripheral optic flow information. Infants' postural adjustments to the visual movement were observed, and Bertenthal and Bai (1989) found a significant trend in these responses among 5-, 7-, and 9-month-old infants: the youngest age group showed very little postural response, the middle group showed some response, and the oldest group showed the most postural adjustment. As crawling onset occurs during this age range, further tests of this phenomenon were carried out by Higgins et al. (1996). First, Higgins et al. tested 7-, 8-, and 9-month-old infants and narrowed the time of the typical developmental shift to between 7 and 8 months of age. Subsequently, they tested prelocomotor, walker-using, and crawling infants, as in the Kermoian et al. (1992) study. Cross-correlations were calculated for 100 time intervals per infant to assess the relation between infant postural sway and wall movement. Results showed that crawling infants' postural sway correlated most highly with the room movement ($r = .65$), walker-using infants had the next highest correlation ($r = .56$), followed by the prelocomotor infants ($r = .32$). Although the values of the correlations suggest medium-to-large effect sizes (see Appendix A), the correlations themselves are not specifically measuring the effect of crawling. Nonetheless, these results suggest that response to peripheral optic flow may be a corollary of self-produced locomotion.

Moving oneself typically provides consistent information about movement in the peripheral field of vision, because doing so usually requires looking in the same direction as the movement. In contrast, passively moved infants are free to look in any direction and may not make the connection between movement in the visual field and balance

(Bertenthal & Campos, 1990). Additionally, "such passive movement does not require a high level of attention by the infant to the spatial organization of the world" (Schmuckler, 1993, p. 149). However, once crawling begins the infant learns about the spatial layout and about the relationships among objects in the environment. This increased understanding of spatial organization may help the infant search for hidden objects, which has been studied in terms of the A-not-B-error (Bertenthal et al., 1994; Horobin & Acredolo, 1986; Kermoian & Campos, 1988; Thelen & Smith, 1994). This error occurs when children continue to search in the same location they found an object previously, even after they witness the object being hidden in a new location. In general, studies have found that infants with more crawling experience make fewer errors. Bai and Bertenthal (1992) built on this work and tested infants in a task where the *infant* was moved rather than the hidden object. Infants were shown an object being hidden in one of two coloured containers on the table in front of them. Then the infants were moved around the table 180º. Results showed that prelocomotor infants searched significantly more often in the wrong container; that is, if the object was hidden in the container to their left, after being moved, the infants searched in the container to their left. This suggests that they used "an egocentric frame of reference for coding the location of the hidden object" (Bai & Bertenthal, 1992, p. 220). In contrast, infants with crawling or creeping experience searched more often in the correct container after being moved: 57% compared to 25% for the prelocomotor infants, showing a medium-to-large effect size (h = .61; see Appendix A). These results suggest that the infants with self-produced locomotion ability were able to use cues external to them to locate the hidden object (Clearfield, 2004).

Thus, it appeared that locomotor experience gave the infants a new understanding about the world around them.

From the studies presented in this section, it may be concluded that the onset of locomotion is an important step in various aspects of visual and perceptual development. However, it is also possible that vision plays a "central role in the achievement of mobility and locomotion" (Adelson & Fraiberg, 1974, p. 119; Bremner, 1993; Gibson & Schmuckler, 1989; Schmuckler, 1993). In fact, studies with blind infants have shown that crawling is one of the few motor achievements that is delayed in these infants (Adelson & Fraiberg, 1974; Bigelow, 1992; Levtzion-Korach, Tennenbaum, Schnitzer, & Ornoy, 2000; Maida & Mccune, 1996; Tröster & Brambring, 1993). The reasons for the delay are unclear, but researchers have suggested that blind infants do not have the same visual enticement into movement that sighted infants do. Rather, they rely on sounds to encourage them to move, and the threshold for an exciting sound may be higher than for an exciting sight because moving through space without visual guidance is difficult for any person and likely more so for an immobile infant.

Thus, the most appropriate conclusion may be that "perception guides action, and action gives rise to new perceptual information, in a continuously interactive cycle" (Schmuckler, 1993, p. 163). The integration of perception and action has been studied extensively (Lockman & Thelen, 1993), and researchers have suggested that this integration occurs through two visual pathways (e.g., Bertenthal, 1996; Goodale, 2001). One pathway is responsible for the visual perception of objects and the other is responsible for the visual control and guidance of action. Thus, once capable of self-locomotion, infants likely use their conscious visual perception of, and interest in, objects at a distance to influence their visual action pathway to direct their bodies toward the desired object. The journey and the destination then lead to increased perceptual knowledge and more desire for exploration.

1.6.3 Is the Evidence Good Enough?

The suggestion that the onset of crawling can affect psychological development in the infant may be subject to criticism, even after evidence such as that presented above is provided. Indeed, the proponents of this idea would not suggest that crawling is necessary or sufficient for cognitive development (Bushnell & Boudreau, 1993), because many clues suggest otherwise. For example, some skills typically produced after locomotor onset have been observed before its onset (Bertenthal et al., 1984; Campos et al., 2000). However, the conclusion that crawling may "play at least a facilitative role in the development of other skills" (Bertenthal et al., 1984, p. 201), or that it may simply "elevate some psychological skills to a much higher level" (Campos et al., 2000, p. 151) has by no means been contradicted by the results presented here.

However, one key question is yet to be addressed here: whether differences in the age of attainment in crawling can facilitate changes in cognitive ability that would still be evident over a year later. If crawling causes diverse enriched experiences, which, in turn, affect the retention and strengthening of neural connections (Biringen, Emde, Campos, & Appelbaum, 1995; Greenough, Black, & Wallace, 1993), then it may be possible that early crawlers have more capacity for cognitive skills at 2 years of age. Biringen et al.

(1995) assessed a similar question for the development of walking. They tested infants three times: (a) before walking onset at 9.5 months of age, (b) when half of the infants had attained walking at 12 months, and (c) at 14 months when all infants were walking. While differences were evident between infants who had attained walking and those who had not at 12 months, Biringen et al. found no differences between early and later walkers at 14 months of age on any of their dependent measures, including the BSID-MDI (Bayley, 1969).[1] These results may have suggested a null result for the present study, but the present study differed from the study of Biringen et al. in two main ways. First, crawling instead of walking was assessed, and it is possible that the psychological differences are greater between the pre- and post-onset of crawling periods versus those of walking, and second, a continuous variable, age of attainment, was used instead of a dichotomous grouping, which utilized more of the available information (MacCallum et al., 2002). Thus, the current study broke new ground as it explored the variations in cognitive sequelae from different timings of crawling onset.

In conclusion, Campos et al. (2000) ended their review of crawling by highlighting the fact that locomotor experience is more than just another step in a line of successive developments. Crawling is “like the supporting frame of a building, always necessary for the building’s integrity” (Campos et al., 2000, p. 210), and because motor development holds such an important place in psychological development, the authors hoped for a rejuvenated interest in its study, and the present study contributes to this goal.

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[1]Not enough information was provided to calculate an effect size.

1.7 The Triad: Breastfeeding, Crawling, and Cognition

While the current study was the first to assess the relationships among specifically breastfeeding duration, crawling onset, and cognition, other studies have assessed triads of similar variables. For example, Pollitt et al. (2000) used structural equation modeling (SEM) to assess the effects of an energy supplement on motor and mental development, as measured by the BSID (Bayley, 1969), in a sample of undernourished Indonesian children. Pollitt et al. tested the model shown in Figure 1.2 and found poor fit to their data using both a 12-month-old and an 18-month-old cohort. However, once additional direct paths were added to the model from motor to mental development and from motor activity to mental development, the fit of the model greatly improved.[2] Also of note in terms of the present study, Pollitt et al. did not find a significant direct effect from energy intake to motor development and suggested that "this finding raises doubts as to whether the nutritional factor was an antecedent of the *motor* → *mental* path" (p. S111). However, their modified model did suggest a significant *indirect* path from energy intake to motor development through the construct of motor activity, which was not measured in the present study. Further, Pollitt et al. did not test a direct effect from energy intake to cognitive development, but the current study did test a direct path from nutritional status to cognition. Thus, while Pollitt et al. studied the effects of a dietary supplement on motor and cognitive outcomes for undernourished children, the current study added new information to the research on the relationships

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[2]Cohen (1988) does not provide guidelines to calculate effect sizes for SEM analyses.

between feeding, motor development, and cognitive outcomes by examining a well-nourished sample of children.

A second study that assessed feeding, motor, and cognitive variables in an undernourished population was that of Whaley, Sigman, Espinosa, and Neumann (1998). They operationalized infant nutritional status during the first 6 months of life through measurements of birth weight and length, weight, and upper arm circumference because "direct measurements of infant food intake cannot be made in a breast-fed population" (Whaley et al., 1998, p. 170). Instead, the infant anthropometric measurements provided an estimate of fatness, a good indicator of infant nutritional status. Whaley et al. used the BSID (Bayley, 1969) to measure motor development at 6 months of age and mental development at 30 months of age. Results showed that greater mean arm circumference during the first 6 months of life significantly correlated with motor scores at 6 months ($r = .19$, small-to-medium effect size, see Appendix A), suggesting "that the nutritional status of the [undernourished] infant has some impact on motor abilities early in life" (Whaley et al., 1998, p. 176). Further, arm circumference and 6-month motor scores significantly correlated with mental scores at 30 months of age ($r = .20$ and $r = .19$, respectively; small-to-medium effect sizes). The current study built on these significant results by testing duration of breastfeeding instead of infant size, onset of crawling instead of BSID motor score, an index of verbal and nonverbal cognitive abilities instead of BSID mental scores, and a well-nourished population from a developed country rather than an undernourished population.

1.8 Conclusion and Hypotheses

This introduction has provided information on three domains of infant development, as well as the supporting evidence for the potential relationships among them. While breastfeeding does not clearly fall into the domain of the developmental researcher, and the study of motor development "could easily be dismissed as of minor interest to the psychologist" (Bremner, 1988, p. 35), this amalgamation of topics explored a new thread in the web relating early feeding mode to infant cognitive development. This new thread of crawling was assessed in the current study by employing several of the best components of previous studies. First, both key predictors, breastfeeding duration and crawling attainment, were measured as continuous variables, which reduced measurement error, increased power, and came closer to the true phenomena than most of the previous studies have (MacCallum et al., 2002). Second, several confounding variables from Table 1.1 were evaluated for potential inclusion in the regression analyses. Controlling for such variables, in general, allows any significant findings to be attributed more clearly to the variable under investigation. Third, the outcome measures assessed very specific aspects of toddlers' verbal and nonverbal cognitive abilities and were interesting to parents, which may have aided in obtaining complete data. Finally, the current study used the longitudinal method, which "is the lifeblood of a developmental science" (Appelbaum & McCall, 1983, p. 418).

To test the importance of the hypothesized new thread in cognitive development, a mediational analysis was used as modeled in Figure 1.3 (Baron & Kenny, 1986; Kenny, Kashy, & Bolger, 1998; Shrout & Bolger, 2002). Step 1 of the mediational analysis tested the relationship between breastfeeding duration and cognitive development, which, based on the evidence presented in this introduction, was predicted to be significant. That is, longer durations of breastfeeding were predicted to be associated with higher cognitive scores at 2 years of age. Step 2 was to show that breastfeeding duration was also related to crawling onset, which again, was predicted to be significant, with longer durations of breastfeeding relating to earlier crawling attainment. Step 3 was to show that crawling onset was associated with cognition while controlling for breastfeeding duration, and by using crawling onset as a continuous variable, earlier crawling was predicted to be related to higher cognitive scores. Finally, step 4 was to show that the relationship between breastfeeding duration and cognition was reduced or eliminated when the mediator of crawling was controlled. Reduction in the relationship, or partial mediation, was expected because as shown in Figures 1.1 and 1.2, the relationship between breastfeeding duration and cognitive development is multi-faceted; thus, the intermediary of crawling attainment was not expected to completely mediate the relationship, but rather to account for only a segment of it.

Thus, as a synopsis of the first chapter, this study joined the three developmental variables of breastfeeding duration, crawling onset, and cognition with the goal of uncovering additional knowledge of the system of the developing infant. As this study was the first known study to specifically address this triad of relationships in a well-nourished population, it was considered exploratory in nature.

Chapter 2: Method

2.1 Participants

Mother and infant participants for the current longitudinal study were initially enrolled in Dr. Warren Eaton's Infant Milestones Study (IMS), which was funded by the Social Sciences and Humanities Research Council of Canada and designed to assess seasonal influences on the age of attainment for motor milestones in the first year of life (Eaton & Bodnarchuk, 2004). IMS participants were recruited shortly after the birth of the infant and were followed prospectively until the attainment of crawling or walking. A sample for the current study was drawn from these infants and followed up at 2 years of age. To be eligible for follow-up, the infant had to turn 2 years of age after December 1, 2003; be full term (gestational age of 37 weeks or greater); and have complete data for the milestone of crawling (see *Section 2.3.1.2 Crawling Onset*). All mothers of infants who met these requirements were contacted for follow-up, and follow-up continued until 76 mothers were contacted. This target sample size was determined from a power calculation.

A power calculation can be used to determine the sample size required to find a statistically significant effect if one exists or to determine the power that a study had to find a statistically significant effect. Both of these calculations require four variables: the effect size, the power, the significance criterion, and the sample size; the value for the variable of interest is determined by assigning values to the other three and proceeding to find those values in a table (e.g., Cohen, 1988). Because the variable of interest in the current calculation was sample size, values for the other three variables needed to be assigned.

First, the effect size for the current analysis was estimated based on studies explored in Chapter 1. From these studies, it was found that typically when breastfeeding duration or crawling onset were measured as continuous variables, as in the present study, a medium-to-large effect size was found between breastfeeding and cognition, and between breastfeeding and crawling. Further effect size analyses for the relation between crawling and cognition showed a range of effect sizes, but only one of the studies treated crawling as a continuous variable. Thus, these studies were not weighted as heavily in the effect size decision. Rather, based on the medium-to-large effect size typically found for breastfeeding's relation to crawling and cognition, the conventional effect size of *medium* for a multiple regression was chosen for the current study ($f^2 = .15$; $R^2 = .13$; Cohen, 1988, p. 413). Second, power was determined. Power is equal to $1 - \beta$, thus, the higher the power, the less chance of making a "Type II" error, or falsely accepting the null hypothesis (i.e., saying there is not an effect when there truly is). The determination of a preferred value of power is subjective, but the value of .80 is the conventional choice (Cohen, 1988). The final variable to have a value assigned was the significance criterion, or alpha, and the conventional value of .05 for alpha, the Type I error rate, was used for each separate regression. Because three regressions were planned (see *Section 2.3.4 Mediational Analysis*), the overall Type I error was .14 (Toothaker, 1991) and was more typical of exploratory studies, such as the current one.

Given a medium effect size, a power of .80, and an alpha value of .05, one can proceed to look up the required sample size in one of Cohen's (1988) tables. Cohen provides power tables for several types of analyses, and because a multiple regression was used in the present study, one additional variable was needed: the number of predictors in the regression. Three regressions were conducted in the present study; the first and second each contained two key predictors and the third contained three key predictors. Thus, with the goal of obtaining a power of .80 in a multiple regression with three predictors and an alpha value of .05, where at least a medium effect size was estimated to exist, a sample size of 76 was targeted (Cohen, 1988, Table 9.4.2, p. 452; Green, 1991). Of these 76 contacted participants, some participants were expected to have missing data, thereby reducing the number of participants for the final, complete sample. However, this was considered a minor problem given the potential medium-to-large effect size in the population, the fact that falling short of the goal power of .80 would still leave a relatively high power, and the fact that the study was exploratory.

2.2 Materials and Procedure

2.2.1 Recruitment, Checklists, and Demographics

Brochures describing the IMS were delivered to new mothers via various routes, mainly in a package of materials given to new mothers at the St. Boniface General Hospital in Winnipeg, Manitoba, the largest maternity hospital in the province. Participants were also recruited in several other ways, including through an invited front-page article in the Community Review section of the *Winnipeg Free Press* (Armstrong, 2002), an invited news segment on CKY local news, by "word-of-mouth" from friends and relatives, and at the Birth Roots Doula Collective Parenting and Birth Fair.

Interested parents phoned the project coordinator, who described the general nature of the study. If the parent verbally agreed to participate, the project coordinator recorded some initial participant information, which included the infant's and mother's birth dates and the sex of the infant (Appendix B). A package was then mailed to the parent that contained two copies of a consent form (Appendix C), age-appropriate versions of a daily checklist with corresponding instructions (see example items in Bodnarchuk & Eaton, 2004a), and postage-paid envelopes for returning the consent forms and checklists. Once the checklists were photocopied and coded electronically, the original checklists were returned to the parent, along with an IMS bib and a "Baby of Science" diploma (Appendix D).

The daily parent checklist we developed for the IMS was based on a daily diary used by Dr. Karen E. Adolph at New York University (personal communication), and included items like those on the DDST (Frankenburg & Dodds, 1992) and the AIMS (Piper & Darrah, 1994). The format of the checklist required daily entries, which made the process easy and routine for parents. As well, this format allowed prospective data to be obtained on breastfeeding, crawling, and other developmental milestones and activities. Such daily recording provided the necessary data for capturing changes during infancy, a time when "even weekly observations may miss the critical transitions" (Thelen & Smith, 1998, p. 602).

Health and demographic questions were originally asked over the phone, but after August 19, 2002, the Health and Demographics Questionnaire (HDQ; Appendix E) was also sent in the initial package of materials. The HDQ was made up of selected questions from the National Longitudinal Survey of Children (Statistics Canada, 1995) and covered issues such as family income, mother's educational level and smoking status during pregnancy, and infant's birth order, birth weight, and gestational age.

2.2.2 Home Visits and the AIMS

In addition to correspondence over the phone and through the mail, we also visited roughly one-third of the IMS mother-infant pairs in their homes. During home visits, we performed a series of activities such as measuring the weight and length of the infant.[3] A key part of every home visit was our assessment of the infant using the AIMS (Piper & Darrah, 1994), which provided a means to validate the gross motor information obtained from the parent-completed checklists. When we compared the presence or absence of crawling at the home visit to the same dichotomy from the parent checklists for the week before the home visit, we found that parents were reliable reporters of their infants' crawling development, with Cohen's kappas of .86 to .96, representing almost perfect agreement (Bodnarchuk & Eaton, 2004a, 2004b; Landis & Koch, 1997).

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[3]Not all infants were visited, and weight and length data were not captured on the checklists; thus, potentially useful analyses using these anthropometric data were not possible.

The AIMS (Piper & Darrah, 1994) is an assessment tool for motor development in infants from birth to the onset of walking. It allows fine-detailed discrimination of motor development on four subscales: prone, supine, sitting, and standing. The prone subscale is used to assess infants lying on their bellies; it includes items such as *extended arm support* and *reciprocal crawling*. The supine subscale assesses infants lying on their backs and includes items such as *hands to knees* and *rolling supine to prone with rotation*. The sit subscale includes items such as *pull to sit* and *sitting without arm support*. Finally, the stand subscale includes items such as *pulls to stand with support* and *controlled lowering from standing*.

Piper and Darrah (1994) assessed the reliability of the AIMS by comparing scores from two different assessors as well as from two different time points. As well, they tested the concurrent validity of the AIMS by comparing AIMS scores to BSID-PDI (Bayley, 1969) scores and to gross motor scores from the Peabody Developmental Motor Scales (PDMS; Folio & Fewell, 1983; Redfern & Maguire, 1994). The reliability across assessors was very high: .99 for 253 infants. When these results were broken down by the age of the infants, the reliability remained uniformly high, ranging from .96 to .98 for infants 0-3, 4-7, 8-11, and 12 or more months of age. The reliability across two time points separated by 3 to 7 days was also high. Using the same assessor at both time points, overall reliability was .99 and was .95, .92, .98, and .86 across the four age groups. When a different assessor was used at the two time points, reliability was .99 overall and ranged from .82 to .94 for the four age groups. Concurrent validity, that is, whether a new measure is related to a preexisting, validated measure, was assessed with

Pearson correlations between the AIMS, the BSID-PDI, and the PDMS. For infants between birth and 13 months of age (n=103), correlations were .99 (AIMS/PDMS), .97 (AIMS/BSID-PDI), and .98 (PDMS/BSID-PDI). When these results were broken down by age, the correlations all remained above .83.

2.2.3 Breastfeeding Questionnaire

Because crawling is attained in a relatively narrow age range, it was easily captured with the checklists. In contrast, the age at which breastfeeding is discontinued is much wider and was not adequately captured on the checklists for all infants (Bodnarchuk et al., 2005). Thus, a separate feeding questionnaire (Appendix F) was sent out to the parents to obtain the age at which various transitions in feeding occurred. The questionnaire was mailed after the last checklist was mailed to us and after a thank-you package was sent to the participant. The information obtained from these retrospective questionnaires was likely subject to memory biases, but such biases may have been small for two reasons. First, memory biases in recall of feeding transitions are small for mothers of infants and toddlers at 6 months (Quandt, 1987) and at 1, 1 1/2, and 2 years of age (Huttly, Barros, Victora, Beria, & Vaughan, 1990; Laurner et al., 1992). Second, the memory of the mothers in the current study may have been aided by the activity of completing the checklists; therefore, data obtained from the questionnaires were expected to be accurate. Further, these data were only used when the “gold standard” longitudinal checklist data (Aarts et al., 2000) were not available, which usually occurred when the infant began supplementation or was weaned before or after checklist completion.

2.2.4 Measurement of Cognitive Abilities: The MCDI and the PARCA

Approximately 2 weeks before the child's second birthday, the parents were contacted by phone to inquire whether they were willing to complete the MCDI (Fenson et al., 1993) and the PARCA (Saudino et al., 1998). If the parent agreed to complete the MCDI and the PARCA, a package was mailed to the parent containing instructions (Appendix G); two copies of a consent form (Appendix H); the MCDI; the PARCA; a set of 10 plain, wooden blocks (3.5 cm per side); and a postage-paid envelope for returning the MCDI, PARCA, and consent form. Once the information was returned and the data were coded electronically, a copy of the MCDI and the original PARCA were returned to the parent. As well, the parents were allowed to keep the wooden blocks for their children.

2.2.4.1 The MCDI. The MCDI is a parent-completed assessment of language development for 16- to 30-month-old children. It consists of two sections; the vocabulary production section first lists 680 words in 22 different categories, such as animals, clothing, people, adjectives, and helping verbs, and then has five questions about the toddler's references to the past, future, and absent objects and events. The syntax section has five parts, two of which address word endings such as *-s*, *-ing*, and *-ed*. A third part asks about irregular nouns and verbs that the child has used (e.g., mice, went), and the final two parts concern word combinations, including the longest sentences spoken by the child and the child's transition from two-word to multi-word speech.

Fenson et al. (1993) reported good reliability and validity for the MCDI. Two measures of reliability were assessed: (a) internal consistency was high for both vocabulary production (Cronbach's alpha = .96) and for syntactic development (Cronbach's alpha = .95), and (b) the test-retest scores for vocabulary had Pearson correlation values of greater than .9 at every month of age. Fenson et al. also assessed face, content, convergent, concurrent, and predictive validities. Face validity refers to whether a given test appears to measure what it was designed to measure, and content validity addresses whether a test captures the full definition of a measure (Leary, 1995; Neuman, 1997). Fenson et al. considered the MCDI to have good face and content validities. Convergent validity describes whether several assessments of the same idea come to the same conclusion (Neuman, 1997); Fenson et al. compared results from the MCDI to results in the literature and concluded that there was a close parallel. Concurrent validity requires that a new measure be associated with an existing indicator already deemed valid (Neuman, 1997), and was assessed by comparing parent reports to laboratory measures. Correlations in three studies ranged from .40 to .85, and from .60 to .88, for vocabulary production and syntactic development, respectively (Dale, 1990; as cited in Fenson et al., 1993; Dale, 1991; O'Hanlon & Thal, 1991; as cited in Fenson et al., 1993). Finally, predictive validity, which means a measure can predict related future events or behaviours (Leary, 1995; Neuman, 1997), was assessed through correlations between time 1 and time 2 measurements that were 6 months apart. The correlations were .71 for vocabulary and .62 for syntax (Fenson et al., 1993).

2.2.4.2 The PARCA. The PARCA (Saudino et al., 1998) was designed as a parent measure of nonverbal cognitive abilities to complement parent-completed language measures such as the MCDI. It consists of both a parent-report and a parent-administered component. Parent-report questions were designed to assess the areas of quantitative skills, spatial abilities, symbolic play, planning and organizing, adaptive behaviours, and memory. The questions were phrased in terms of activities that the parents had actually observed their children performing (e.g., “Does your child ever pretend that one object, such as a block, is another object, such as a car or a telephone?”). If the parents were unsure whether their children could perform the activity, they were allowed to try the task with their children. Saudino et al. reported that the internal consistency of the parent-report component, as estimated by Cronbach’s alpha coefficient, was .74.

The parent-administered component of the PARCA consists of four categories of tasks: design drawing, match-to-sample, block building, and imitative action. In all tasks but match-to-sample, the parent first demonstrates the task and then asks the child to perform the same task. For example, during design drawing, the parent draws a horizontal line and then asks the child to draw a horizontal line. In the match-to-sample tasks, the parent shows the child a shape and asks the child to find its match among four choices. Saudino et al. (1998) reported that the internal consistency of this component was .83.

To validate the PARCA, Saudino et al. (1998) compared PARCA scores to BSID-MDI (Bayley, 1993) scores obtained from 107 infants with a mean age at time of testing of 2.2 years. Both the parent-reported and parent-administered scores correlated significantly with the BSID-MDI, and when the two parent scores were combined, the correlation with the BSID-MDI was strengthened. Furthermore, when an “anglicized” adaptation of the MCDI consisting of a 100-item short form MCDI vocabulary checklist (Fenson, Pethick, & Cox, 1994; as cited in Saudino et al., 1998) and 12 of the 37 MCDI sentence pairs were included, prediction of BSID-MDI scores again improved. Each of the four scores, that is, the parent-reported, the parent-administered, the short form vocabulary, and the short form sentences, made a statistically significant unique contribution to the prediction of the BSID-MDI. Finally, Saudino et al. determined whether parents could use the PARCA to provide information distinctly about their children’s nonverbal abilities compared to their verbal abilities; indeed, scores on the parent-completed nonverbal measure correlated more highly with the nonverbal subscale constructed from the BSID-MDI, and the same was found for the verbal measures. Thus, Saudino et al. concluded that the PARCA could be used to provide valid estimates of 2-year-old children’s nonverbal cognitive abilities.

The current study employed both the MCDI and the PARCA to measure verbal and nonverbal cognitive development, respectively, at 2 years of age. These two measures have routinely been used in a large longitudinal twin study in the United Kingdom (Eley et al., 1999; Plomin, Price, Eley, Dale, & Stevenson, 2002; Price et al., 2000; Purcell et al., 2001; Saudino et al., 1998). However, that study employed the anglicized adaptation of the MCDI described above; whereas, the current study used the full, English version of the MCDI.

2.3 Data Analysis

2.3.1 Calculation of Key Variables

The breastfeeding duration variables were obtained from a combination of data sources (i.e., the checklists and the feeding questionnaires), the crawling variable was obtained from the daily checklists, and cognition was collected from two measures (i.e., the MCDI and the PARCA). While calculation of variables seems like it would be a clear-cut matter, there were complexities in the creation of these variables, with different issues relevant for each one.

2.3.1.1 Breastfeeding Duration. "Breastfeeding is not a dichotomous variable, but rather a continuous variable whose effects can be assumed to vary directly in proportion to the length of time to weaning and the daily dose of breastfeeding" (Fredrickson, 1995, p. 407). While this statement is true, operationalizing the breastfeeding variable in such a way to capture this complexity and still be able to conduct statistical analyses has proven difficult (Bodnarchuk et al., 2005; Fredrickson, 1995; Martens, 2000). Some solutions to the problem seem better than others, and the solution utilized in the present study was based on work by Quandt (1987), Johnson et al. (1996), and Bodnarchuk et al. (2005).

Two variables were used to measure breastfeeding duration: one continuous variable was defined as the age of the infant in months when *exclusive* breastfeeding ended, and the other continuous variable was defined as the age of the infant in months when *any*, or *partial*, breastfeeding ended. More specifically, the end of exclusive breastfeeding was defined from the checklists as the age of the infant on the first day of the week in which an infant previously fed only breast milk was first given other foods, including formula (Bodnarchuk et al, 2005). This variable was only calculated for infants whose checklists started with exclusive breastfeeding. The checklists did not start at birth, so it was possible that infants exclusively BF at the start of their checklists had not been exclusively BF since birth. However, the feeding questionnaires provided additional information regarding the infants' feeding histories and allowed the checklist information to be verified. Furthermore, for infants who were either partially BF or not BF at all at the start of their checklists, the questionnaire data provided information regarding the duration of exclusive breastfeeding (see Appendix F, questions 2 and 6). Information regarding the end of partial breastfeeding was also obtained primarily from the checklists, defined as the age of the infant on the first day of the week in which a previously BF infant was first given no breast milk. This information was verified with the questionnaire data, and for infants who were completely weaned before or after checklist completion, the questionnaires provided data for this variable (see Appendix F, question 3).

Given that over 90% of Manitoba mothers initiate breastfeeding in hospital (Breastfeeding Promotion Steering Committee of Manitoba, 1998), very few infant participants were expected to be completely FF, and as the results will show, no completely FF infants were included in the current study. If these infants had been included, both the exclusive and partial breastfeeding variables would have been given a value of zero.

Finally, for infants with missing data for one of the two breastfeeding variables, the missing data were imputed through a regression technique (Tabachnick & Fidell, 2001). That is, the exclusive breastfeeding variable was regressed on the partial breastfeeding variable, and vice versa, for the entire sample. The equations generated from these regressions then used the infants' nonmissing breastfeeding values to predict the missing values. These predicted values were checked for compliance with the possible range of values known for each infant from the checklists. This technique was used to preserve the data for these infants for use in the regressions rather than deleting the cases. The regression technique was more objective than a guess as to the value of the missing breastfeeding variables and more exact than using the grand mean (Tabachnick & Fidell, 2001). However, this technique also has some disadvantages, such as reducing variability due to the predicted scores likely being closer to the mean than the real scores would have been. Another typical disadvantage of this technique, not having adequate predictors, was not the case in the present study because exclusive and partial breastfeeding correlated quite highly (see *Section 3.3 Mediational Analysis*).

2.3.1.2 Crawling Onset. Crawling has often been measured as a dichotomous variable at one point in time; either a baby can or cannot crawl at a given age (e.g., Campos et al., 2000; Piper & Darrah, 1994). However, babies begin crawling at various ages; thus, it is best measured as a continuous variable, which gives a better estimate of the true variability (MacCallum et al., 2002). The current study used such a continuous variable, which was created as part of the IMS using the checklist data.

The time of crawling onset may or may not be an immediate transition from stationary status (Bushnell & Boudreau, 1993). For example, if a baby crawls one day, he or she will not necessarily crawl the next day. Such flexibility suggests that it may be better to consider several days together to obtain a more stable estimate for the age of attainment (Epstein, 1980, 1986). Thus, as part of the IMS a procedure was designed to capture the onset of crawling that considered crawling observations over five consecutive days. A moving 5-day window tracked the checklist over time until the first time 3 of the 5 days within the window showed crawling had been observed. The day of attainment was then considered to be the middle day of that particular 5-day window, and the infant's birth date was subtracted from that date to produce the infant's age of attainment for crawling.

This procedure worked well in all cases where we had checklist data before crawling onset. However, in the cases where the infants had been crawling prior to the start of checklist recording, our procedure was assigning the age of attainment to the first day of checklist completion. This error resulted in an overestimate for the age of attainment for some infants (e.g., for an infant who crawled 2 weeks before checklist commencement, this procedure would have assigned the onset of crawling 2 weeks late). This would have upwardly biased our average age of crawling onset, and may have contributed to Type II error. To remedy this problem, we also checked for the absence of crawling, that is, we also required that 3 days *without* an observation of crawling exist in the 5 days preceding the 5-day window of crawling attainment. This correction decreased error variance and added to the sensitivity of our measurement.

2.3.1.3 Cognition. The cognitive variable was calculated by summing standardized scores from the PARCA (Saudino et al., 1998) and the MCDI (Fenson et al., 1993) to create one continuous outcome variable. The PARCA standardized scores were calculated based on the strategy described by Dale, Plomin and colleagues (Eley, Dale, Bishop, Price, & Plomin, 2001; Galsworthy, Dionne, Dale, & Plomin, 2000; Price et al., 2000). First, a total score was calculated for both the parent-administered and the parent-reported subscales by summing the number of correct or affirmative answers. Each of these scores was then standardized to a mean of zero and a standard deviation of one based on the current sample. The standardized subscale scores were then summed and the sum was standardized to a mean of zero and a standard deviation of one. Although Dale, Plomin and colleagues did not use the full version of the MCDI, the same scoring strategy was used in the present study for both the nonverbal and verbal cognitive measures so that they were equally weighted. Thus, for the MCDI, a total score was calculated for both the vocabulary and syntax sections by summing the number of positive responses in the vocabulary section and awarding higher points (i.e., 2 instead of 1 point) for more complex sentences in the syntax section (Dale, Dionne, Eley, & Plomin, 2000). Each of these scores was then standardized to a mean of zero and a standard deviation of one, summed, and standardized again. The standardized PARCA score and the standardized MCDI score were summed to get the cognitive score. Because the cognitive variables were measured on or near the toddlers' 2nd birthdays, no age adjustments were done.

2.3.2 Descriptive Analyses

The sample was described using maternal education level and age at infant's birth; household income; and infant birth weight, birth length, and gestational age, as well as with the results on each of the key variables described in the previous section. Each descriptive variable was checked for normality and tested for sex differences. When all normality tests (the Shapiro-Wilk W statistic and three goodness-of-fit tests: the Kolmogorov-Smirnov D statistic, the Anderson-Darling statistic, and the Cramer-von Mises statistic) were nonsignificant ($\alpha \geq .05$), parametric tests were performed to test sex differences. However, when even one of the normality tests was significant, nonparametric analyses were performed.

For categorical descriptive variables, differences between the two groups (males and females) were tested with a Chi-square test, or, where that was invalid due to small cell sizes, a Fisher's Exact test. For continuous descriptors, sex differences were tested with an Analysis of Variance (ANOVA) for normally distributed variables and a Wilcoxon/Mann-Whitney for nonnormal data (Maxwell & Delaney, 2000; SAS Institute Inc., 1999).

2.3.3 Analyses of Potential Covariates

The relationships between potentially confounding covariates and the key variables under investigation were assessed. The confounding variables were chosen based on those typically used in studies presented in Chapter 1 (see Table 1.1 for a summary) and because of the practical aspect of whether they were already collected as part of the IMS. Thus, the selected confounding variables included maternal age at infant's birth, alcohol use and smoking during pregnancy, education level, ethnicity, and parity; infant birth weight, gestational age, and sex; and household income, which were all obtained either at the initial phone call or from the HDQ.

Based on the normality tests for the key variables described in the previous section, parametric or nonparametric tested were used. For categorical covariates, an Analysis of Variance (ANOVA) was performed for normally distributed variables, and a Wilcoxon/Mann-Whitney was used for nonnormal data when the covariate had two groups or a Kruskal-Wallis when the covariate had more than two groups. For continuous covariates, correlations were performed, using a Pearson correlation for normal data and a Spearman correlation for nonnormal data (SAS Institute Inc., 1999). Only those variables that were significantly related to the key variables were planned for inclusion as covariates to aid in interpretation of the results from the mediation regression analyses.

In addition to the variables listed above, the onset of crawling was also tested in relation to both experience in the prone position and season of birth. Experience in the prone position was measured by the percent of checklist days, from the beginning of checklist completion to the attainment of crawling, that the infant was placed in the prone position during either sleep or play (Davis et al., 1998), and season of birth was assessed using December, January, and February as "winter," and so on. Again, analyses were carried out pending results from normality tests and only the significant variables were planned for inclusion in the regression models as covariates.

Because numerous statistical tests were conducted during these analyses, an adjustment was made for Type I error. In total, ten potential covariates were tested against the three predictors and the outcome; two additional tests compared crawling to prone placement and season of birth. Thus, overall 42 tests were planned. Control of the overall Type I error rate was desired because including extra predictors in the regressions would reduce the cases-to-predictors ratio, causing problems for interpretation (Green, 1991; Tabachnick & Fidell, 2001); however, at the same time, this study was exploratory and inclusion of covariates by chance was not considered a large risk. Thus, only moderate control of the Type I error rate was sought by setting alpha for each covariate analysis at .005, which led to an overall Type I error rate for these analyses of .19 (i.e., alpha = $1 - (1-.005)^{42}$; Toothaker, 1991, p. 11). In other words, this study had approximately a 19% chance of making at least one Type I error during the covariate analyses.[4]

2.3.4 Mediational Analysis

To test crawling onset as an intermediary between breastfeeding duration and cognitive development, a mediational analysis was conducted. Mediational analyses have often been used in the psychological literature (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002; Shrout & Bolger, 2002), and traditionally have employed the

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[4]An alpha value of .05 for these analyses would have led to an overall Type I error rate of .88, or an 88% chance of making at least one Type I error.

methodology outlined by Baron and Kenny (1986), which has recently been updated (Kenny et al., 1998; Shrout & Bolger, 2002). Although this traditional approach has limitations, it does test all of the logical relationships among the variables (MacKinnon et al., 2002), which was conceptually central to the present study, and thus was chosen to guide the analysis.

Mediational analyses can be carried out using SEM or multiple regression (Kenny et al., 1998). SEM is preferred when the model includes latent constructs, but regression is better when all variables are measured, which was the case in the present study. Thus, regression, and more specifically, backward stepwise regression, was used, and three regressions were performed as outlined by Kenny et al. (1998). First, duration of exclusive and any breastfeeding were included in the prediction of the outcome of cognition. Second, the two breastfeeding duration variables were used to predict the mediator of crawling onset. The third regression incorporated both steps 3 and 4 of the mediational analysis, and included both breastfeeding duration variables as well as crawling onset to predict cognition. For step 3, the result of interest was the significance of the crawling onset coefficient in predicting cognition while controlling for breastfeeding duration. For step 4, the result of interest was the significance of the breastfeeding duration coefficients in predicting cognition, which was the same result of interest from the first regression. However, this time the mediating variable, crawling onset, was added to the regression and the difference in the breastfeeding duration regression coefficients from the first and third regressions determined whether mediation occurred. The hypothesis was that longer durations of breastfeeding would significantly predict both higher scores on the cognitive outcome and earlier crawling attainment, that earlier crawling would significantly predict higher cognitive scores while controlling for breastfeeding duration, and that the relation between breastfeeding duration and cognitive outcomes would be reduced when crawling onset was included in the model.

All analyses were performed using SAS-PC version 9.1 (SAS Institute, Inc., Cary, NC) and alpha values were .05 unless otherwise noted.

Chapter 3: Results

3.1 Participants

3.1.1 Exclusions

Of the 171 infants born between December 1, 2001 and July 31, 2002 who enrolled in the IMS, 160 (94%) were full term infants, and of those, 82 (51%) had complete crawling data. These 82 were selected for follow-up, but six (7%) of these participants had a telephone number no longer in service or did not answer the original telephone call; the remaining 76 (93%) were contacted and formed the targeted sample.

Of the targeted sample, four (5%) mothers refused at the initial phone call and 14 (18%) did not return a phone call after one or two messages were left on an answering machine; the remaining 58 (76%) participants were successfully contacted and were sent the cognitive measures through the mail. Participants typically returned completed forms by one month after the infants' birthdays, and a protocol was in place for reminder telephone calls to occur at this time (i.e., approximately 6 weeks after the package was mailed). Data collection continued until September 30, 2004, at which time 47 (81%) of the 58 participants had returned completed measures and of those who had not, the latest birthday was July 11, 2004. Thus, all participants were given ample time to return completed measures, and all completed MCDIs and PARCAs were returned within 6 months of the children's second birthdays, which was the criterion for inclusion used by Plomin et al. (2002) and Price et al. (2000) in their studies using these two measures.

Of the 47 infants with complete cognitive data, two infants (4%) had missing data for one of the two breastfeeding variables; a value was imputed for the missing data as described in *Section 2.3.1.1 Breastfeeding Duration*.[5] Three infants (6%) had missing data for both breastfeeding variables; thus, imputation was not performed. Hence, a final sample size of 44 infants was used in the present analyses. Information on the 38 infants who met the original follow-up criteria but did not complete all measures is presented in Appendix I; these infants did not differ significantly from those of the current sample.

3.1.2 Sample Characteristics

Almost all (n = 43, 98%) participating families lived in the province of Manitoba, with most of those (n = 39, 91%) living in the city of Winnipeg. Participants came from a range of SES backgrounds, but mothers in the current study were better educated than Manitoba females in the 20- to 44-year-old age range. As well, at least two-thirds of the families had higher annual household incomes than the provincial median (Table 3.1). Male and female infants were similar at birth (Table 3.2); no significant differences were found for birth weight, $F(1, 42) = 2.43$, $p = .13$; gestational age, $F(1, 42) = 0.35$, $p = .55$; or mothers' age at the birth of the infant, $F(1, 42) = 0.08$, $p = .78$. However, a significant difference was found for birth length (Fisher's Exact test: P = .00, p < .05)[6]; on average,

[5]The two (5%) missing values were expected to have little effect on the results either with or without imputation of predicted values. Indeed, when the mediation regression analyses were run with and without these imputed cases, the results were not significantly different, and the cases were retained.

[6]In the IMS, birth length was recorded to the nearest inch, creating a 5-category variable.

Table 3.1

Distribution of Mothers' Education and Household Income Levels

Mothers' Highest Education Level with Sample and Comparison Values					Annual Household Income		
	Sample		W[a]	M[b]		Sample[c]	
	n	%	%	%		*n*	%
Less than high school	0	0.0	16.7	21.4	< $40,000	10	22.7
High school and/or some postsecondary	10	22.7	29.3	28.8	$40,000 - $60,000	5	11.4
Trades certificate or diploma	4	9.1	9.0	9.5	$60,000 - $80,000	14	31.8
College certificate or diploma	7	15.9	20.1	19.8	> $80,000	14	31.8
University certificate, diploma, or degree	23	52.3	25.0	20.6	Not Stated	1	2.3

[a]City of Winnipeg. [b]Province of Manitoba. [c]Winnipeg median = $43,385; Manitoba median = $41,661 (Statistics Canada, 2001)

males were 0.7 in. longer than females. Such a significant difference was unexpected in this sample, because while significant birth length differences have been found, they have been small. For example, males were 0.3 in. longer than females on average in a recent study of 1,218 full term infants (Hindmarsh, Geary, Rodeck, Kingdom, & Cole, 2002).

Table 3.2

Characteristics of Participants at the Birth of the Infant

	Females					Males				
	n	*M*	*SD*	Min.	Max.	*n*	*M*	*SD*	Min.	Max.
Weight (pounds)	21	7.7	1.0	6.2	9.5	23	8.1	0.7	7.0	10.2
Length (inches)	20	20.4	1.0	19.0	22.0	22	21.1	0.8	20.0	23.0
Gestational age (weeks)	21	40.1	1.1	38.0	42.0	23	39.9	1.0	37.9	41.3
Mother's age (years)	21	31.0	4.9	20.3	38.6	23	31.4	4.2	22.7	38.7

Summary results for the key variables of breastfeeding duration and crawling onset are presented in Figures 3.1 and 3.2, respectively. Figure 3.1 shows the percentage of infants in the sample who were exclusively BF and partially BF by age. Exclusive breastfeeding showed a relatively steep decline at 4 months of age, with cessation for all infants by 7 months. These results were as expected, because infant feeding recommendations in Canada at the time of this study suggested exclusive breastfeeding for at least the first 4 months of life (Canadian Paediatric Society et al., 1998), and other recommendations at that time (American Academy of Pediatrics Working Group on

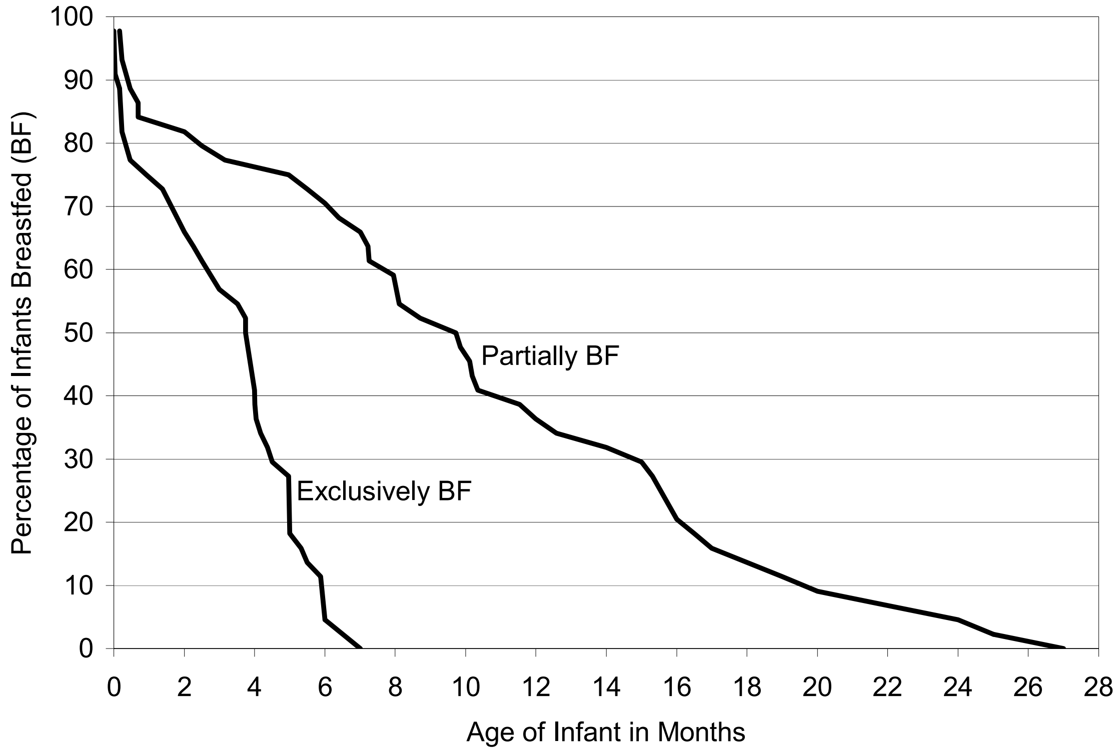


Figure 3.1. Percentage of infants exclusively and partially BF by age.

Breastfeeding, 1997; World Health Organization, 1989), as well as the revised Canadian and American guidelines (American Academy of Pediatrics Section on Breastfeeding, 2005; Health Canada, 2004), suggest exclusive breastfeeding up to 6 months of age.

Infants in this sample were partially BF for longer than expected based on 1996 provincial statistics (Martens et al., 2002). These longer durations were most notable starting at 3 months of age: at 3 months 77% of sample infants were still breastfeeding compared to 57% (± 7%) at the provincial level, at 6 months 70% of sample infants were breastfeeding compared to 36% (± 7%) provincially, and at one year, more than twice as

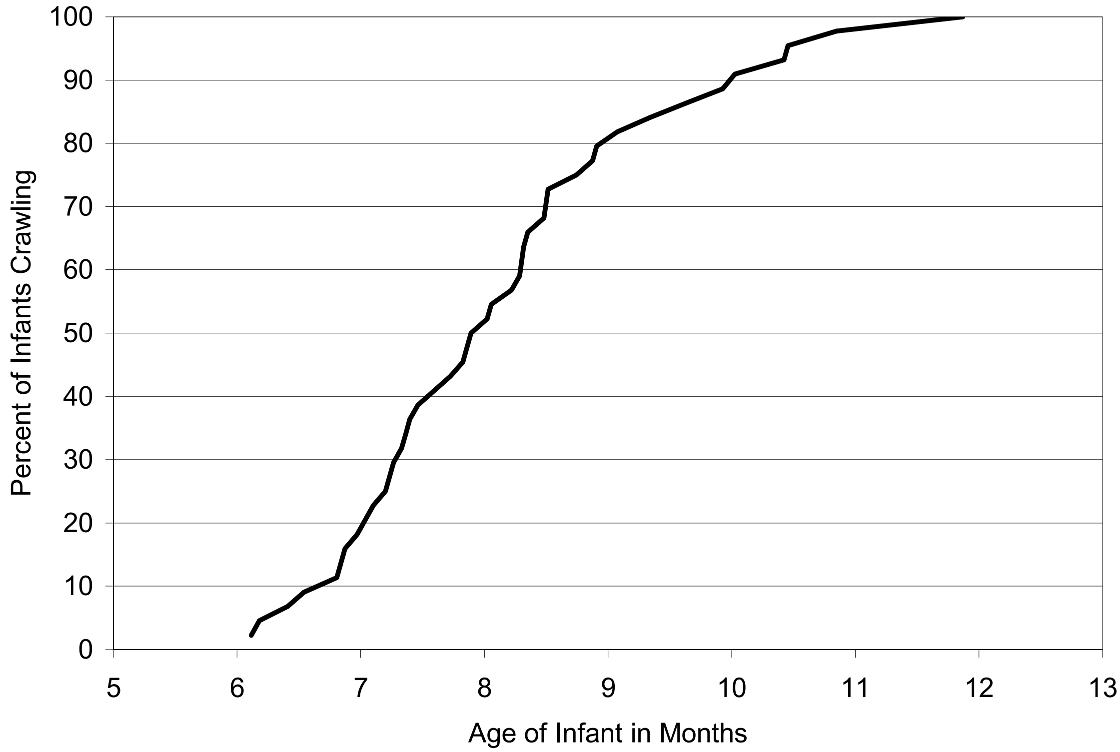


Figure 3.2. Percentage of infants who attained crawling by age.

many sample infants were breastfeeding (36%) compared to the provincial estimate (15 ± 6%). This lengthened breastfeeding duration may have been expected based on the results showing higher than average education and income levels in the current sample (Bertini et al., 2003; Breastfeeding Promotion Steering Committee of Manitoba, 1998; Dennis, 2002). The mean durations of breastfeeding were not significantly different for male and female infants, for either exclusive breastfeeding, Wilcoxon Statistic = 470.0, $p = .96$, or partial breastfeeding, $F\ (1, 42) = 0.00$, $p = .98$ (figures not shown).

Figure 3.2 shows visually that the median age of crawling was just under 8 months of age and that crawling onset ranged from 6 to 12 months. These estimates match the expected distribution (Piper & Darrah, 1994), and the mean age at crawling attainment was not significantly different between males and females, $F(1, 42) = 0.00$, $p = .95$ (figure not shown).

Finally, a summary of the raw scores for the cognitive measures is presented in Table 3.3. PARCA parent-administered scores were calculated partly through assessment of toddler's drawings, and an intraclass correlation (ICC; Shrout & Fleiss, 1979) was calculated to test the reliability of the scoring protocol in a sample of 20 PARCAs between the "gold standard" scorer (research assistant 1) and two other scorers who scored 10 PARCAs each (author, research assistant 2). An overall ICC of .94 was obtained, indicating high reliability.

Because Galsworthy et al. (2000) found significant sex differences for both the PARCA and for a short-form of the MCDI, these differences were tested in the current sample. The parent-administered PARCA scores and the MCDI syntax raw scores were not normally distributed and did not show significant sex differences (Wilcoxon Statistic = 457.0, $p = .72$; Wilcoxon Statistic = 502.0, $p = .50$; respectively). Parent-reported PARCA scores and the MCDI vocabulary raw scores were normally distributed and showed no sex differences ($F[1, 42] = 0.07$, $p = .79$; $F[1, 42] = 2.22$, $p = .14$; respectively). Galsworthy et al. tested over 3000 pairs of 2-year-old twins, an extremely large sample size, which allowed the "predominantly small effect sizes, especially for the non-verbal measure," (p. 212) to be detected. Further, although some reports have found

Table 3.3

Raw Scores on the PARCA and MCDI Cognitive Measures

	Females					Males				
	n	*M*	*SD*	Min.	Max.	*n*	*M*	*SD*	Min.	Max.
PARCA										
Parent-administered (range 0 – 52)	21	28.6	5.3	15	40	23	27.7	7.5	3	37
Parent-reported (range 0 – 26)	21	19.5	2.6	15	25	23	19.3	2.7	13	24
MCDI										
Vocabulary (range 0 – 680)	21	383	182	51	665	23	307	154	48	609
Syntax (range 0 – 159)	21	63.2	29.9	6	113	23	53.3	30.0	6	104

greater variance in cognitive abilities for young males (e.g., Feingold, 1992), tests of homogeneity of variance for the PARCA and the MCDI in the current study and in that of Galsworthy et al. (2000) did not. In the current study, the tests showed no significant variance differences for the PARCA parent-administered (p = .12) and parent-reported (p = .85), and for the MCDI vocabulary (p = .44) and syntax (p = .99). Galsworthy et al. (2000) showed no significant variance differences for the PARCA (p = .15) and for the short-form MCDI (p = .79). All infants scored within the mid-range of the measures and no ceiling or floor effects were evident. The raw scores presented in Table 3.3 were standardized as described in *Section 2.3.1.3 Cognition*. These standardized variables, and the overall cognitive score created by their combination, which passed the normality tests, were used in the analyses described next.

3.2 Analyses of Potential Covariates

The variables of maternal age at infant's birth, alcohol use and smoking during pregnancy, education level, ethnicity, and parity; infant birth weight and gestational age; and household income were tested for the significance of their relationships to the key variables at an alpha level of .005 (see *Section 2.3.3 Analyses of Potential Covariates*). The potential covariate of infant sex was tested and discussed in the previous section. No covariates reached significance in the present sample; thus, no covariates were included in the mediational analyses (see Appendix J for details of the statistical tests, excluding those for infant sex).

3.3 Mediational Analysis

A mediational analysis was conducted to test the hypotheses of this study, using the model in Figure 1.3 and following the procedure outlined by Kenny, Bolger, and colleagues (Baron & Kenny, 1986; Kenny et al., 1998; Shrout & Bolger, 2002). The regression assumptions of normality, linearity, and homoscedasticity were checked by examining the residuals scatter plots; all assumptions were satisfactorily met (see

Appendix K; Tabachnick & Fidell, 2001). Multicollinearity was checked by examining the correlations among the three predictor variables (see Table 3.4). Although the correlation between exclusive and partial breastfeeding was very high, it did not reach the level of multicollinearity as defined by Tabachnick and Fidell (2001; correlation of .90). Table 3.4 also shows the correlations between the predictor variables and the outcome: the overall cognition score and the MCDI correlated significantly only with the predictor

Table 3.4

Intercorrelations Among the Three Predictor Variables, the Components of the Outcome, and the Outcome

	1[a]	2	3	4	5	6
1. Exclusive breastfeeding	–					
2. Partial breastfeeding	.75***	–				
3. Crawling	.16	.20	–			
4. MCDI	-.02	-.04	-.34*	–		
5. PARCA	.17	-.13	-.22	.49**	–	
6. Cognition	.07	-.10	-.33*	.88***	.85***	–

[a]Correlations in this column are Spearman correlations due to the nonnormal distribution of Exclusive breastfeeding. All other correlations are Pearson correlations.

*$p < .05$ ** $p < .001$ ***$p < .0001$

of crawling, but the PARCA component of the cognitive score did not reach a statistically significant correlation with any of the predictors.

The mediational analysis consisted of three regressions (Baron & Kenny, 1986; Kenny et al., 1998; Shrout & Bolger, 2002). Table 3.5 displays the intercept, unstandardized regression coefficients (*B*), and standardized regression coefficients (β) for all regressions discussed here. The predictor variables were centered (i.e., the grand mean was subtracted from each infant's score) prior to these analyses so that the intercept was interpretable as the score of an average infant rather than the usual interpretation as the score of an infant for whom all predictor variables had a value of zero.

Table 3.5

Summary of the Mediational Standard Regression Analyses

	Variable	B (unique)	*SE* B	β	R^2	Adjusted R^2
	First Regression: Initial Variable on Outcome (Cognition)					
(a)	Intercept	0.09	0.24		.03	.00
	Exclusive breastfeeding	-0.14	0.16	-.29		
	Partial breastfeeding	0.05	0.05	.36		
(b)	Intercept	0.09	0.24		.01	.00
	Partial breastfeeding	0.02	0.03	.15		

Table 3.5 *(continued)*

	Variable	B (unique)	*SE* B	β	R^2	Adjusted R^2
	Second Regression: Initial Variable on Mediator (Crawling)					
(c)	Intercept	0.00	0.20		.04	.00
	Exclusive breastfeeding	0.05	0.13	.09		
	Partial breastfeeding	0.02	0.04	.13		
(d)	Intercept	0.00	0.19		.03	.01
	Exclusive breastfeeding	0.11	0.09	0.18		
	Third Regression: Initial Variable and Mediator on Outcome (Cognition)					
(e)	Intercept	0.09	0.23		.13	.06
	Exclusive breastfeeding	-0.16	0.16	-.34		
	Partial breastfeeding	0.04	0.05	.29		
	Crawling	0.41	0.19	.53*		
(f)	Intercept	0.09	0.23		.11	.07
	Exclusive breastfeeding	-0.06	0.11	-.14		
	Crawling	0.42	0.18	0.55*		
(g)	Intercept	0.09	0.23		.11	.09
	Crawling	0.40	0.18	0.53*		

* $p < .05$

The goal of the first regression was to show that the initial variable of breastfeeding duration, as measured by durations of both exclusive and partial breastfeeding, predicted the outcome of cognitive development, as measured by the sum of the standardized scores of the MCDI and the PARCA. Results showed no significant relationship between breastfeeding duration and cognitive outcome at 2 years of age when both exclusive and partial breastfeeding durations were included in the model, F (2, 41) = 0.54, p = .59 (Table 3.5a). Thus, a backward stepwise regression was used, which removed exclusive breastfeeding duration from the model. The model containing only the predictor of partial breastfeeding duration again did not reach statistical significance, F (1, 42) = 0.39, p = .54 (Table 3.5b). Further, the expected medium-to-large effect size was not present in this analysis, but rather the adjusted R^2 showed zero effect (Adjusted R^2 = .00). The nonsignificant results obtained for this first analysis step were not detrimental to the overall mediational analysis because it was not essential to show that the initial variable predicted the outcome, especially in cases where the initial variable is distant in time from the outcome, as in the current study (Kenny et al., 1998; Shrout & Bolger, 2002). Rather, the key steps in the analysis were steps 2 and 3.

Step 2 of the current mediational analysis was to show that breastfeeding duration predicted the mediator of crawling onset (Baron & Kenny, 1986; Kenny et al., 1998; Shrout & Bolger, 2002). Results showed no significant relationship between breastfeeding duration and crawling onset when breastfeeding duration was measured by both exclusive and partial durations, F (2, 41) = 0.90, p = .41 (Table 3.5c). Next, as indicated for the backward stepwise regression, duration of partial breastfeeding was removed. This made statistical as well as practical sense because duration of partial breastfeeding extended beyond crawling age for a considerable number of the infants; thus, it was not likely contributing to the onset of crawling. When the relationship was tested again using only exclusive breastfeeding duration, nonsignificant results were found again, $F(1, 42) = 1.46$, $p = .23$ (Table 3.5d), and a zero-to-small effect size was present, as measured by the adjusted R^2 (.01, $f^2 = .01$, see Appendix A). These results therefore suggested that mediation was not likely, but nonetheless, the mediational analysis was completed for the current study.

The third regression completed both steps 3 and 4 of the mediational analysis (Baron & Kenny, 1986; Kenny et al., 1998; Shrout & Bolger, 2002). It used both breastfeeding duration variables as well as crawling onset to predict cognition. Although the overall regression was nonsignificant when using all three predictor variables, $F(3, 40) = 2.00$, $p = .12$ (Table 3.5e), a small-to-medium effect was present (adjusted $R^2 = .06$, $f^2 = .06$, see Appendix A). Further, the result of interest for step 3 of the mediational analysis was the significance of the crawling coefficient in predicting cognition while controlling for breastfeeding duration, and crawling did reach significance ($p = .03$). When the regression was repeated after removing the least significant predictor of partial breastfeeding duration, again an overall nonsignificant result was found, $F(2, 41) = 2.65$, $p = .08$ (Table 3.5f), but crawling onset remained significant ($p = .03$) and the effect size stayed constant (adjusted $R^2 = .07$, $f^2 = .08$). Next, although no longer a test of the mediation, the final nonsignificant predictor of exclusive breastfeeding duration was removed from the model. This modified regression showed a significant result for crawling age of attainment in predicting cognition at 2 years of age, *F* (1, 42) = 5.05, *p* = .03 (Table 3.5g), and a slight increase in the effect size (adjusted $R^2 = .09$, $f^2 = .10$). Thus, while the overall mediation was inconclusive based on the results from step 2, these results from step 3 suggest that crawling onset is a better predictor of cognitive outcomes at 2 years of age than is breastfeeding duration, and the significant relationship is presented in Figure 3.3.

The nonsignificant bivariate relationships among breastfeeding durations and the outcomes of crawling onset and cognition are shown in Figures 3.4 and 3.5. As well,

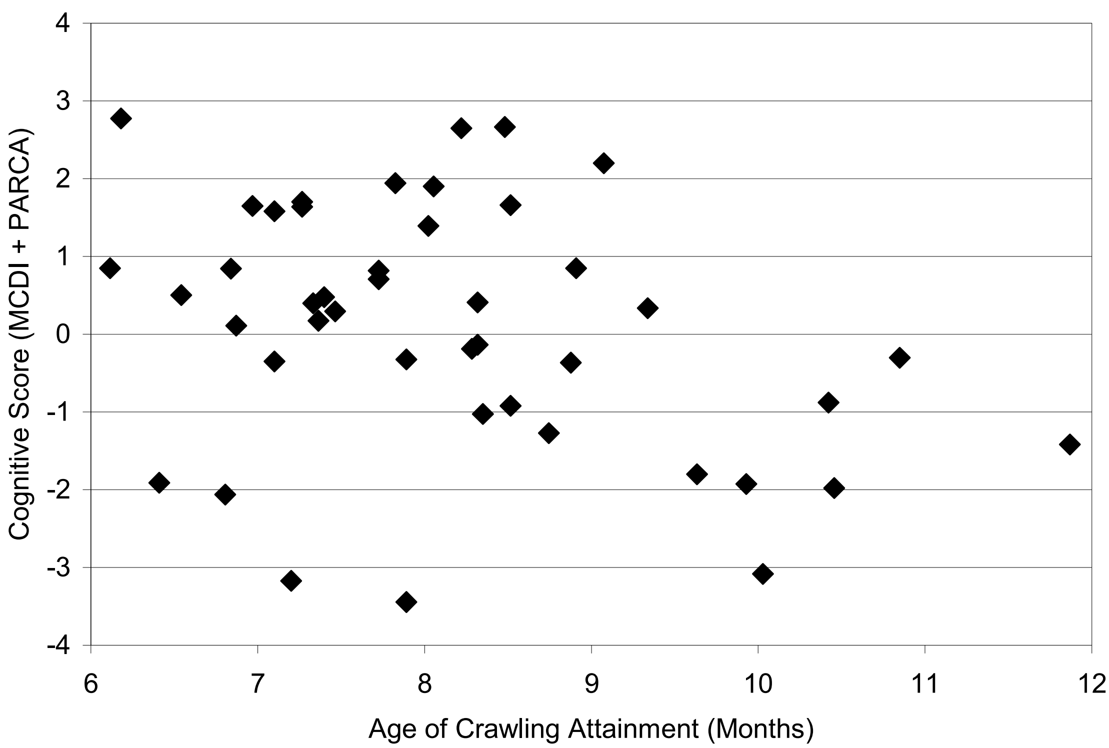
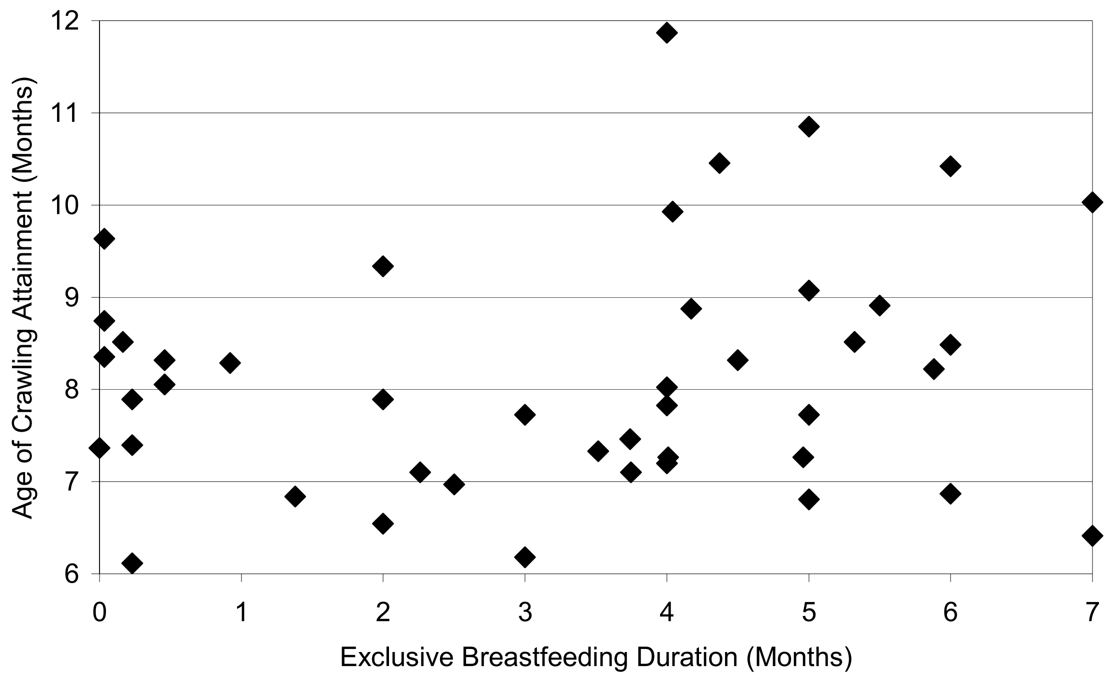


Figure 3.3. Significant relationship between crawling and cognition.



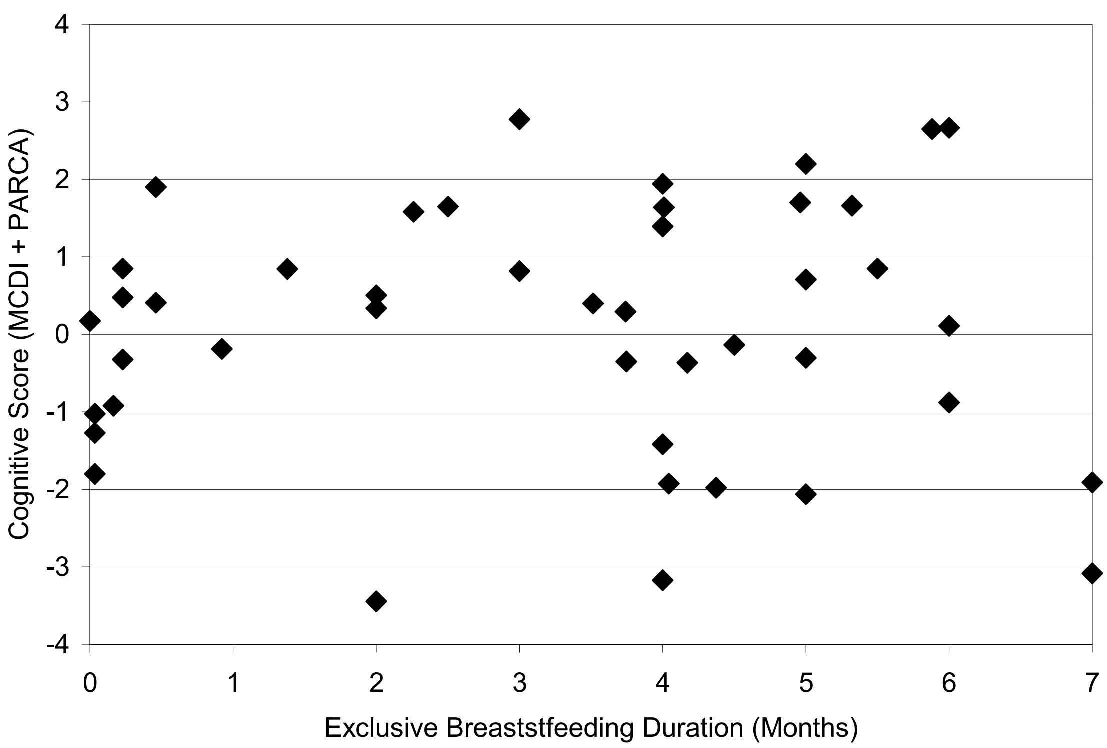


Figure 3.4. Nonsignificant relationship between exclusive breastfeeding duration and the outcomes of crawling attainment (top) and cognitive score (bottom).

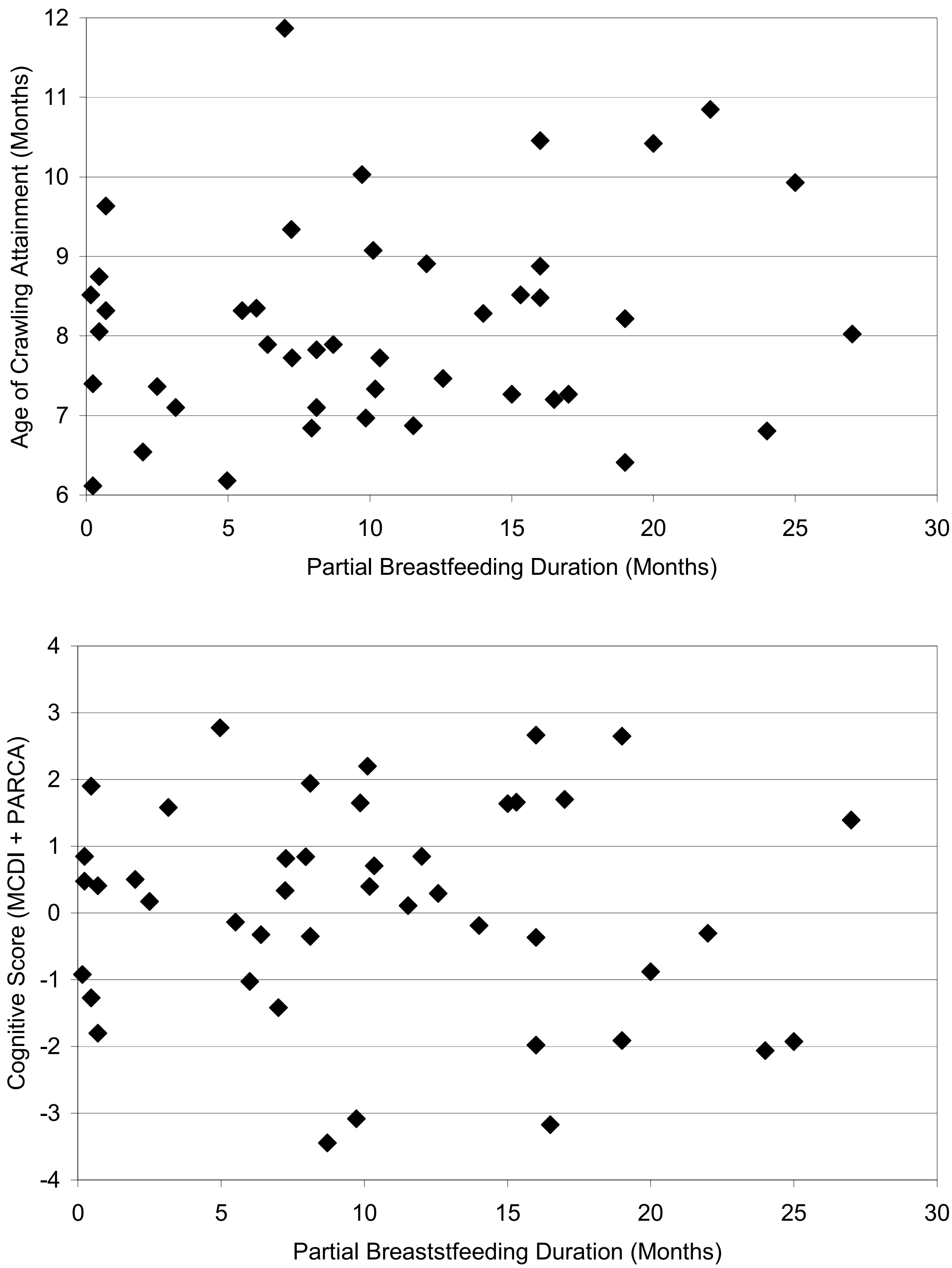


Figure 3.5. Nonsignificant relationship between partial breastfeeding duration and the outcomes of crawling attainment (top) and cognitive score (bottom).

because of the small sample size and potential for Type II error, potential trends by breastfeeding duration were further investigated and are shown in Table 3.6. Categories for breastfeeding duration used in this investigation were chosen based on studies in Table 1.2, and because those studies often did not differentiate between exclusive and partial breastfeeding, data are shown only for duration of partial breastfeeding. As seen in

Table 3.6

Mean Age at Crawling Onset and Mean Cognitive Score by Various Age Categories for Duration of Partial Breastfeeding

	Duration of Partial Breastfeeding		
	<4 months	4+ months	
n	10	34	
Crawling Mean	7.78	8.26	
Cognitive Mean	0.19	0.06	
	<3 months	3 to <6 months	6+ months
n	9	4	31
Crawling Mean	7.85	7.49	8.32
Cognitive Mean	0.03	0.80	0.01

Table 3.6 *(continued)*

	Duration of Partial Breastfeeding						
	<9 weeks	9 to <19 weeks	19 to <49 weeks	49+ weeks			
n	8	2	16	18			
Crawling Mean	7.92	7.23	8.15	8.35			
Cognitive Mean	0.02	0.88	0.12	0.01			
	<1 month	1 to <3 months	3 to <6 months	6 to <8 months	8 to <9 months	9+ months	
n	7	2	4	5	3	23	
Crawling Mean	8.11	6.95	7.49	8.73	7.61	8.32	
Cognitive Mean	-0.05	0.34	0.80	0.05	-0.62	0.09	
	<1 week	1-4 weeks	5-12 weeks	13-24 weeks	25-36 weeks	37-51 weeks	>51 weeks
n	3	4	2	3	8	7	17
Crawling Mean	7.34	8.69	6.95	7.20	8.37	7.98	8.43
Cognitive Mean	0.13	-0.19	0.34	1.41	0.10	-0.21	0.00

Table 3.6, no overall trends are apparent for either crawling age of attainment or cognitive scores at 2 years of age, and no trend tests were conducted.

Finally, to complete the mediational analysis, even though it appeared nonsignificant, step 4 was carried out. For step 4, the result of interest was the significance and size of the breastfeeding duration coefficient in the third regression (Table 3.5e, f, g) compared to the same coefficient from the first regression (Table 3.5a, b). If mediation had occurred, the coefficients in the third regression would have been smaller in absolute value than those in the first regression, suggesting that the relationship between breastfeeding duration and cognition was partially accounted for by the addition of crawling (Baron & Kenny, 1986; Kenny et al., 1998; Shrout & Bolger, 2002). However, as seen in Table 3.5, the exclusive breastfeeding duration coefficient from the third regression (Table 3.5e: $B = -.20$, $\beta = -.44$) was larger than the same coefficient in the first regression (Table 3.5a: $B = -.16$, $\beta = -.36$), and there was no change for the partial breastfeeding coefficient (Table 3.5e: $B = .06$, $\beta =.40$; Table 3.5a: $B = .06$, $\beta = .41$). Thus, the result for the exclusive breastfeeding duration coefficient was in the opposite direction than expected for mediation, likely due to a zero effect size and nonsignificant results; any difference in coefficients may have simply been due to random fluctuation. Further examination of the breastfeeding duration coefficients was not possible because differing variables were selected for removal in the backward stepwise regressions in the first and third analyses.

Thus, in overall summary of the mediational analysis, there was no support for the hypotheses of breastfeeding duration affecting either crawling onset or cognition at 2 years, but crawling onset did show a significant small-to-medium effect on cognition. Separate analyses were performed to assess the relations between breastfeeding duration, crawling onset and (a) verbal abilities as measured by the MCDI standardized score and (b) nonverbal abilities as measured by the PARCA standardized score. The results for the MCDI were substantially the same as for the overall cognitive score, but no significant results were found for the PARCA (results not shown).

Chapter 4: Discussion

The purpose of the present study was to assess a mediational relationship between breastfeeding duration, crawling onset, and cognitive development at 2 years of age. The simple conclusion of the study is that the mediation was not supported with the present sample of well-nourished, healthy Canadian infants. However, the triadic model shown in Figure 1.3 may be supported in other samples, such as infants at risk for poor developmental outcomes (Pollitt et al., 2000; Whaley et al., 1998). Although the overall mediation was not supported, each of the bivariate relationships was assessed via regression, and evidence for a significant relationship between crawling onset and cognition was found. These significant results are explored further in the next section, followed by a discussion of the inconclusive results for the breastfeeding duration analyses, the limitations of the study, what this study contributes to developmental psychology, and finally, general conclusions.

4.1 Crawling Onset and Cognitive Development

A significant relationship between crawling onset and cognitive development was expected based on reasons presented in *Section 1.6 Crawling and Cognitive Development: A Connection*. To briefly reiterate, past research has shown that infants with more crawling experience followed gazes and pointing gestures (Chen et al., 1991; as cited in Campos et al., 1997; Kermoian et al., 1992; as cited in Campos et al., 1997), responded to movement in their peripheral fields of vision (Bertenthal & Bai, 1989;

Higgins et al., 1996), and performed correct spatial searches after they were moved (Bai & Bertenthal, 1992) more often than infants with less crawling experience. In contrast to these studies that assessed crawling's relationship to specific skills and abilities near the time of crawling onset, the current study assessed crawling's link to an index of overall cognitive ability at 2 years of age. This difference in timing of the tests meant that previous research was able to test "crawlers" and "noncrawlers" (i.e., age was held constant and locomotor status varied), but the current study included infants who had all been "crawlers" prior to the cognitive tests (i.e., crawling was held constant and age varied). Thus, transfer of the earlier findings to the current study was not certain, especially when faced with contradictory opinions such as Bertenthal et al. (1984) who concluded that the "effects of locomotion on early development are widespread" (p. 200) and Bai and Bertenthal (1992) who wrote: "It is thus clear that the effects of locomotor experience on infants' performance are quite specific, and we must therefore apply considerable caution in generalizing results from one task to another" (p. 225). Further doubt was added due to the nonsignificant results of Darrah et al. (2003) and Bazylewski (2003), who tested older infants. Nonetheless, those two studies had limitations on which the current study improved, and the hypothesis that earlier crawling attainment would lead to higher cognitive scores at 2 years of age was supported with a significant small-to-medium effect size.

These significant results bolster and extend certain aspects of the findings of Pollitt et al. (2000) and Whaley et al. (1998). In Pollitt et al.'s (2000) longitudinal test of the model presented in Figure 1.2, the fit of the model improved considerably after the model was adjusted to include a direct path from motor development to mental development scores; Whaley et al. (1998) found that motor development at 6 months of age was significantly correlated with mental outcomes at 30 months. The present study extended these results because while these two studies focused on undernourished children in Indonesia and Kenya, respectively, the present study examined predominantly middle-class infants in Canada. Further, while Pollitt et al. (2000) and Whaley et al. (1998) used the BSID (Bayley, 1969) to measure mental and motor development in the first two years of life, the current study measured onset of a specific motor milestone and specific language and nonverbal cognitive abilities.

The similar findings for a relationship between motor and mental development using different populations and distinct operational definitions strengthen the conclusion that a link exists between these two developmental domains. However, it is important to note a key difference among the three studies. For undernourished children, nutrition was related to both motor and cognitive outcomes (Pollitt et al., 2000; Whaley et al., 1998), but for the well-nourished children in the current study, no effect for the nutritional variable of breastfeeding duration was found. In Pollitt et al.'s (2000) study, the motor development of the undernourished children in Indonesia varied due to receipt of one of three dietary supplements. For example, by the time the 12-month-old cohort was 18 months of age, all of the children who received a high energy and micronutrient supplement were walking and running, almost two-thirds of those receiving a low energy and micronutrient supplement were doing so, and half of the children in the low energy and placebo supplement group had attained these milestones (Jahari, Saco-Pollitt, Husaini, & Pollitt, 2000). This range of development suggests that the dietary supplements had a large impact on the development of these children, likely affecting both motor and cognitive outcomes. In contrast, all children in the current sample probably received adequate amounts of energy and micronutrients. Because of these differences in nutrition and the consequential effects on development, it is possible that different mechanisms operate between motor and cognitive development for undernourished compared to well-nourished children. As mentioned in Chapter 1, undernourished children may suffer from iron deficiency anemia, which has deleterious effects on development. Improving the nutrition of these children may treat the iron deficiency, thereby improving motor and cognitive development. Because the current study showed that a relation between motor and cognitive development exists for well-nourished children as well, suggests that mechanisms unrelated to nutrition may act between these domains.

The current research cannot directly address potential mechanisms, but this section explores some possibilities. First, it is possible that the experience of crawling allows enriched interactions with the environment that may lead to, among other things, proliferation of neural synapses. In fact, Bell and Fox (1996) have shown that the onset of crawling correlates with significant changes in neural connections, such that 8-month-old novice crawlers have more neural density than prelocomotor infants. This neural density is then reduced as crawling experience increases to 9 or more weeks, which suggests a possible pruning of synapses, leaving “a more efficient pattern of interconnectivity between cortical areas” (Bell & Fox, 1996, p. 559). If the neural changes of early crawlers differ from those of later crawlers, then that may suggest a pathway by which early crawling leads to higher cognitive scores. A second possibility is reverse causation, that is, that the advanced cognitive skills of some babies drive them to attain crawling sooner so that their curiosity about the world around them can be satisfied. This argument is supported by the results of studies from blind babies. Most blind babies are delayed in their crawling attainment, but not in attainment of stationary milestones such as standing (Bigelow, 1992; Adelson & Fraiberg, 1974). Researchers suggest that the visual enticement to crawling is not present for blind infants as it is with sighted infants, and further, that cognitive achievements such as object permanence may be prerequisites for crawling motivation (Bigelow, 1992; Tröster & Brambring, 1993). Object permanence is more difficult for blind infants to achieve because they must understand that an object exists when they are not touching it, whereas sighted infants use information from their visual senses when learning about object permanence.

Finally, it is likely that the relationship is not a one-way street, but rather that the domains of cognitive and motor development interact and advance each other in an iterative fashion. Further, it is likely that there are variables that affect both crawling and cognition. One such variable, namely breastfeeding duration, was explored in the current study, and the next section discusses the inconclusive results found for this variable.

4.2 Breastfeeding Duration: Inconclusive Evidence

In contrast to the significant results found between crawling onset and cognitive development, nonsignificant results were found for breastfeeding duration in relation to these variables. These nonsignificant results must be interpreted as *inconclusive* based on the low power achieved in the current study. A medium-to-large effect size was expected based on the results of other studies using continuous breastfeeding duration variables. For example, Bauer et al. (1991) found a medium-to-large effect size in a sample of 50 toddlers; however, the results of the current study showed a zero-to-small effect size, which meant that while a power of .80 was originally targeted, a power of less than .10 was actually obtained (Cohen, 1988, p. 416). Thus, this study was unable to adequately test the breastfeeding duration hypotheses, and the results obtained are best described as ambiguous (Cohen, 1988).

Although the results are inconclusive, this study can still provide information for future studies of these hypotheses. First, the current study may provide further evidence that the relationship between breastfeeding duration and cognition may not be due to results for term infants but rather to the results for preterm, low birth weight, and small-for-gestational-age infants (Golding et al., 1997; Rey, 2003; Reynolds, 2001). The current study specifically excluded these infants because the IMS sample which served as the base of the current sample did not contain many of these small babies. However, a study using a methodology similar to that of the current study may be able to find an effect in a sample of these infants.

Second, the significant findings in the literature for the relationship between breastfeeding and cognitive development may be due to differences between FF and BF infants. The current study had planned to include FF infants, but given that very few infants in Manitoba are completely FF and that the characteristics in the current sample suggested that the mothers would be likely to breastfeed their infants, no FF infants were successfully followed to 2 years of age. In contrast, most studies reviewed in Chapter 1 did contain a group of FF infants (see Table 1.2), and some studies were able to find significant differences between the FF and BF infants. Thus, it is possible that one of the driving forces behind the significant results in the literature is not the better scores of infants BF for longer times, but rather the poorer scores of infants not BF at all. However, an additional consideration is that the differences between BF and FF infants may decrease over time. For example, Morrow-Tlucak et al. (1988), who followed infants longitudinally, found decreasing effect sizes as the infants got older: 12% of the variance was explainable by feeding status at 1 year of age, but only 6% was at 2 years. Rogan and Gladen (1993) also found smaller effect sizes at 3 compared to 2 years, but they used different cognitive tests at each age so the results may not be directly comparable.

A third lesson from the current study is that breastfeeding duration remains a hard-to-quantify behaviour. "Perhaps if more emphasis were placed on total feeding experience, rather than on the mechanical duration of breastfeeding, more comprehensible relationships would be found" (Newton, 1971, p. 1001). Likewise, it may be important to put more emphasis on the nutritional content of the breast milk rather than on duration (e.g., Whaley et al., 1998). It may be that breastfeeding duration defined as it was in the current study led to a dilution of the effect (H. Weiler, personal communication, August 12, 2004). That is, longer durations of breastfeeding may not have contributed much to the enhancement of the children's abilities beyond the benefits gained in the first year. This view is supported by the results of Johnson et al. (1996), who showed that “as the duration of breast feeding increases, the magnitude of the relation decreases…, after 18 months or so of breast feeding, further increases in duration have little additional relation” (p. 1184). Indeed, given that infants in the current study were partially BF up to a maximum of 27 months of age, which was considerably longer than average compared to provincial statistics (Martens et al., 2002), this dilution of effect may have contributed to the nonsignificant and further, inconclusive, results. Finally, it may be that the effect of breastfeeding duration is far more complex than any research has been able to assess thus far: “there may be geographical regions, historical times and specific subgroups of mothers, parents and children where the [effect of breastfeeding duration] could be different” (Burgard, 2003, p. 9).

Thus, given the inconclusive results of the current research, studies that are more powerful are required to answer more definitely the question of whether breastfeeding duration has an effect on cognitive and motor development. Future studies should build on the results presented here by (a) including preterm, low birth weight, or small-for-gestational-age infants; (b) including FF infants; and (c) operationalizing breastfeeding duration in a way that incorporates its nutritional components or the “total feeding experience” (Newton, 1971, p. 1001). The next section suggests further ways that future studies could be improved as it explores the limitations of the current study.

4.3 Limitations

This study was not without limitations. First, because this study was drawn from a sample of mothers willing to participate in longitudinal, university-based research, and further, because some of these mothers were recruited through friends and relatives already in the study, the final sample may have been relatively homogeneous. Such homogeneity may have reduced the variability in the sample; however, as seen in Figures 3.1, 3.2 and Table 3.3, the scores obtained for the key infant variables did cover an appropriate range. Nonetheless, because this was a volunteer sample, the conclusions drawn from this study may not generalize to the larger population of infants in Manitoba or elsewhere. Caution must be used in interpreting these results, and further studies should attempt to replicate and extend the current findings. Of note, however, is the fact that the results found here for motor and cognitive development did support similar results for infants and toddlers in developing countries (Pollitt et al., 2000; Whaley et al., 1998).

Infants in the current sample may be different from infants who originally enrolled in the study but did not have complete data. Approximately half of the original 171 infants who enrolled in the IMS had incomplete data for the variable of crawling attainment. This was due to several factors. First, early on in the IMS we used two different checklists, one that ended when the infant was able to sit unsupported for 30 sec, and one that ended when the infant could crawl. Not all mothers who completed the sit checklist continued to a crawl checklist. Thus, crawling data would be missing for these infants. Second, some participants who had data around the age of crawling onset did not provide data for the specific week of crawling attainment for which we were interested. These infants would also have missing crawling data. Finally, some infants likely did not crawl, but proceeded developmentally to walking at the appropriate age

(Adolph, 1997; Adolph et al., 1998; Dewey et al., 2001). The limited data available for these infants with missing crawling data, along with the 11 preterm or low birth weight infants were not compared to the data of the current sample. However, data for the infants who had complete crawling data and were selected for follow-up, but not followed, showed no significant differences from the current sample.

Infants were lost to follow-up for various reasons. Mothers of 2-year-old children are no doubt very busy. Unlike the mothers of infants under 1 year, mothers of older children may have gone back to work or may be caring for a new baby. Thus, these mothers did not always complete the cognitive measures or the breastfeeding questionnaires that filled in missing data from the checklists. Further, we adopted the policy of typically only phoning the mothers once to remind them to return the items because we did not want to be a nuisance to these mothers. Thus, follow-up was not as successful as it could have been had we been more persistent.

This loss to follow-up resulted in a relatively small sample size compared to the studies reviewed in Chapter 1. This small sample size was responsible for the inability to test adequately the small effect breastfeeding duration had on crawling onset, and may have contributed to the finding of zero effect of breastfeeding duration on cognition. To appropriately test the small effect breastfeeding duration had on crawling onset using the current methodology would have required a sample size of over 500 infants (Cohen, 1988; Green, 1991). However, the small sample size that was obtained was adequate to find a significant small-to-medium effect for the relationship between crawling onset and cognition.

As mentioned earlier in the limitations, the current study ignored infants who may not have attained crawling during their development. This exclusion means that this study provides no evidence that crawling per se has an impact on cognitive outcomes. Rather, this study supports the possibility that for infants who do attain crawling, earlier attainment is related to improved cognitive outcomes; nothing can be learned from this study regarding infants who do not crawl. Similarly, if a significant relationship had been supported between breastfeeding duration and crawling or cognition, a conclusion that breastfeeding itself contributed to the results would not have been possible, because the study excluded completely FF infants. Thus, just as a recommendation in the previous section stated that future studies should include FF infants, future studies should also include infants who do not attain crawling.

A final limitation of the study was the potential bias introduced through collecting data from only one source: the parents of the infant participants. However, the risk of bias was counteracted by the fact that parents are in the best position to observe their infants' development. The advantages of parent report are covered briefly in the next section.

4.4 Parent Report

Parents know their children very well and have an extremely large sample of behaviour to choose from when drawing general conclusions about their children's abilities and behaviours. Further, parent reports are a simple, low-cost method of collecting data on infants and children. In contrast, the brief observational samples obtained by home visitors or laboratory assessors can be expensive in terms of time and resources. These brief encounters can have low reliability or be unrepresentative, which can offset the objectivity of such a methodology (Epstein, 1980, 1986; Hagekull, Bohlin, & Lindhagen, 1984).

Even though parents have the advantage of huge amounts of observational time, the scientific quality of their reports has been questioned for several decades and for several reasons (Wallace, Franklin, & Keegan, 1994). Some critics argue that parents simply cannot be objective in the observation of their own infants. An additional concern is that parents' purposeful observation will cause them to report behaviors that are not actually present. However, as Reznick and Schwartz (2001) found, this is more likely with phenomena where parents' interpretation of the infants' behavior is important. For example, motor development is rather easily observed and thus less likely to be misinterpreted than changes in less overt domains of development. Another potential shortcoming of parent reports is that parent memory of their infants' development and milestones may be inaccurate (Hart, Bax, & Jenkins, 1978). This problem can be ameliorated by asking the parents to concurrently record details of their infants' development (Knobloch, Stevens, Malone, Ellison, & Risemberg, 1979).

The parent reports obtained in the present study complied with several "best practice" rules for parent report (Hagekull et al., 1984; Squires, Nickel, & Eisert, 1996; Squires & Bricker, 1991; Stiles, 1994). First, all measures focused on specific, concrete behaviours of the children. For example, the checklists directed the parents' attention to specific behaviors, the MCDI asked for specific words that the toddler had spoken, and the PARCA asked the parents about specific activities they had seen their children perform. Second, all measures except the retrospective breastfeeding questionnaire asked parents to report on the current behaviours and activities of their infants and toddlers. Finally, the parent-based measures used in this study were all validated against external sources of information. The parent checklists developed as part of the IMS were validated against home visitor assessments for the motor milestone items (Bodnarchuk & Eaton, 2004a, 2004b), the breastfeeding duration data were obtained from two sources and compared to provincial statistics (Bodnarchuk et al., 2005; Martens et al., 2002), and the cognitive measures used in the present study, the MCDI and the PARCA, were validated by Fenson et al. (1993) and Saudino et al. (1998), respectively. Thus, the parent reports used in the current study were valid, and based on multiple comments and responses, the completion of these measures was enjoyable for the participants as well.

4.5 The Dynamic System of the Developing Infant

As this document nears conclusion, it is important to briefly consider what this study might contribute to the field of developmental psychology. Most notably, it contributes to the dynamic systems view that domains of infant development should be considered in unison and not as separate components (e.g., Gottlieb, Wahlsten, & Lickliter, 1998; Thelen, 1989; Thelen & Smith, 1994). For example, motor and mental development are often considered as two separate tracks in an infant's life, but the current study and others (e.g., Campos et al., 2000; Pollitt et al., 2000; Whaley et al., 1998) show that the developmental research community should consider influences of one when studying the other. Some proponents of dynamic systems theory even see motor development as a kind of guide or template to emphasize the connections among domains in the system of the developing infant:

> Movement is the "final common pathway" for many sub-systems working together to accomplish a task or goal. For a child to move, perception, motivation, plans, physiological status, and affect must all interact with a mechanical system that is composed of muscles, bones, and joints. Although we may not choose to study all these contributing elements at the same time, it is conceptually impossible (and empirically foolish) to encapsulate the movement outcome from the motives that inspired it, the information that guided it, and the body parts that produced it. (Thelen, 1989, p. 946)

From this view, even the current study that included three domains of infant development fell short of the true research goal for understanding such development.

Once research more consistently includes multiple domains of development within one study, the field of developmental psychology may move forward as it disentangles the reasons for the interrelatedness among domains. For example, it may be argued that an overarching control parameter sets the speed, timing, and course of development for an infant, which results in the infant both crawling sooner and gaining cognitive skills more quickly. However, the counter-argument, which is supported by studies explored in Chapter 1, is that once the infant is able to crawl, that ability sets in motion later changes that result in better cognitive abilities, such that earlier crawling leads to higher cognitive scores at a given age. The current study was not able to clearly support one argument over the other, but future studies that explore intervening or mediating variables between crawling and cognitive outcomes may be able to do so.

Another recent and recurring theme in the developmental literature that may be guided by dynamic systems theory is the importance of *variability* in infant development as opposed to *average* infant development (Courage & Howe, 2002; Thelen, 1989; Thelen & Smith, 1994). Indeed, variability was exemplified in the current study in all key variables: partial breastfeeding showed a wide variation, from 1 day to 27 months (see Figure 3.1); crawling spanned the range from 6 to 12 months (see Figure 3.2); and cognitive scores covered large amounts of the available ranges (see Table 3.3). This variability, coupled with the notion that the system of the developing infant is not isolated, but interacts with and depends on the environmental context to guide moment-to-moment change (Thelen & Smith, 1994), suggests how complex and difficult it is to find general themes in development. For example, it may be that the relationship between breastfeeding duration and cognition is more complex and variable than the relationship between crawling onset and cognition, which may help to explain the inconclusive results of the present study: there simply may not be a "typical" pattern for how breastfeeding duration affects cognition.

Thus, in conclusion, the current research agrees with Courage and Howe (2002), who suggest that the focus of research should shift, and is shifting, "from the task of searching for stability and order in unidimensional structures to that of finding patterns of stability and order in the enormous variability both within and across domains of human behavior" (p. 252).

4.6 General Conclusions

The present research explored three domains of infant development that are rarely studied in concert. In doing so, the goal was to contribute to the collection of recent studies that are acknowledging the highly interconnected web of infant and child development. Studying this web is not easy and requires a broad range of knowledge. For example, the cognitive abilities that children possess may be influenced by their feeding status and their motor experience, as well as an immeasurable number of other determinants. Development is an amazing creature in itself and we as a research community must be willing to accept the challenge of considering children as whole beings and not simply as component parts that act in isolation. The current study and others that consider multiple aspects of children’s lives help us to accelerate the journey toward an improved understanding of child development.

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Appendix A-1

Effect size (ES) formulas and conventional levels.

ES Index	Formula(s)	Conventional Levels		
		Small	Medium	Large
f	$f = \frac{\sigma_m}{\sigma}$ where $\sigma_m = \sqrt{\frac{\sum_{i=1}^{k}(m_i - m)^2}{k}}$ where $m = \frac{\sum n_i m_i}{N}$ (Cohen, 1988, p. 275, 359)	.10	.25	.40
f^2	$f^2 = \frac{R^2_{Y \cdot A,B} - R^2_{Y \cdot A}}{1 - R^2_{Y \cdot A,B}}$ where the effect of interest is specified separately, or $f^2 = \frac{R^2_{Y \cdot A,B}}{1 - R^2_{Y \cdot A,B}}$ when it is not. (Cohen, 1988, p. 410)	.02	.13	.35
r	r (Cohen, 1988, p. 77)	.10	.30	.50

Appendix A-2

Effect size (ES) formulas and conventional levels *(continued)*

ES Index	Formula(s)	Conventional Levels		
		Small	Medium	Large
h	$h = \| \varphi_1 - \varphi_2 \|$ where $\varphi = 2 \arcsin \sqrt{P}$ (Cohen, 1988, p. 181)	.20	.50	.80

Appendix B

Intake form used to record information from initial phone call from parent.

Intake Telephone Protocol ID # ____________

Infant Milestones Study, Dr. Warren Eaton and Ms. Jen Bodnarchuk, University of Manitoba

Date: ______________________________ Caller initials:_______
Family ID: _________

Thank you for calling our Infant Milestones Study, my name is ___, and I am the project coordinator. How did you find out about the study?____________________________. First I will tell you a little more about the project. If everything sounds good to you and you would like to participate, then I will need to get some information from you.

We are conducting the infant milestones study to determine if the age when infants reach certain milestones differs by season. If you decide to participate in this study we would send you some checklists. Each checklist has about 15 items and we want you to mark each day on the checklist that your baby does the certain things we are looking for. We would like you to fill out the checklists for several months. During that time we will be in regular contact with you to answer any questions you have. Also, at some time during your observations we may arrange a visit with you and your baby so that we can measure your baby's length, weight, and head size. We would like to make these measurements ourselves so that each baby is measured in the same way. During the visit we would also watch for baby postures similar to those on the checklist (they are part of the Alberta Infant Motor Scale). At the end of the study you will receive a diploma and a small gift.

Do you have any questions?
Are you interested in participating? **No** - OK, that's fine. Thank you very much.
Yes - OK, now I would like to get some information from you.

Basic Contact Information

Who would be doing most of the observing or watching of the baby and filling in the checklists?

Observer's name: ____
Relationship to baby: ___biological mother ___biological father ___other
If "**other**", what is relationship to baby:______________________________

Telephone: Home _______________ Answering machine? Yes No
If no answering machine, other number: ________________
E-mail (optional):____
Mailing address:

Baby: Name:____
Gender: ___male ___female
Birthdate: Year________Month_________Day________
Birth **due date**: Year________Month_________Day________
Biological mom's birth month and year:____________________

Thank you for that information. We will be sending you a packet in the mail that has a copies of the checklists and a consent form for you to sign. We look forward to you and your baby's participation!

Appendix C-1

Consent form - front.

UNIVERSITY OF MANITOBA

Dr. Warren O. Eaton | Department of Psychology | Winnipeg, Manitoba
Canada R3T 2N2

Sign this copy and return to us in postage paid envelope.

Dear Parent,

Thank you for your interest in our research project. As you know from an earlier telephone conversation with Wendy, our project coordinator, we are asking parents of young babies to help us understand how infants change. This letter repeats what you were told on the phone and asks for your written agreement to participate. If after reading the form you wish to participate, please sign and return one copy of this form to us in the postage-paid envelope.

Yours truly,

Warren O. Eaton, Ph.D. Jennifer Bodnarchuk, M.A.

Information about the Infant Milestone Study

Why are we doing this research? New parents know how exciting it is to watch a baby grow and change. We, too, are interested in these changes, and we are studying the possibility that the season of a baby's birth (spring, summer, winter, or fall) has an influence on this process. We need the help of many parents who would be willing to keep records of their infant's progress with a standard checklist.

What would I do? You would be asked questions about your household, your health, and your baby's pregnancy and delivery. You would also be asked to watch for the baby behaviours listed on the enclosed checklist. At the end of each day for the next few months, you would mark whether or not you saw your baby do each behaviour on the list. You could miss an occasional day, and would continue with recording the next day. Once each checklist is complete, you would mail it to us in a postage-paid envelope. When you see your baby do a checklist item marked with a double asterisk (**), you would be asked call Wendy, who might ask if she could make a 30-minute visit to your home. During that visit, she would measure your infant's length, weight, and head size. She would also watch for baby postures similar to those on the checklist (they are part of the Alberta Infant Motor Scale). Of course, you could choose not to have her visit.

Are there any risks for my baby or me? No. Your baby's life would not be altered, and you would do nothing more than observe and record. The home visitor would observe, weigh and measure your baby in the same way that your family doctor would.

Are there any benefits for my baby or me? Yes. When the project is complete, we'll return your checklists along with a diploma and a small gift for your baby as souvenirs. You will probably notice more about the ways in which your baby changes, which is interesting. You will also receive a general

E-mail: Warren_Eaton@Umanitoba.ca Telephone: 204 474-9933 Fax: 204 474-7599

Appendix C-2

Consent form - back.

summary of what we learned from the study. Finally, you would help us learn more about how babies grow and whether season of birth has a role in development.

Who will know about our participation? Only Dr. Eaton, Ms. Bodnarchuk, and research coordinators will know about your participation or about your baby's behaviour. All information about you will be kept in locked locations. We will prepare scientific reports about the study, but nothing in those reports would allow someone to identify you or your infant.

If I start the study, can I quit? Yes. Your participation and your infant's participation in the research study is entirely voluntary. You may withdraw from the study at any time, for any reason, and without any consequences.

Has anyone reviewed this study for acceptability? Yes. This study has been approved by the University of Manitoba's Psychology/Sociology Research Ethics Board. If you have a complaint about the project, you should contact the University's Human Ethics Secretariat at 474-7122.

What if I have other questions? Call Wendy at 474-9933 or Warren Eaton at 474-9739.

OK, I want to participate. What do I do now? Read and sign one copy of this form (the other copy is for you to keep) and mail it in one of the postage-paid envelopes.

Infant Milestone Study Consent Form

By signing this consent form, I confirm that I have read the above information and understand that:

- my participation is entirely voluntary;
- I can withdraw myself and my baby from the study at any time and for any reason;
- I will be asked questions about my household, the pregnancy, and my baby's delivery;
- I will complete an observational checklist daily for several months;
- my baby may be measured for length, weight, and head size; and
- information about myself and my baby will be kept confidential and in locked locations.

In addition,

- I have been given a copy of this form;
- I know to contact the Human Ethics Secretariat at 474-7122 with any complaints; and
- I can contact Wendy at 474-9933 or Warren Eaton at 474-9739 if I have any other questions.

Baby's name: ______________________________

Parent's name (please print): ______________________________

Parent signature: ______________________________

Date: ______________________________

Appendix D

Example of the “Baby of Science” diploma mailed to completed participants.

The

University of Manitoba

on the recommendation of the Board of Trustees of the
Infant Milestones Study
has conferred on

Baby Name

who has completed all the requirements therefore
the Degree of

Baby of Science

with all the rights and privileges thereunto appertaining.
Given on this eighth of April, two thousand and four.

Appendix E-1

Health and Demographics Questionnaire - p. 1

Health and Demographics Questionnaire for the Infant Milestones Study

Dr. Warren Eaton and Ms. Jen Bodnarchuk, University of Manitoba

Please take a few minutes to answer the following questions and return this questionnaire to us along with the consent form in one of the postage paid envelopes that is provided.

At anytime if you feel uncomfortable with a question you may skip that question and go on to the next one. If you prefer to answer the questions over the phone, you may call Wendy, the project coordinator, at 474-9933 for assistance. Thank you.

Family ID: Date: ___________________

Parent Name: ____

Baby Name: ____

1. Do other children currently live in your household?
   ___ 1. Yes ___2. No - Go to question #3

2. What are their ages?
   Child 1 is ____ years Child 3 is ____ years
   Child 2 is ____ years Child 4 is ____ years

3. During the pregnancy with Corbin did you suffer from any of the following:
   pregnancy diabetes? ___ yes ___ no ___ don't know
   high blood pressure? ___ yes ___ no ___ don't know
   other physical problems? ___ yes ___ no ___ don't know
   Explain:____
   ____
   ____
   ____

4. From whom did you receive pre-natal care?
   ___ a Doctor ___ a Nurse ___ a Midwife ___ Other ___ Nobody

5. Did you smoke during your pregnancy with Corbin?
   ___1. Yes ___2. No - Go to question #8

6. How many cigarettes per day did you smoke during your pregnancy with Corbin?
   _____ Number of cigarettes

7. At what stage in your pregnancy did you smoke this amount? (Mark all that apply.)
   ___1. During the first trimester. ___3. During the third trimester.
   ___2. During the second trimester. ___4. Throughout.

Appendix E-2

Health and Demographics Questionnaire - p. 2

8. Did you consume alcohol during your pregnancy with Corbin (for example, Beer, wine, liquor)?
___1. never - Go to question #11
___2. less than once a month
___3. 1-3 times a month
___4. once a week
___5. 2-3 times a week
___6. 4-6 times a week
___7. everyday

9. On the days when you drank, how many drinks did you usually have?
___1. 1 to 2
___2. 3 to 4
___3. 5 or more
___4. don't know

10. At what stage in you pregnancy did you consume this quantity? (Mark all that apply.)
___1. during the first trimester.
___2. during the second trimester.
___3. during the third trimester
___4. throughout
___5. don't know

11. Were you required to take any prescription medications during your pregnancy with Corbin?
___1. Yes
___2. No - Go to question #13
___3. Don't know - Go to question #13

12. At what stage in your pregnancy did you take these? (Mark all that apply)
___1. During the first trimester.
___2. During the second trimester.
___3. During the third trimester.
___4. throughout
___5. Don't know

13. Did you take any over-the-counter drugs including Tylenol, Tums etc., during your pregnancy with Corbin?
___1. Yes
___2. No - Go to question #15
___3. Don't know - Go to question #15

14. At what stage in your pregnancy did you take these? (Mark all that apply)
___1. During the first trimester.
___2. During the second trimester.
___3. During the third trimester.
___4. Throughout
___5. Don't know

The following are questions concerning Corbin's birth.

15. Was he/she born before or after the due date?
___1. Before
___2. After
___3. On due date - Go to question #17

Appendix E-3

Health and Demographics Questionnaire - p. 3

16. How many days or weeks before or after the due date was he/she born?
____ days (or) ________ weeks

17. What was his/her birth weight in pounds and ounces or kilograms and grams?
_____ lbs. _______ oz. (or) _____ Kg. _______ g.

18. What was his/her length at birth in inches or centimeters?
____ inches (or) ______ cms.

19. Was this a single birth or twins, or triplets?
___1. Single birth
___2. Twins
___3. Triplets
___4. More than triplets

20. Was the delivery vaginal or caesarian?
___1. Vaginal
___2. Caesarian – Go to question #23

21. Was Corbin born head first?
___1. Yes
___2. No
___3. Don't know

22. Were birthing aids used?
___1. None
___2. Forceps
___3. Cupping glass (suction cup)
___4. Don't know

23. Did Corbin receive special medical care following his/her birth?
___1. Yes
___2. No - Go to question #26
___3. Don't know - Go to question #26

24. What type of special medical care was received? (Mark all that apply)
___ Intensive care
___ Transfer to a specialized hospital
___ Don't know – Go to question #26
___ Ventilation/oxygen
___ Other – Explain: ______________
____

25. For how many days, in total, was this care received?
_______days

26. Compared to other babies in general, would you say that Corbin's health at birth was:
___1. Excellent?
___2. Very good?
___3. Good?
___4. Fair?
___5. Poor?
___6. Don't know

Appendix E-4

Health and Demographics Questionnaire - p. 4

27. Were you hospitalized for special medical care for any period immediately following the birth of Corbin?
___1. Yes ___2. No – Go to question #29
Explain:____
____

28. For how many days? ______ days

The following are some general background questions.

29. In what country were you born?
___ 01 Canada
___ 02 China
___ 03 France
___ 04 Germany
___ 05 Greece
___ 06 Guyana
___ 07 Hong Kong
___ 08 Hungary
___ 09 India
___ 10 Italy
___ 11 Jamaica
___ 12 Netherlands
___ 13 Philippines
___ 14 Poland
___ 15 Portugal
___ 16 United Kingdom
___ 17 United States
___ 18 Viet Nam
___ 19 Other: _________

30. To which ethnic or cultural group(s) did your ancestors belong? (For example: French, British, Chinese) (Mark all that apply.)
___ 01 Black
___ 02 Canadian
___ 03 Chinese
___ 04 Dutch (Netherlands)
___ 05 English
___ 06 French
___ 07 German
___ 08 Inuit/Eskimo
___ 09 Irish
___ 10 Italian
___ 11 Jewish
___ 12 Métis
___ 13 N. American Indian
___ 14 Polish
___ 15 Portuguese
___ 16 Scottish
___ 17 South Asian
___ 18 Ukrainian
___ 19 Other _________

31. In what language(s) can you conduct a conversation? (Mark all that apply.)
___ 01 English
___ 02 French
___ 03 Arabic
___ 04 Chinese
___ 05 Cree
___ 06 German
___ 07 Greek
___ 08 Hungarian
___ 09 Italian
___ 10 Korean
___ 11 Persian (Farsi)
___ 12 Polish
___ 13 Portuguese
___ 14 Punjabi
___ 15 Spanish
___ 16 Tagalog (Filipino)
___ 17 Ukrainian
___ 18 Vietnamese
___ 19 Other______________

32. Excluding kindergarten, how many years of elementary and high school have you successfully completed? (Mark one only.)
___ 1-5 Years ___ 6 ___ 7 ___ 8 ___ 9 ___ 10 ___ 11 ___ 12 ___ 13
___ 0 No schooling - Go to question #38

33. Have you graduated from high school?
___ 1. Yes ___ 2. No

34. Have you ever attended any other kind of school such as a university, community college, business school, trade or vocational school, CEGEP or other post-secondary institution?
___ 1. Yes ___ 2. No - Go to question # 36

Appendix E-5

Health and Demographics Questionnaire - p. 5

35. What is the highest level of education that you have attained? (Mark one only.)
___ 1. Some Trade, Technical or Vocational School, or Business College
___ 2. Some Community College, CEGEP, or Nursing School
___ 3. Some University
___ 4. Diploma or certificate from trade, technical or vocational school, or business college
___ 5. Diploma or certificate from Community College, CEGEP or Nursing
___ 6. Bachelor or undergraduate degree, or teacher's college (eg. B.A., B.SC., LL.B.)
___ 7. Master's (eg. M.A., M. SC., M.ED.)
___ 8. Degree in medicine, dentistry, veterinary medicine or optometry (eg. M.D., D.D.S., D.M.D., D.V.M., O.D.)
___ 9. Earned doctorate (eg. PH.D., D.SC., D.ED.)
___ 0. Other specify____

36. Are you currently attending a school, college or university?
___ 1. Yes ____ 2. No - Go to question #38

37. Are you enrolled as a full-time or part-time student?
___ 1. Full-time ____ 2. Part-time

38. Are you currently working outside the home?
___ 1. Yes ____ 2. No – Go to question #41

39. Do you work full-time or part-time?
____ 1. Full-time ____ 2. Part-time

40. Who looks after your infant while you are at work?
___1. Spouse/Partner ___3. Family member
___2. Daycare ___4. Babysitter

41. Are you on maternity leave?
___ 1. Yes ____ 2. No

42. Can you estimate in which of the following groups your **household** income falls?

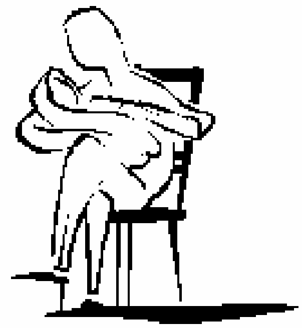
_____ 0 - $ 5,000	_____ $30,000 - $39,999
_____ $ 5,000 - $ 9,999	_____ $40,000 - $49,999
_____ $10,000 - $14,999	_____ $50,000 - $59,999
_____ $15,000 - $19,999	_____ $60,000 - $80,000
_____ $20,000 - $29,999	_____ $80,000 or more

Thank you very much; we look forward to you and your baby's participation.

Appendix F-1

Breastfeeding Questionnaire Instruction Letter

Milestones Study



Department of Psychology
University of Manitoba 204 474-9933
Winnipeg MB R3T 2N2 Fax: 204 474-7599

<Date>

Dear <Parent>,

We would like you to answer a few questions on your infant's early feeding. We want to thank you for the feeding information you already gave us on the checklists, but while reviewing the checklists we realized that some additional information on feeding would be useful to our study. We will use the information you provide along with information from all the other babies in the Milestones Study to look at how different feeding patterns might relate to infant development.

We have enclosed a survey that asks you a few short questions about feeding. Please answer the questions on the enclosed two-page survey as best you can and return it in the postage paid envelope. If you'd prefer, you can also call Wendy to tell her your answers.

Completion of the questionnaire shows us that you give your consent. All questions are entirely voluntary, and if you would like to only answer some of them, that is fine – we would still be interested in your responses. The questionnaire has been approved by the Psychology/Sociology Research Ethics Board of the University of Manitoba, and if you have concerns or complaints about the study, you may contact the Human Ethics Secretariat at 474-7122.

Thank you so much for your participation in the Milestones Study. If you have any questions regarding this survey or the study, please feel free to call Wendy at 474-9933.

Yours truly,

Warren Eaton, Ph.D. Jennifer Bodnarchuk, M.A.

Appendix F-2

Breastfeeding Questionnaire – front.

Baby First Name:
ID #:

Feeding Questionnaire
Milestones Study

The following are a few questions on infant feeding. For the questions regarding your baby's age, please be as specific as possible and indicate whether you are answering in "months" or "weeks" of age.

1. Was your baby breastfed even if only for a short time?

   ☐ (1) yes
   ☐ (2) no ~ **please skip to question # 4.**

2. How old was your baby when he or she first began to receive other foods at least 1 day a week? Other foods include anything other than breast milk and non-diluted vitamin supplements (supplements with no added water).

3. How old was your baby when he or she was last breastfed at least 1 day a week?

4. Was your baby fed formula even if only for a short time?

   ☐ (1) yes
   ☐ (2) no ~ **please skip to question # 8.**

5. What kind(s) of infant formula(s) was your baby fed?

6. How old was your baby when he or she ***first*** began to receive formula at least 1 day a week?

Appendix F-3

Breastfeeding Questionnaire – back.

7. How old was your baby when he or she was ***last*** fed formula at least 1 day a week?

8. Did your baby ever receive vitamin supplements?

☐ (1) yes
☐ (2) no ~ **please skip to question # 12.**

9. What supplement(s) did he or she receive (e.g., Tri-Vi-Sol)?

10. How old was your baby when he or she began to receive vitamin supplements at least 1 day a week?

11. How old was your baby when he or she was ***last*** given vitamin supplements at least 1 day a week?

12. Did the baby's mother take any vitamin or mineral supplements during the pregnancy?

☐ (1) yes
☐ (2) no ~ **please skip to the end.**

13. What vitamin or mineral supplement(s) did the mother take?

14. During what stage of the pregnancy did the mother begin taking the supplement(s)?

15. During what stage of the pregnancy or postnatal period did the mother stop taking the supplement(s)?

Appendix G-1

Instructions for MCDI and PARCA completion – front.

Infant Milestones Study

Department of Psychology
University of Manitoba 204 474-9933
Winnipeg MB R3T 2N2 Fax: 204 474-7599

<Date>

Dear <Parent>,

Thank you for participating in the newest part of the Infant Milestones Study: toddler development. Included in this package you will find two consent forms, one for you to keep and one for you to sign and send back to us. You will also find two surveys. We suggest that you read over the surveys a couple of days before you complete them. This way, you might be more aware of what we are looking for, such as the words your child is saying and what kinds of things your child does during play-time.

The first survey is a four-page booklet called the *MacArthur Communicative Development Inventory: Words and Sentences*. This booklet is used to measure the language development of children who are between the ages of 18 and 30 months. We are interested in knowing about <Baby>'s language at 24 months of age, so we would like you to complete the inventory as close to your child's second birthday as possible.

When completing the language survey, please make sure to use a pencil so that the computer will be able to read what you have filled out. First enter the date on the top of the form where your child's name, birth date, and gender is already filled out.

The first section asks that you go through the list and mark the words you have heard <Baby> use. Your child probably *understands* a lot of words, but we are only looking for a list of the words that your child *says*. Like the instructions say in the booklet, if <Baby> uses a different pronunciation for a word, you can mark it as a word produced.

The second part of the inventory asks questions regarding your child's use of sentences and grammar. There is another list of words for you to mark off if <Baby> uses them, including words that are spoken incorrectly. The incorrect use of these words is a sign of progress in your child's language development.

The last section of the inventory has to do with words that your child uses in combination, for example, "more cookie." In addition to asking you about word forms and endings, this section lists some pairs of phrases, and you are asked to choose the one that sounds most like what <Baby> would be most likely to say.

Appendix G-2

Instructions for MCDI and PARCA completion – back.

Exposure to another language can influence how quickly a toddler picks up English, so we've included a couple of questions about language experience on the consent form. As you'll see, we simply ask you to identify any non-English language that your toddler regularly hears and to estimate the amount of experience with that language.

If you have any additional comments about <Baby>'s language development specifically, or development in general, please write these on a separate piece of paper, and include this with the inventory in the postage-paid envelope.

The second survey is a 43-page booklet called the Parent Report of Children's Abilities. This booklet has several short sections. It does not have to be done all at one time, but we would like you to complete all the sections during the week around your child's second birthday. Please mark the date you complete each section on the top of each page.

The first five sections are interactive tasks for you to try with <Baby>: drawing, matching, block-building, folding paper, and follow-the-leader. For the block-building, we have provided 10 blocks for you to use. The blocks are a present for your child so you do not need to return them. Try to do the tasks when your child is cheerful and alert.
All of the tasks are simple and were designed for children 2 to 4 years old, so don't worry if <Baby> can't do all the tasks.

The next three sections of the survey are questions for you to answer about your child's behavior, language, and play-time activities. The last section asks for some information to update our files.

More instructions are provided in the booklet as you go through each section.

When you have completed both surveys, please mail them back to us, along with your signed consent form, in the enclosed envelope. We will return the surveys once we have made a copy for our research purposes.

If you have any questions regarding the surveys or the study, please feel free to call Wendy at 474-9933.

Yours truly,

Warren Eaton, Director
Infant Milestones Study

Appendix H-1

Consent form for MCDI and PARCA – front.

UNIVERSITY OF MANITOBA

Dr. Warren O. Eaton Department of Psychology Winnipeg, Manitoba
Canada R3T 2N2

Sign this copy and return to us in postage paid envelope.

Dear Parent,

Thank you for your continued interest in the Milestones project. As you know from an earlier telephone conversation, we are asking parents to complete two surveys: one of their toddler's language and another about their children's abilities, such as copying a simple drawing. These surveys will be used to see if your toddler's development at 2 years of age is related to the age when certain milestones like sitting and crawling were reached. This letter repeats what you were told on the phone and asks for your written agreement to participate. If you wish to participate after reading the following information, please sign and return one copy of this form to us along with the completed questionnaire in the postage-paid envelope.

Yours truly,

Warren O. Eaton, Ph.D.

Information about the Milestones Toddler Study

Why are we doing this research? We appreciate the time that you have already taken to complete the checklists for the original Milestones study. We are now extending the study to examine whether a child's development at 2 years of age is related to their rate of motor development. We are asking parents who have already filled out the checklists for their child's motor development to now fill out a survey about their child's language development and other abilities.

What would I do? We ask that you complete the surveys included in this package, regarding your child's language skills and other abilities. The language survey consists of a list of words divided into categories such as Animals, Food, Body Parts, and People. We are asking that you go through the survey and mark off the words that your child says. The other survey asks you about things your child can do and asks you to do simple tasks with your child. These tasks do not all have to be completed at the same time. Please try to do them when your child is cheerful and alert.

Are there any risks for my toddler or me? No. You are asked to do nothing more than record information about what you have heard you child say or seen your child do, and try simple, fun tasks with your child.

Are there any benefits for my toddler or me? Yes. First, it's interesting to document your child's language progress and to play these simple games with your child. Second, you will receive a general summary of what we have learned from the study. You will also help us continue to learn more about the nature of children's development.

E-mail: Warren_Eaton@Umanitoba.ca Telephone: 204 474-9933 Fax: 204 474-7599

Appendix H-2

Consent form for MCDI and PARCA – back.

Who will know about our participation? Only Dr. Eaton and research coordinators will know about your participation or about your child's language skills. All information that we have about you and your child will be kept in locked locations. We will prepare scientific reports about the study, but nothing in those reports would allow someone to identify you or your child.

If I start the study, can I quit? Yes. For this aspect of the study, we are asking that you fill out two surveys. If you do not want to fill out the whole survey or if you want to complete only one of the surveys, that is okay. Your participation and your infant's participation in the research study are entirely voluntary. You may withdraw from the study at any time, for any reason, and without any consequences.

Has anyone reviewed this study for acceptability? Yes. This study has been approved by the University of Manitoba's Psychology/Sociology Research Ethics Board. If you have a complaint about the project, you should contact the University's Human Ethics Secretariat at 474-7122.

What if I have other questions? Call Wendy at 474-9933 or Warren Eaton at 474-9739.

OK, I want to participate. What do I do now? Complete the surveys within one week of your child turning 24 months old. Sign one copy of this form (the other copy is for you to keep) and mail it back to us along with the survey in the postage-paid envelope.

Is your child regularly exposed to a language other than English? **YES** ☐ **NO** ☐
If YES: What Language? ________________ By whom? ______________________________
Days per week? ________ # Hours per day?___________
Since what age (in months)? ____________

Toddler Study Consent Form

By signing this consent form, I confirm that I have read the above information and understand that:

- my participation is entirely voluntary;
- I can withdraw myself and my child from the study at any time and for any reason;
- I will complete a survey about the language that my child uses;
- I will also complete a survey about my child's abilities and I will try simple tasks with my child;
- information about myself and my child will be kept confidential and in locked locations.

In addition,

- I have been given a copy of this form;
- I know to contact the Human Ethics Secretariat at 474-7122 with any complaints; and
- I can contact Wendy at 474-9933 or Warren Eaton at 474-9739 if I have any other questions.

Baby's name: ____

Parent's name (please print): ____

Parent signature: ____

Date:____

Appendix I-1

Characteristics of infants eligible for follow-up who were not followed.

Participants who were eligible for follow-up, but who were not successfully followed (n = 38) did not differ significantly from those who were. Each variable used to compare the samples was checked for normality. When all normality tests (the Shapiro-Wilk W statistic and three goodness-of-fit tests: the Kolmogorov-Smirnov D statistic, the Anderson-Darling statistic, and the Cramer-von Mises statistic) were nonsignificant ($\alpha \geq .05$), parametric tests were performed; however, when even one of the normality tests was significant, nonparametric analyses were performed. For categorical variables, differences between the two groups were tested with a Chi-square test, or, where that was invalid due to small cell sizes, a Fisher's Exact test. For continuous descriptors, differences were tested with an Analysis of Variance (ANOVA) for normally distributed variables and a Wilcoxon/Mann-Whitney for nonnormal data (Maxwell & Delaney, 2000; SAS Institute Inc., 1999).

No significant differences were found for mothers' education (Fisher's Exact test, P = .00, $p = .20$), annual household income (χ^2 [4, $n = 82$] = 3.07, $p = .55$), infant birth weight (F [1, 80] = 0.49, $p = .49$), infant birth length (Fisher's Exact test, P = .01, $p = .98$), infant gestational age (F [1, 80] = 0.07, $p = .79$), mothers' age (Wilcoxon Statistic = 1571.0, $p = .96$), infant age of attainment for crawling (Wilcoxon Statistic = 1558.5, $p = .87$), duration of exclusive breastfeeding (Wilcoxon Statistic = 899.5, $p = .78$), and duration of partial breastfeeding (Wilcoxon Statistic = 875.5, $p = .99$). See the following Appendix I pages for further descriptive information.

Appendix I-2

c.f. Table 3.1

Distribution of Mothers' Education and Household Income Levels

Mothers' Highest Education Level with Sample and Comparison Values	Sample		W[a]	M[b]	Annual Household Income	Sample	
	n	%	%	%		*n*	%
Less than high school	0	0.0	16.7	21.4	< $40,000	11	29.0
High school and/or some postsecondary	13	34.2	29.3	28.8	$40,000 - $60,000	8	21.1
Trades certificate or diploma	3	7.9	9.0	9.5	$60,000 - $80,000	10	26.3
College certificate or diploma	1	2.6	20.1	19.8	> $80,000	9	23.7
University certificate, diploma, or degree	21	55.3	25.0	20.6			

[a]City of Winnipeg. [b]Province of Manitoba (Statistics Canada, 2001)

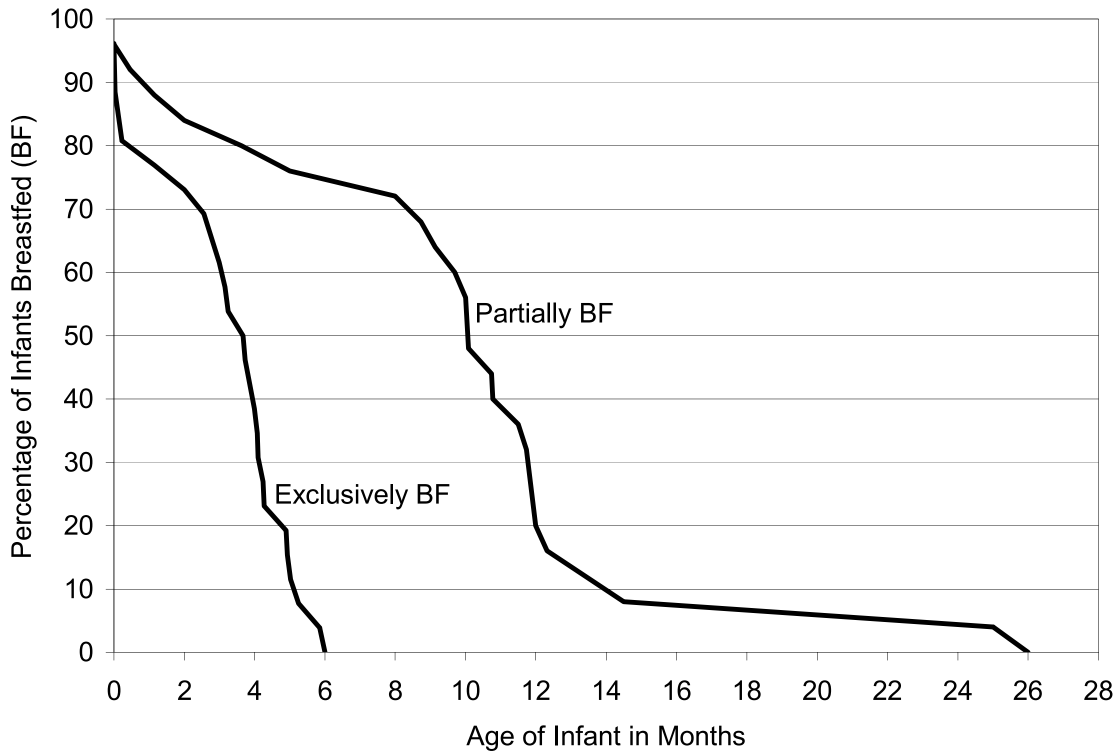
Appendix I-3

c.f. Table 3.2

Characteristics of Participants at the Birth of the Infant

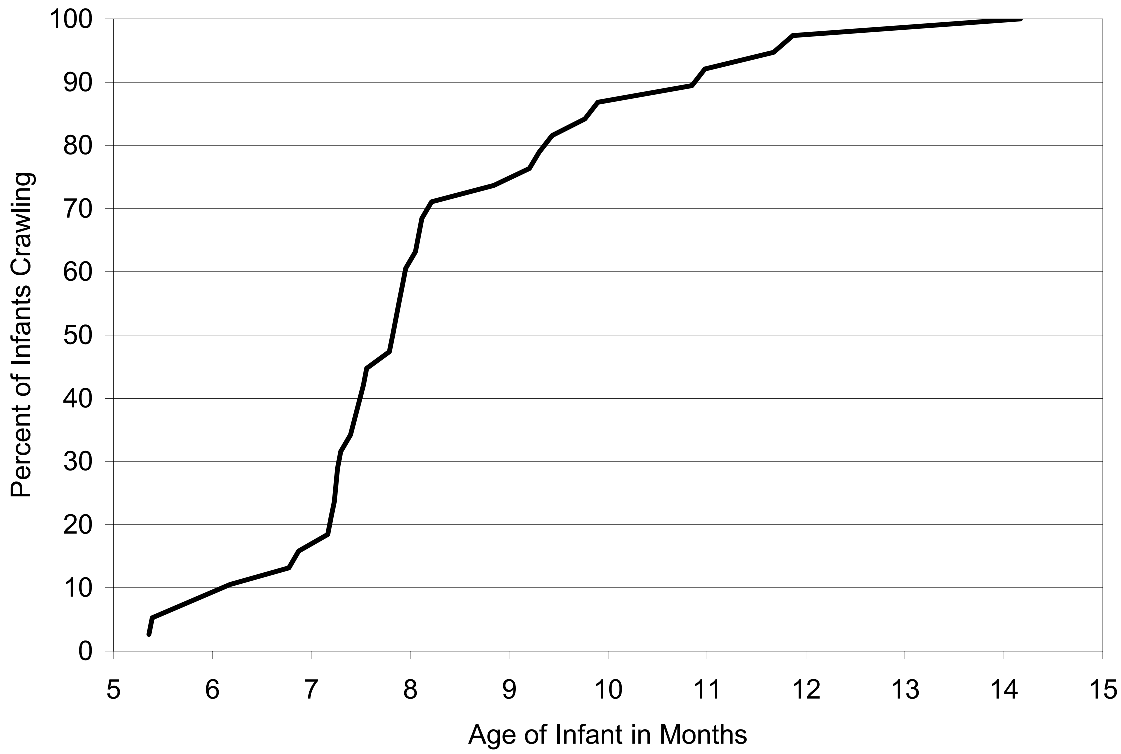
	Females					Males				
	n	*M*	*SD*	Min.	Max.	*n*	*M*	*SD*	Min.	Max.
Weight (pounds)	18	7.6	1.0	5.9	9.6	20	7.8	1.4	5.6	10.2
Length (inches)	18	20.6	1.1	19.0	23.0	19	20.8	0.9	19.0	22.0
Gestational age (weeks)	18	39.9	1.5	37.4	42.9	20	39.9	1.0	38.4	41.4
Mother's age (years)	18	32.1	4.4	21.2	38.0	20	30.1	4.5	22.1	37.5

Appendix I-4



c.f. *Figure 3.1. Percentage of infants exclusively BF and partially BF by age.* Twelve infants had missing values for exclusive breastfeeding duration and 13 infants had missing values for partial breastfeeding duration. Note that participants who did not return the cognitive measures (and thus were not successfully followed) also tended to not return the feeding questionnaires; thus, these participants had more missing data on both ends of the breastfeeding continuum (i.e., before and after checklist completion, respectively). This resulted in a smaller sample size for the above figure and is partly responsible for the different shapes of these lines compared to the lines in Figure 3.1.

Appendix I-5



c.f. *Figure 3.2. Percentage of infants who attained crawling by age.* This graph shows that excluded infants crawled at a median age very similar to sample infants, but both the earliest and latest crawlers were excluded from the current study's sample, which suggested slightly reduced variability.

Appendix J-1

Analyses of Potential Covariates

Potential Covariate Variables[a]		Key Variables[b]			
	E		P	C	O
1. Maternal age in years at infant's birth					
Spearman Correlation:	.17	Pearson Correlation:	.31	.14	.05
p value:	.26	*p* value:	.04	.35	.77
2. Maternal alcohol use during pregnancy					
		Mean (No, n = 38):	10.1	8.1	0.1
		Mean (Yes, n = 6):	12.3	8.8	0.0
Wilcoxon Statistic:	163.0	F (1, 42):	0.47	1.58	0.01
p value:	.35	*p* value:	.50	.22	.92
3. Maternal education level					
		Mean (High school and/or some post-secondary, n = 10):	7.8	7.9	0.4
		Mean (Trades certificate or diploma, n = 4):	10.3	9.0	-1.7
		Mean (College certificate or diploma, n = 7):	11.6	7.9	0.5

Appendix J-2

Analyses of Potential Covariates *(continued)*

Potential Covariate Variables[a]		Key Variables[b]			
	E		P	C	O
3. Maternal education level *(continued)*					
		Mean (University certificate, diploma, or degree, *n* = 23):	11.1	8.2	0.1
Kruskal-Wallis, χ^2 (3, *n* = 44):	3.2	*F* (3, 40):	0.55	0.80	2.13
p value:	.36	*p* value:	.65	.50	.11
4. Maternal parity					
		Mean (1 child, *n* = 24):	10.2	8.2	0.2
		Mean (2 children, *n* = 17):	10.8	8.2	0.1
		Mean (3 or more children, *n* = 3):	9.4	7.2	-0.8
Kruskal-Wallis, χ^2 (2, *n* = 44):	.08	*F* (2, 41):	0.05	0.85	0.55
p value:	.96	*p* value:	.95	.43	.58
5. Infant birth weight					
Spearman Correlation:	.09	Pearson Correlation:	.15	.08	-.06
p value:	.55	*p* value:	.34	.61	.71

Appendix J-3

Analyses of Potential Covariates *(continued)*

Potential Covariate Variables[a]		Key Variables[b]			
	E		P	C	O
6. Infant gestational age					
Spearman Correlation:	-.07	Pearson Correlation:	-.03	-.17	.07
p value:	.67	*p* value:	.85	.28	.66
7. Household Annual Income[c]					
		Mean (<$40,000, *n* = 10):	10.3	8.0	0.1
		Mean ($40-60,000, *n* = 5):	8.7	8.4	-0.5
		Mean ($60-80,000, *n* = 14):	11.1	7.7	0.4
		Mean (>$80,000, *n* = 14):	9.7	8.7	0.1
Kruskal-Wallis, χ^2 (3, *n* = 44):	1.56	*F* (3, 39):	0.15	1.32	0.37
p value:	.67	*p* value:	.93	.28	.78
8. Season of birth					
	–	Mean (Winter, n = 18):	–	8.4	–
	–	Mean (Spring, n = 15):	–	7.9	–

Appendix J-4

Analyses of Potential Covariates *(continued)*

Potential Covariate Variables[a]	Key Variables[b]				
	E		P	C	O
8. Season of birth *(continued)*					
	–	Mean (Summer, n = 11):	–	8.0	–
	–	F (2, 41):	–	0.81	–
	–	*p* value:	–	.45	–
9. Prone placement for sleep or play on 90% or more of checklist days before crawling					
	–	Mean (Yes, *n* = 20):	–	7.8	–
	–	Mean (No, *n* = 24):	–	8.4	–
	–	*F* (1, 42):	–	2.49	–
	–	*p* value:	–	.12	–

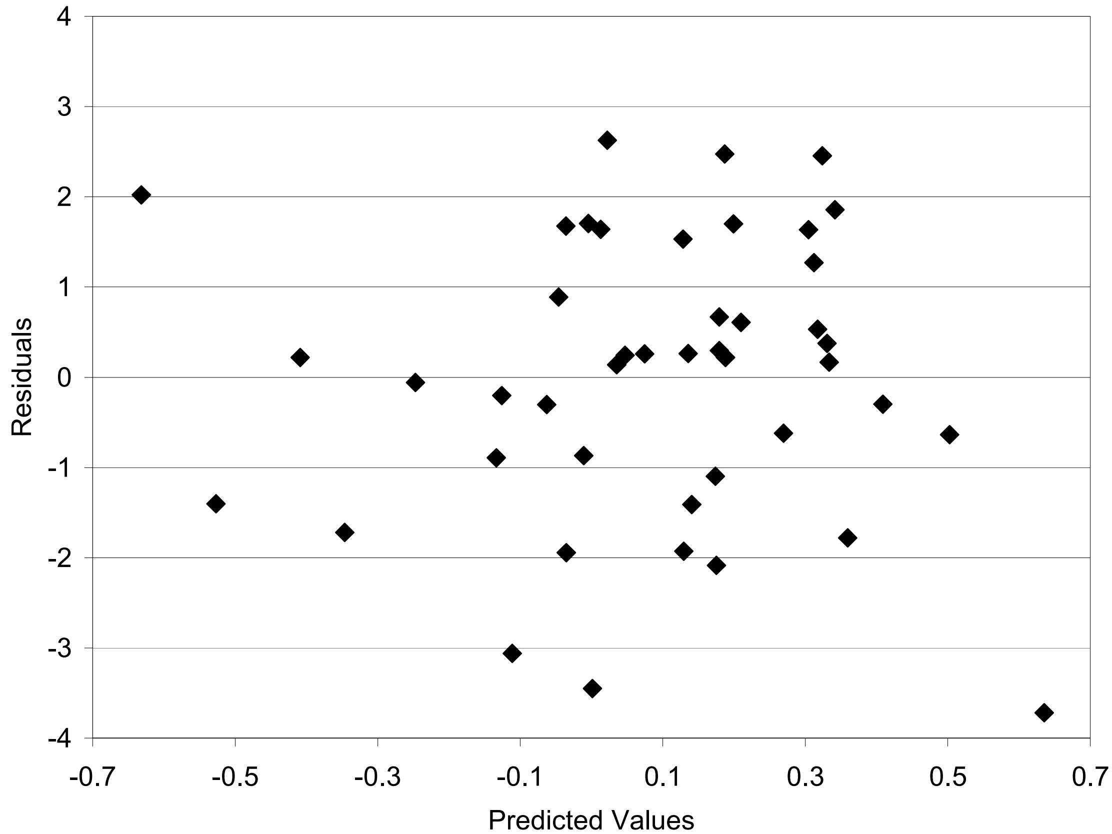
[a]No statistical tests were performed for maternal smoking or for maternal ethnicity, due to not enough and too much variation, respectively. One mother smoked during pregnancy. Maternal ancestries varied: Canadian (n = 15, 34%), English (n = 15, 34%), Irish (n = 12, 27%), and Scottish (n = 11, 25%; more than one ancestry was allowed per mother). Fewer than 10 mothers reported ancestries of Austrian, Belgian, Dutch, French, German, Icelandic, Italian, Mennonite, Metis, Polish, Russian, Slovakian, Swiss, or Ukrainian.

[b]E = Exclusive breastfeeding duration, P = Partial breastfeeding duration, C = Crawling onset, O = Outcome: cognition. E, P, and C means were measured in months; O means were measured as the sum of the standardized scores from the MCDI and the PARCA.

[c]One family did not report an income and was not included in this analysis.

Appendix K-1

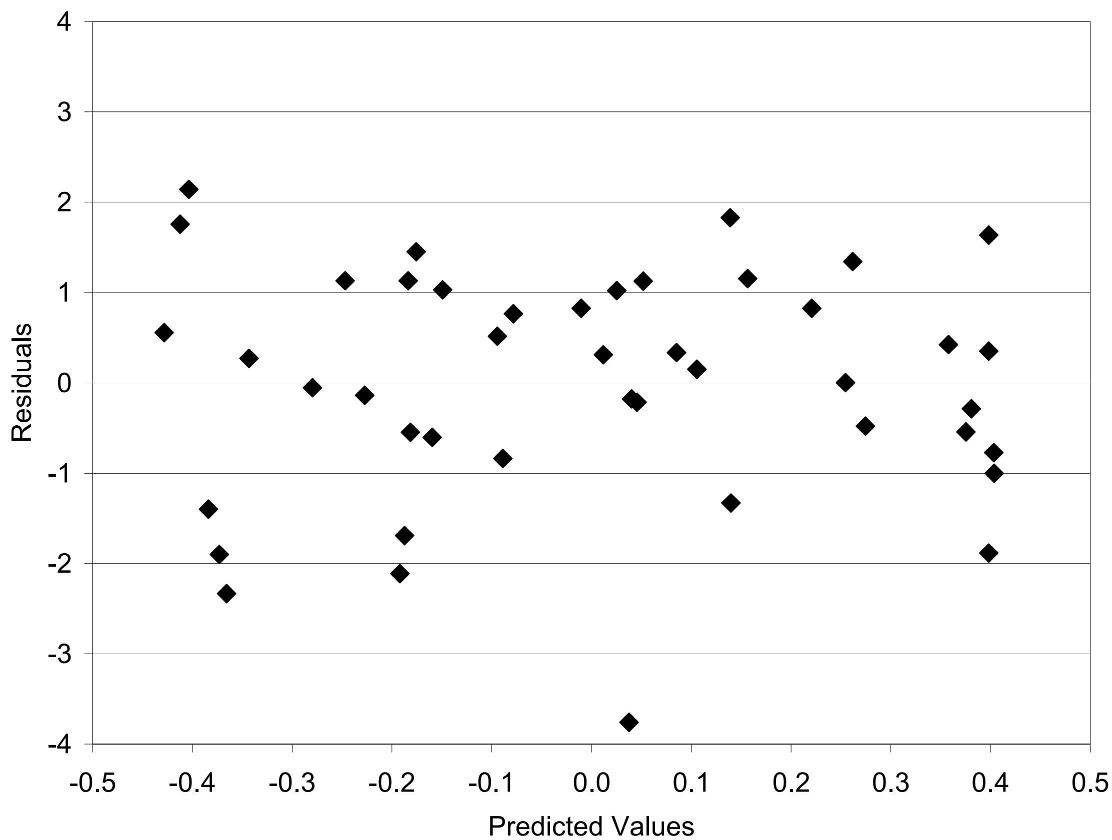
Examination of Residuals Scatter Plots



Residuals and predicted values of exclusive and partial breastfeeding durations regressed on the outcome of cognition.

Appendix K-2

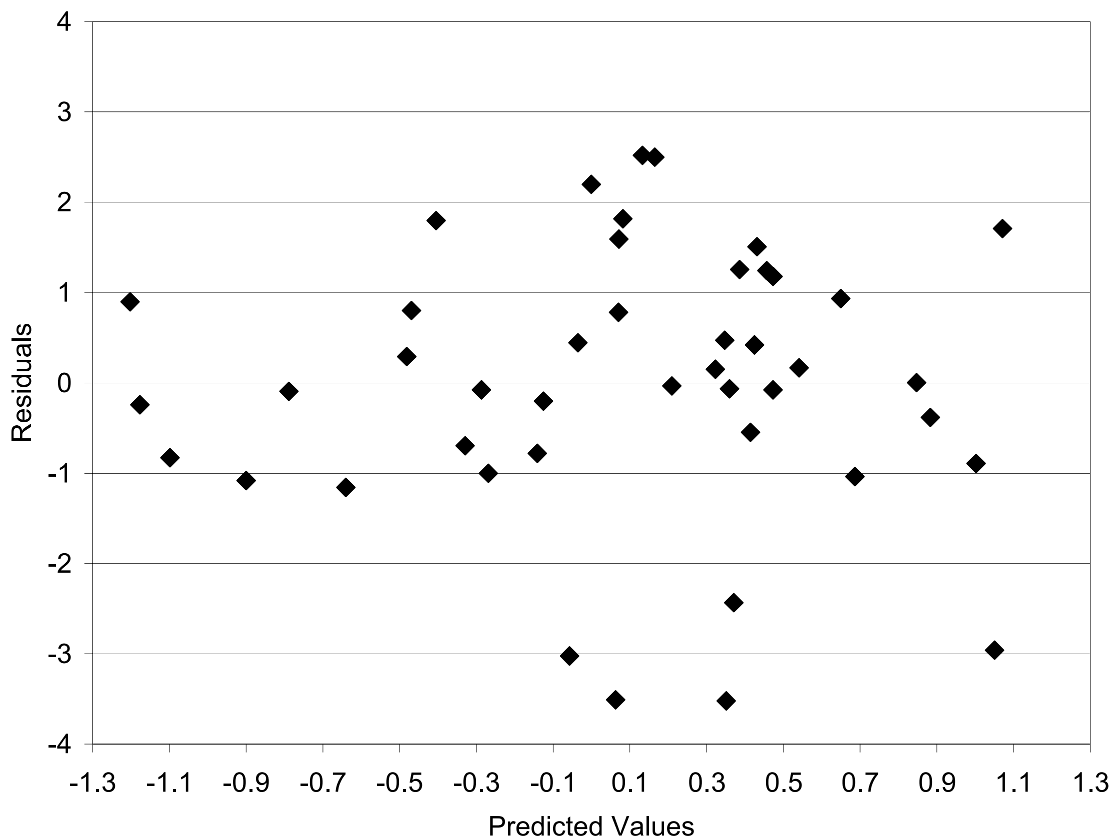
Examination of Residuals Scatter Plots *(continued)*



Residuals and predicted values of exclusive and partial breastfeeding durations regressed on the outcome of crawling onset.

Appendix K-3

Examination of Residuals Scatter Plots *(continued)*



Residuals and predicted values of exclusive breastfeeding duration, partial breastfeeding duration, and crawling onset regressed on the outcome of cognition.