THE RELATIONSHIP OF BREASTFEEDING TO MENTAL AND MOTOR DEVELOPMENT IN CHILDREN UNDER TWO YEARS OF AGE

by

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ABSTRACT

Occupational therapists are involved also in the rehabilitation of infants with feeding difficulties in a variety of health care and community settings. Breastfeeding involves the occupational performance of a mother-child dyad within a physical, social, economic and cultural environment and, for many mothers, constitutes the primary occupation of motherhood for the greater part of the child's first year. Based on numerous known child health, maternal health, and community benefits of breastfeeding, the AAP (2005) and the World Health Organization (WHO, 2004) recommended exclusive breastfeeding of infants for 6 months and breastfeeding with introduction of solid foods thereafter, with no upper limit on duration.

The existing literature on the relationship of breastfeeding and neurodevelopment is explored, including behavioral, physiological, and genetic explanatory theories. In particular, motor development, visual acuity, educational achievement, and psychosocial adaptation are examined as neuro-developmental outcomes. Significant and widespread methodological limitations in the available research are then discussed.

Subsequently, we report on an observational study of the relationship of exclusive and partial breastfeeding duration to mental and motor development as measured by the Mental Development Index (MDI) and Psychomotor Development Index (PDI) of the Bayley Scales of Infant Development, Revised (Bayley, 1993). Because breastfeeding mothers are typically older, more educated, with higher family income and more social support, numerous possible confounding variables (covariates) were examined along with breastfeeding for their effect on child development. Data collection, occurring in Phase II, a retrospective survey of participants in a previous study, and Phase II, a prospective recruitment of volunteer from community organizations, yielded 80 mother-child dyads. Differences between Phase I and II groups were not considered to affect results. Correlation coefficients (*r*) for the relationships between exclusive or partial breastfeeding and MDI or PDI were not significant and very weak ($r = 0.14$ to 0.21). None of the covariates studied confounded to relationship between breastfeeding and MDI or PDI. Therefore, this study does not support the existence of a dose-response relationship between breastfeeding duration and mental or motor development.

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LIST OF ABBREVIATIONS

LCPUFA	Long-Chain Polyunsaturated Fatty Acid
DHA	Docosaheaneoic Acid
AA	Arachidonic Acid
BSID-II	Bayley Scales of Infant Development, Second Edition
MDI	Mental Development Index, BSID-II
PDI	Psychomotor Development Index, BSID-II
HOME	Home Observation for Measurement of the Environment

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DEDICATION

To my daughters, Olivia Labelle and Anya Labelle,
my partners in breastfeeding,

and

To my husband, Tim Labelle,
whose support makes anything possible...

CO-AUTHORSHIP STATEMENT

Chapter 1 represents a manuscript accepted for publication in Infants and Young Children, and is co-authored by Susan R. Harris, Roberta Hewat, and Lyn Jongbloed. My contributions to this manuscript include: Conducting the literature search and selecting relevant information; synthesizing findings into a review form; updating literature review for current publications; preparing the initial draft of the manuscript and incorporating co-author suggestions and edits into subsequent versions. I am the primary author and identified as the corresponding author for the journal submission.

Chapter 2 represents a manuscript to be submitted to the American Journal of Occupational Therapy, and is co-authored by Susan R. Harris, Roberta Hewat, and Lyn Jongbloed. My contributions to this manuscript include: designing the research project under the supervision of the co-authors; obtaining funding from the Ministry of Children and Family Development via the Human Early Learning Project, under the direction of Susan R. Harris; coordinating recruitment and data collection with a research assistant and community organizations; meeting with a statistician to collaboratively identify appropriate statistical analysis and interpretations; preparing the initial draft of the manuscript and incorporating co-author suggestions into subsequent versions. I am the primary author and identified as the corresponding author for the journal submission.

Chapter 3 is a summary and conclusions of this thesis and not intended for publication.

CHAPTER 1

Breastfeeding and Neurodevelopment[1]

The American Academy of Pediatrics has outlined numerous child health, maternal health, and community benefits of breastfeeding (2005). Based on these benefits, the American Academy of Pediatrics (2005) and the World Health Organization (2004) recommended exclusive breastfeeding of infants for 6 months, breastfeeding with introduction of solid foods thereafter with no upper limit on duration, and appropriate environmental and professional support for breastfeeding mothers. The World Health Organization (2004), American Academy of Pediatrics (2005) and Breastfeeding Committee for Canada (1999), following UNICEF guidelines (UNICEF, 1989; UNICEF, 1990) have also recommended active public health campaigns to promote breastfeeding.

Although the benefits of breastfeeding to an infant's immune system are well known (Xanthou, 1998), other lesser-known benefits have also been reported. Of particular interest is the influence of breastfeeding on brain development. Some critics, however, have noted significant and widespread methodological limitations in the available research in this area and have warned against exalting the benefits of breastfeeding (Drane & Logemann, 2000; Rey, 2003). This review will summarize the majority of existing studies on breastfeeding and neurodevelopment, explore past limitations in methodology and provide suggestions for future research.

The relationship between having been breastfed and neurodevelopmental outcome was first discussed in 1929 when Hoefer and Hardy examined the mental and physical outcomes of children aged 7 to 13 years. They concluded that children who had been breastfed for 4 to 9 months outperformed their artificially fed peers in intelligence, educational achievement, motor, and language development (Hoefer & Hardy, 1929). Since then, motor development, visual acuity, educational achievement, and psychosocial adaptation have all been investigated as neuro-developmental outcomes in children who were breastfed (Golding, Rogers & Emmett, 1997). Studies of breastfeeding in children born at risk for neurological impairment, such as those born prematurely, provide more specific evidence of the association of breastfeeding with these outcomes (Rey, 2003).

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1.1 Motor Development

In the earliest study to examine motor development of breastfed children, the 1946 national maternity survey in England, a significant positive relationship was found between duration of breastfeeding and the age of first walking (Douglas, 1950). In a later study, the relationship between early motor milestones and having been breastfed did not persist when maternal confounders, such as mental ability, education, and socio-economic class, were considered (Silva, Buckfield, & Spears, 1978). Subsequent studies (Angelsen, Jacobsen, & Bakketeig, 2001; Florey, Leech, & Blackhall, 1995; Paine, Markrides, & Gibson, 1999; Rogan & Gladen, 1993) failed to find a relationship between duration of breastfeeding and motor scale scores (Psychomotor Developmental Index or PDI) on the Bayley Scales of Infant Development-II (Bayley, 1993). Assessment with the Motor Sub-scale of the McCarthy Scales of Child Development (McCarthy, 1972) also failed to demonstrate a difference between breastfed and formula-fed groups at ages 3, 4 and 5 years (Rogan & Gladen, 1993).

In a study of premature infants, Lucas, Morley, Cole and Gore (1994) examined PDI scores at 18 months' corrected age, with infants randomly assigned to feedings of pasteurized donor breast milk or premature, nutritionally fortified formula. Interestingly, there were no significant differences between these groups, "despite the very low nutrient content of donor milk" (Lucas et al., 1994, p. F143).

In a study on the neurological function of children at low risk for neurological problems, Lanting and colleagues (1998) reported better quality and "fluency" of movements in children aged 42 months who were fully breastfed for 6 weeks or more, compared with children who had been formula fed since birth. This result remained after adjusting for mother and child characteristics as well as birth circumstances. Bouwstra and colleagues (2003) also investigated quality and fluency of movement with the scale of general movements (GM), previously shown to be a strong predictor of neurological outcome. They found that exclusive breastfeeding for greater than 6 weeks was associated with optimal neurological function on the GM. Because the quality of movements is likely associated with brain integrity, this suggests that a mechanism influencing overall brain development also effects neuromotor development (Lanting et al., 1998).

More recently, the duration of exclusive breastfeeding has been shown to be associated with motor development (gross motor, fine motor, and self help skills) at 6 years of age, after controlling for gender and socioeconomic confounding variables (Thorsdottir, Gunnarsdottir, Kvaran & Gretarsson, 2005). As well, in a lower socioeconomic sample of 5 ½ year olds, motor development as measured by the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978) followed a significant non-linear relationship with breastfeeding duration (Clark et al., 2006). Children who breastfed exclusively for less than 2 months or more than 8 months, had lower motor scores than those who breastfed 2 to 8 months (Clark et al., 2006). Generally, while earlier studies failed to support the findings of Douglas (1950) in terms of breastfeeding's effect on motor milestones, recent research is beginning to build new support (Bouwstra et al., 2003; Clark et al., 2006; Lanting, Patandin, Weisgals-Kuperus, Touwen & Boersma 1998; Thorsdottir et al., 2005).

1.2 Visual Development

A number of studies have reported better visual development in children who were breastfed compared to children who were formula-fed. Visual-evoked potentials (VEP), forced-choice preferential looking (FPL) and stereovision were used as outcome measures for visual development. Without controlling for maternal or social factors, Birch and colleagues (1993) found VEP and FPL were significantly higher, at 4 months and 3 years of age, in breastfed infants than in infants fed a corn oil-based formula. After controlling for maternal education, maternal age, maternal smoking, financial difficulties, and diet in later childhood, Williams and colleagues (2001) reported that children aged 3.5 years who were breastfed for at least 4 months had better stereovision than formula-fed children. Jorgensen, Hernell, Lund, Holmer and Michaelson (1996) compared the visual acuity of breastfed and formula-fed infants and found that not only was visual acuity better in breastfed infants throughout the first four months of life, but this advantage correlated to levels of docosaheaneoic acid (DHA) in the child's red blood cells.

Recently, Chong, Liang, Gazzard, Stone and Saw (2005), in a study of grade 1 to 3 students in Singapore, found the prevalence of myopia was lower in children that were breastfed, after controlling for child and socio-economic factors, including mother's intelligence. Overall, while studies appear to show a link between breastfeeding and visual development, lack of control of possible confounding variables weakens the evidence in this area.

1.3 Educational Achievement

As an outcome measure, educational achievement has not been studied as frequently as cognitive ability. In 1978, Rodgers reported that bottle-fed infants scored more poorly on mathematics and reading tests at 15 years of age after controlling for social class, parental education, parents' interest in the child's education, birth rank, sex, and birth weight. When maternal age, maternal education, and sibling order were controlled, Rogan and Gladen (1993) found that report card English grades, from grade 3 upwards, were higher in longer breastfed children than shorter breastfed or formula-fed children. However, in a study published the following year, no significant association was found between having been exclusively breastfed and reading, mathematics or spelling at 10 years of age, after adjustment for social confounders (Pollock, 1994).

More recent studies have found significant relationships between educational achievement and breastfeeding. In an investigation of long-term outcomes of breastfed children, Horwood and Fergusson (1998) examined teacher ratings of school performance, standardized achievement tests in 8, 10, 12, and 13 year-old children, and high school outcomes on certificate examinations leading to qualifications for university at 18 years of age. Increased duration of breastfeeding was significantly associated with better performance on academic achievement measures both in middle school and at age 18. Children who had been breastfed for 8 months or more were one-third less likely to leave high school, without qualifications for university, as children who were not breastfed (Horwood & Fergusson, 1998). Similarly, in a Brazilian study of 18-year-old-boys, the duration of schooling was positively correlated with exclusive or predominant breastfeeding (Victora, Barros, Horta & Lima, 2005). Finally, in a large British cohort, children breastfed for 7 months or longer had greater educational achievement at 26 years than those not breastfed (Richards, Hardy & Wadsworth, 2002).

1.4 Psychosocial Adaptation

The outcome that has been least studied is psychosocial adaptation, a surprising finding considering that breastfeeding is thought to create a stronger attachment between mother and child, thus promoting a child's ability to establish other relationships (Fergusson & Woodward, 1999; Golding et al., 1997). Lundqvist-Persson (2001) studied the ability of 3-day-old newborns to self-regulate their physiological states, including sleeping and crying. Early ability to self-regulate is thought to be predictive of social skills later in life. In this small study (n=36), the duration of breastfeeding was not associated with a child's early ability to self-regulate, suggesting that children who succeed in breastfeeding are not innately better at social interaction (Lundqvist-Persson, 2001). Social interaction skills may, in fact, be the product rather than the pre-requisite for successful breastfeeding.

In a study of 1,000 8-year-olds, conduct disorder was significantly less prevalent in children who had been breastfed vs. those who had been bottle-fed (Fergusson, Horwood, & Shannon, 1987). However, maternal ratings of conduct disorder for their children were lower in mothers who breastfed than were the ratings provided by teachers, suggesting that breastfeeding mothers appear to see their children in a more positive light. When subjected to multiple regression analysis, the influence of lower maternal ratings, as well as other social confounders (family social position, economic situation, and family life changes), decreased the association between conduct disorder and breastfeeding, such that this was no longer significant (Fergusson, et al., 1987).

This view of a mother's positive attitude about her child's behaviour is contrasted with the finding that breastfeeding mothers are more likely to show depressive symptoms during the first three months post-partum (Rogers, Golding & Emmett, 1997). Post-partum depression has been associated with decreased social and emotional development of the child, secondary to impaired interaction and establishment of a positive mother-child relationship (Murray, 1992; Murray & Cooper, 1997). Women who experienced post-partum depression were significantly more likely to stop breastfeeding within 2 months than women who were not depressed (Cooper, Murray, & Stein, 1993). Termination of breastfeeding may compound the effects of post-partum depression on the social and emotional development of the child. In fact, breastfeeding may protect the child from the effects of post-partum depression by strengthening the mother-infant relationship (Uauy & Andraca, 1995).

Psychosocial adaptation was studied in a group of 999 adolescents aged 15 and 18 years (Fergusson & Woodward, 1999). Longer duration of breastfeeding was not associated with better outcomes, e.g. fewer juvenile legal offences, less substance abuse or fewer psychiatric disorders, after adjusting for measures of family and social history and peri-natal outcome. However, teenagers who were breastfed longer tended to perceive their mothers as more nurturing and caring. This may mean that breastfeeding improves bonding, leading to more positive perceptions of parents by their children, or that breastfeeding creates a more nurturing environment for the child (Fergusson & Woodward, 1999).

1.5 Cognitive Development

1.5.1 General Population Evidence

Intelligence testing has been the most widely used measure for evaluating the effects of breast milk on the neurological system and has been investigated in individuals aged 6 months to adulthood using a variety of psychometric tests of intelligence and language skills (Jain, Concato & Leventhal, 2002). The earliest studies reported conflicting results. Hoefer and Hardy (1929) concluded that children breastfed for 4 to 9 months were mentally superior to those breastfed for shorter perriods, whereas children exclusively breastfed more than 9 months were poorer in mental skills than those breastfed for shorter periods or not at all. Silva and colleagues (1978), in a sample of 1037 three-year-old children, found no significant relationship between having been breastfed and cognitive ability after controlling for maternal IQ, education level, socio-economic level, and childhood experience. In a sample of more than 2300 children, Rodgers (1978) found higher picture intelligence at 8 years and non-verbal ability at 15 years in children who were never bottle-fed compared to children who were never breastfed, after controlling for some maternal and early childhood factors.

Studies in the 1980's and early 1990's began to control regularly for maternal and other potential influences on child intelligence, including variables such as training in child rearing, birth weight and gestational age (Fergusson, Beautrais, & Silva, 1982), race, maternal age, prenatal maternal substance abuse, social and emotional aspects of the home environment (Morrow-Tlucak, Haude, & Ernhart, 1988), parental occupation, and birth order (Rogan & Gladen, 1993). In these studies of children aged 2 years to elementary school, small but significant improvements in cognitive ability were shown to be associated with having been breastfed. Furthermore, a dose-response pattern was suggested between the duration of breastfeeding and cognitive ability (Morrow-Tlucak, et al., 1988).

In the mid-1990's, studies continued to be published with greater control for maternal and early childhood confounders and larger sample sizes. In a study of 592 children, Florey and colleagues (1995) found that 18-month old children who had been breastfed for at least 2 weeks after birth scored 3.7 points higher on the Mental Developmental Index (MDI) of the Bayley Scales of Infant Development-II. In a study of exclusively breastfed one-year-old children, duration of breastfeeding was positively associated with MDI scores for boys but not for girls (Paine, et al., 1999). Another study of 229 toddlers aged 18 to 29 months found significantly lower MDI scores in formula-fed children compared to children breastfed for 3 or more months (Temboury, Otero, Polanco, & Arribas, 1994), despite the inclusion of children who were breastfed for less than one month in the formula-fed group. Niemela and Jarvenpaa (1996) examined cognitive, visual-motor integration and language development in children aged 4 1/2 years. Breastfeeding for 5 months or more was significantly associated with higher scores on tests of cognitive abilities and visual-motor integration but not on those for vocabulary.

In an 18-year longitudinal study involving more than 1000 children, Horwood and Fergusson (1998) investigated cognitive ability in school-aged children. In children 8 and 9 years of age, scores on the Wechsler Intelligence Scale for Children (WISC-R; Wechsler, 1974) increased significantly with increased duration of breastfeeding after adjusting for social and maternal con-founders. Children who were breastfed for more than 8 months had scores on cognitive tests from 0.11 to 0.30 of a standard deviation higher than children who had never been breastfed, leading the authors to conclude that a dose-response relationship exists between breastfeeding and cognitive ability. Although the size of these associations decreased with control for maternal and early childhood variables, the relationships remained significant. These results have been supported by recent studies of children from birth to 6 ½ years of age (Angelsen et al., 2001; Clark et al., 2006; Gustafsson, Duchen, Birberg & Karlsson, 2004; Quinn, et al., 2001; Thorsdottir et al., 2005)

Few studies have investigated the effects of having been breastfed on cognitive ability in the adult years. Because intelligence varies significantly in childhood but stabilizes in adulthood, the cognitive advantage to breastfed children may no longer exist in adulthood (Mortensen, Michaelsen, Sanders, & Reinisch, 2002). In adults in their 60's and 70's, Gale and Martyn (1996) found no association between scores on IQ tests and having been breastfed as infants, after adjusting for father's occupation, number of older siblings, and maternal age (collected retrospectively). However, this sample may not have been representative of the original population because subjects were selected by virtue of continuing to live in the same town and agreeing to an IQ test (Gale & Martyn, 1996). In a more rigorously designed, prospective study, Mortensen and colleagues (2002) reported on two independent groups of adults tested for intelligence between 17 and 34 years of age. They concluded that a dose-response relationship existed between breastfeeding duration (up to 9 months) and adult intelligence, after adjusting for potential confounders.

The best-designed studies, that controlled confounding variables directly linked to cognitive development, maternal intelligence and characteristics of the home environment, found that the benefit of breastfeeding to cognitive development was not as robust (Wigg et al., 1998). However Jacobson, Chiodo and Jacobson (1999) found that the longer 4- and 11-year old children were breastfed, the greater were their scores on several measures of cognitive ability and language skills, even after adjusting for socio-economic class, maternal education and other standard confounding variables. However, when mother's intelligence, measured by the Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn, 1981) and scores on the Home

Observation for Measurement of the Environment (HOME, Caldwell & Bradley, 1984) were included as potential confounds, the significant relationship between breastfeeding and cognitive development disappeared.

1.5.2 The Neurologically "at Risk" Evidence

The effects of breastfeeding on neurological development have been investigated in children born to hypertensive mothers (Ounsted, Moar, Cockburn, & Redman, 1984), children with cardiac conditions (Lambert & Watters, 1998), children with phenylketonuria (Riva et al., 1996), children born small-for-gestational age (Ounsted, Moar, & Scott, 1988; Rao, Hediger, Levine, Naficy & Vik, 2002; Slykerman et al., 2005), and children born pre-term (Horwood, Darlow, & Mogridge, 2001).

Morley, Cole, Powell, & Lucas (1988) compared cognitive ability of children born pre-term whose mothers had chosen, within 72 hours of delivery, to provide breast milk by tube to children of mothers who chose not to provide breast milk. At 18 months of age, children whose mothers had decided to provide breast milk scored 4.3 points higher on the MDI of the Bayley Scales (Bayley, 1969), after adjusting for maternal and peri-natal confounds. However, the authors conceded that it was impossible to determine if this advantage related to the mother's parenting practices or to substances in human milk, since neither the amount of breast milk ingested nor the characteristics of the mother-child relationship were measured (Morley et al., 1988).

Lucas, Morley, Cole, Lister, and Leeson-Payne (1992) studied the same group of children at 7.5 to 8 years of age. Children whose mothers wanted to provide breast milk for their child but were unsuccessful were considered separately from children of mothers who chose not to provide breast milk at all. Children receiving human milk by tube scored 8.3 points higher on the Wechsler Intelligence Scale for Children, Revised (WISC-R) than children who had not received breast milk, after adjustment for social class, maternal education, sex, and days of ventilation. Of the children who received breast milk, a significant dose-response relationship was found, after adjusting for confounders, between amount of breast milk ingested and intelligence (Lucas et al., 1992). In addition, children of mothers who chose to breastfeed but were unsuccessful in providing their breast milk had similar intelligence as children of mothers who chose not to provide breast milk (Lucas, et al., 1992). These findings suggest that it may be a breast milk substance rather than mothering attitude and behaviour that influences cognitive development in pre-term infants (Rey, 2003).

Lucas. Morley, Cole and Gore (1994) also examined Bayley MDI scores of premature infants at 18 months of age, who were randomly assigned to feedings of pasteurized donor human milk or nutritionally fortified, premature formula. The effect of mother's attitude was removed because all children were those of mothers who elected not to provide their own breast milk (Rey, 2003). MDI was not significantly different in the children receiving donor breast milk vs. those receiving pre-term formula. When comparing the group of children receiving donor breast milk to the group receiving term formula (a non-randomized comparison across two studies), MDI scores were 9 points higher in the donor breast milk group (Lucas et al., 1994). Human breast milk, even when pasteurized and apparently inferior in nutritional content to artificial formulas, may convey substantial benefits to the developing nervous system of pre-term infants. However, it is not known what types of formula were given to these study groups after discharge from hospital (Rey, 2003). Consequently, these findings may or may not be the result of a very short period of dietary influence, i.e. 4 weeks while in hospital (Rey, 2003).

1.5.3 Meta-analysis and Critical Evaluations

A meta-analysis was conducted for 20 studies published from 1966 to 1996 that examined the association between having been breastfed and cognitive ability, including infants born at term and pre-term (Anderson, Johnstone, & Remley, 1999). Adjusted scores on cognitive achievement tests were found to be 3.16 points higher in children who were breastfed $\geq$4 weeks compared to those who were not breastfed. A more recent re-examination of this meta-analysis criticized the inclusion of several methodologically poor studies (Rey, 2003) including retrospective collection of infant feeding data, small sample sizes, cognitive testing conducted by testers who were not blind, and inadequate control of confounding home and maternal variables (Rey, 2003).

Since then, several critical evaluations of the evidence supporting the beneficial effect of breastfeeding on cognitive development have been published. While all agreed that the majority of studies were methodologically poor, they disagreed on the general conclusions that can be drawn from the field of study. Some said too few studies met acceptable standards of validity to draw firm conclusions (Drane & Logemann, 2000; Jain, et al., 2002), whereas others were confident in saying breastfeeding provides a measurable advantage in cognitive development (Anderson, et al., 1999; McCann & Ames, 2005). According to one reviewer, four studies that met validity standards showed a beneficial effect of breastfeeding on cognitive development of the magnitude of 2 to 5 points on standard IQ tests, that was durable into adulthood (Drane &

Logemann, 2000). In the pre-term population, IQ advantage may be as much as 8 points (Drane & Logemann, 2000).

1.6 Explanatory Theory

If breastfed children do have globally enhanced brain function (Anderson et al., 1999), including cognitive function, visual function, motor function, emotional and behavioral adaptability and academic skills, how is this explained? The child's genetic predisposition, the substances in breast milk, and the breastfeeding socio-emotional environment are suggested explanations in the literature.

1.6.1 Genetic Predisposition

Infants who succeed at breastfeeding may have a better genetically determined neurological system from the moment of conception. Superior neurodevelopmental outcome and longer breastfeeding duration would be co-occurring phenomena but not causally related. Presently it is extremely difficult to remove this possible explanation from the conclusions of any observational studies. Maternal intelligence can represent the child's genetic potential, however, it is also related to the quality of the child's stimulation. Genetic markers for aspects of development are something of the far future.

1.6.2 Substances in Human Breast Milk

It is well established in animals that nutrition during a vulnerable period of brain development has permanent effects on the nervous system (Lucas, 1998). Randomized controlled trials have also been conducted of the effects of early feeding on the mental abilities of premature children (Lucas et al., 1990; Lucas, Morley, & Cole, 1998). Premature children randomized to receive term formula by tube had significantly lower mental ability, at 18 months of age (Lucas et al., 1990) and 7.5-8 years of age (Lucas et al., 1999), than children who received fortified pre-term formula. Therefore, evidence exists that early nutritional intake, at a vulnerable period during fetal neurological development, can permanently affect the functioning of the nervous system in later years.

Several beast milk compounds have been suggested to explain the advantage held by breastfed children in areas of neurodevelopment. Growth factors, trophic factors, and other hormones in breast milk, which contribute to growth and development of the child, may also be key influences on the development of the nervous system (Donovan & Odle, 1994; Uauy & Andraca, 1995). Recently, antioxidant compounds (Rassin & Smith, 2003), cholesterol, choline, and fat-soluble vitamins A, D, E and K (Cockburn, 2003) in breast milk have been added to the list of possible agents. The relative importance of one component is difficult to determine since many substances can theoretically influence the development of the nervous system (Rey, 2003). However, most attention has been focused on breast milk's long chain polyunsaturated fatty acids (LCPUFA).

LCPUFAs accumulate in the brain and retina prior to birth by placental transfer and after birth through ingestion of breast milk. These fatty acids are found in greatest concentration in membrane synaptic vesicles and photoreceptors and are thought to be essential in cellular differentiation and synaptogenesis of the maturing brain and retina (Xiang, Alfven, Blennow, Trygg, & Zetterstrom, 2000). In particular, the concentrations of LCPUFAs, docosaheaneoic acid (DHA) and arachidonic acid (AA), in the brain increase dramatically in the third trimester of pregnancy when brain growth is most rapid (Hamosh & Salem, 1998).

Adults synthesize DHA from alpha-linoleic acid (an n-3 polyunsaturated fatty acid) and AA from linoleic acid (an n-6 PUFA), essential PUFA that must be obtained in the diet (Cockburn, 2003). While newborn subcutaneous fat contains a 2 to 3 week store of DHA and AA, term infants lack sufficient enzymes to produce adequate amounts of DHA and AA for nervous system growth after this initial period (Cockburn, 2003).

Human milk initially contains high concentrations of DHA and AA. This declines at 4 to 6 months, when infants are thought to be able to produce sufficient DHA and AA endogenously from dietary PUFA (Xiang et al., 2000). Insufficient dietary intake of DHA and AA results in substitution of other forms of LCPUFA in cerebral cortex phospholipid membranes. The substituted LCPUFA are very unstable and may affect the neurotransmission functions of nerve cells (Cockburn, 2003).

Many studies have associated the accumulation of DHA and AA with a child's neurodevelopment. In a study mentioned previously, term and pre-term infants, at 57 weeks and 36 months post conception, with better visual acuity, also had higher red blood cell concentrations of DHA (Birch et al., 1993). Agostoni, Trojan, Bellu, Riva, and Giovannini (1995) found, at 4 months, that psychomotor development was also related to red blood cell levels of DHA and AA. Some have argued that red blood cell DHA concentration does not necessarily represent DHA in brain tissue (Jorgensen, et al., 1996). However, higher concentrations of DHA and AA were found in the brain tissue of breastfed infants, who died of cot death at 2 to 9 months, than those who were formula-fed (Farquharson, Cockburn, Patrick, Jamison, & Logan, 1992; Farquharson, et al., 1995).

Lucas (1998) explained the importance of an experimental approach to determining the nutritional influences in breast milk. Randomized controlled trials, similar to those used to test the effects of various drugs and other substances on humans must be employed to this end (Lucas, 1998). Two Cochrane reviews have been published on randomized trials of the effects of LCPUFA supplementation to infant formula on neurodevelopment, one for term infants (Simmer, 2004) and one for pre-term infants (Simmer & Patole, 2004). The term infant review, last updated in June 2001 and including 8 studies of good quality, concluded that LCPUFA supplementation did not significantly improve the development of term infants including, visual, intellectual, language development and growth (Simmer, 2004). The pre-term infant review, last updated in October 2003 and including 9 studies of high quality, also concluded that LCPUFA supplementation provided no long-term benefits to healthy pre-term infants in visual and intellectual development and growth (Simmer & Patole, 2004). Better studies are suggested including standard LCFUPA dosages, duration and preparations, larger sample sizes, and longer follow-up (Lucas, et al., 1999). However, for both term and pre-term infants, other reviews have reached opposing conclusions and point to the relative safety of supplementing infant formula with DHA and AA as reason to encourage this practice in light of conflicting evidence of developmental benefit (Cockburn, 2003).

1.6.3 The Socio-emotional Environment

What happens during breastfeeding that influences the child's neurodevelopment, other than the ingestion of breast milk substances? Development of the nervous system depends not only on genetic guidance and adequate nutrition but also on the amount, quality, and timing of sensory stimulation to the developing infant (Cockburn, 2003). This sensory stimulation is mostly determined by the child's relationship with the mother, as well as by social and emotional supports she receives while raising her child (Cockburn, 2003). Therefore, the attitudes and behaviors of breastfeeding mothers may be equally important to the substances transferred in breast milk in determining the neurodevelopment of their child.

Several components of the breastfeeding relationship have been suggested as enhancers of infant stimulation. In one study breast odors of unfamiliar lactating women were preferred by infants (with no prior breast feeding experience) to breast odors of non-lactating women (Makin & Porter, 1989). The skin- to-skin contact involved in breastfeeding is thought to decrease stress and irritability in the infant and promote interaction between mother and child (Uauy & Andraca, 1995). Infant sucking releases prolactin and oxytocin in the mother, which are thought to contribute to "mothering behavior" (Drane & Logemann, 2000). Finally, in a study of premature infants, those who received the most breast-milk also received the most maternal affectionate touch and were the most alert during mother-child interactions (Feldman & Eidelman, 2003). The interaction of mother and child during breastfeeding is frequent and complex and it may well be impossible to separate the mother from her milk (Rogan & Gladen, 1993).

While it is commonly believed that breastfeeding strengthens mother-infant bonding, there is little research on mother-child bonding during breastfeeding (Ewing & Morse, 1989). The dominance of the physiological perspective (i.e., LCPUFA) over the behavioral one (i.e., the nursing dyad) appears to reflect the political climate surrounding breastfeeding research rather than a lack of theoretical support for a behavioral advantage of breastfeeding (Ewing & Morse, 1989).

1.7 Methodological Issues

The greatest limitation to quantitative studies of breastfeeding is the self-selection of participants. It is unethical to randomly assign infants to breast milk and formula groups since this would deprive mothers of known health benefits for their children and themselves (AAP, 2005), as well as choice in child rearing. Studies on breastfeeding and childhood intelligence have used observational designs, either case-control designs or descriptive correlational studies (Anderson et al., 1999). Statistical control of potential confounding variables is therefore of great importance to the validity of a study.

Randomized controlled trials of formula vs. breast milk have been possible only with infants born prematurely because food intake by these infants is carefully monitored and ingested in a standard way, i.e. by tube (Lucas et al., 1990; Lucas, et al., 1998). Because of the use of randomized trials, the evidence for beneficial effects of breast milk in pre-term infants is more accepted and compelling by clinical practitioners than evidence in the term population (Rey, 2003). However, results for the premature population, who receive breast milk at a time of nervous system vulnerability, may not be easily generalized to children born at term.

Drane and Logemann (2000) critically evaluated studies on infant feeding and cognitive development published between 1966 and 1998 using the following criteria: definitions of outcomes, classification of infant feeding, and control of confounders. Only 5 of 24 studies met the standards in all three areas of evaluation (Horwood & Fergusson, 1998; Lucas, et al., 1994; Lucas, et al., 1992; Malloy & Berendes, 1998; Pollock, 1994). Some have suggested that even these studies include significant weaknesses (Rey, 2003). Jain and colleagues (2002) also produced a critical analysis of studies on breastfeeding and cognitive development, from 1929 to 2001. With a more detailed examination, they found only two studies were methodologically acceptable, one that supported the relationship between breastfeeding and cognitive development (Johnson, Swank, Howie, Baldwin, & Owen, 1996) and one that did not (Wigg et al, 1998). Burgard (2003) also provided a critical evaluation of the methodology of studies on cognitive development and breastfeeding, including classification of infant feeding, definitions of outcomes, and control for confounding variables. It is clear that there is room for improvement in the way in which research is conducted in this field of study.

1.7.1 Classification of Infant Feeding

Clear and precise operational definitions of breastfeeding intensity and duration have been missing in past studies. The majority of studies used the dichotomous variables of breastfed or formula-fed to define groups (Drane & Logemann, 2000). Misclassification of participants can dilute the differences between groups by combining partially and exclusively breastfed children in the breastfed group (Broad, 1972; Temboury, et al., 1993). When partially breastfed infants were considered separately, effect sizes tended to be larger (Drane & Logemann, 2000). However, there was great variation and lack of clarity as to how much breast milk partially breastfed infants actually received (Vestergaard, et al., 1999). Furthermore, while exclusive breastfeeding is often understood to mean no other types of milk or formula were given, the reader is often left to assume this definition (Agostoni et al., 1995). Even when partially and exclusively breastfed groups were well defined, it may have been difficult for mothers to judge the amounts of breast milk their child ingested as a percentage (R. Hewat, personal communication, June 17, 2002).

Other breastfeeding group classification errors have been reported. For example, groups may be determined by the mother's pre-natal feeding intentions (Lanting et al, 1998) rather than by the actual feeding outcome. In some studies, only short durations of breastfeeding have been considered (Drane & Logemann, 2000). "Bottle-feeding" may have been used to define the formula-fed group (Morrow-Tlucak et al., 1988; Rogan & Gladen, 1993). However, many mothers who bottle-fed their infants expressed breast milk for a number of the feedings. Grouping breastfeeding with bottle-feeding of expressed breast milk reflects the influence of the biochemical hypothesis that a substance in breast milk is the key agent. However, the behavioral hypothesis, that suckling at the breast improves mother-infant bonding and thus affects development, can only be supported by a classification of breastfeeding that considers receiving breast milk from a bottle as a separate group (Gordon, 2000).

Finally, what is understood to be infant formula has changed drastically over the last 100 years. From unmodified cow's milk in the 1920's, to basic commercial infant formula in the 1960's, to today's variety of specialized formulas (e.g. preterm, newborn, toddler) including DHA and AA supplementation, "formula" must not be mistaken to be of static nutrient composition (R. Hewat, personal communication, June 18, 2002).

1.7.2 Definition of Outcomes

Most studies define outcomes using standardized measurements (Anderson et al., 1999; Drane & Logemann, 2000). However, the variety of standardized tests used to study the relationship between breastfeeding and neurodevelopment has led to variations in effect sizes for the positive results of some studies (Drane & Logemann, 2000). In the research on cognitive development in particular, studies often rely on psychometric tests that are well standardized and have good internal consistency but lack the sensitivity and specificity of more functional measures of academic achievement and educational success (Burgard, 2003). Another concern is the lack of specificity of behavioral measures of neurodevelopment in detecting subtle biochemical changes in the nervous system (Uauy & Peirano, 1999). Recent studies have used electrophysiologic measurements, such as brainstem auditory-evoked responses measuring brainstem maturation, to detect the benefits of breastfeeding (Amin, Merle, Orlando, Dalzell and Guillet, 2000).

1.7.3 Control for Confounding Variables

Neurodevelopment is related to multiple, sometimes interrelated, factors (confounders or covariates). Genetics, child health, pregnancy and birth events will all affect developmental outcome. Environmental factors, such as economic deprivation (Duncan, Brooks-Gunn, & Klebanov, 1994), family ecology, mother-child interaction, environmental quality (Bee et al., 1982), maternal smoking (Niemela & Jarvenpaa, 1996), maternal obesity (Neggers, Goldenberg, Ramey, & Cliver, 2003), postpartum depression (Murray, 1992), maternal education, ethnic background (Ivanans, 1975) and parental life changes (Bee, Hammond, Eyers, Barnard, & Snyder, 1986), have been shown to affect a child's development.

A mother's choice to provide breast milk to her child has nearly always been found to be associated with the mother's education, socioeconomic status, and other "positive health behaviours" that can independently favour neurodevelopment (Lucas et al., 1992). Exclusion criteria to control for such factors often create a uniform group of children from "well off" families with advantaged medical and social histories, which may be unrepresentative of the wider population (Pollock, 1994). To further complicate matters, health education programs promoting breastfeeding may alter the environmental factors associated with breastfeeding over time (Pollock, 1994; Rogan & Gladen, 1993).

Without the ability to randomly assign groups, studies on breastfeeding must control possible confounding factors by statistical means. Most studies gather information on 5 to 12 possible confounders (Anderson et al., 1999) but rarely provide reasons for inclusion of these particular variables (Burgard, 2003). Confounding variables most frequently controlled are socioeconomic status, maternal education, child's sex, and birth weight (Burgard, 2003). Less frequently controlled are maternal smoking, drug or alcohol use during pregnancy, infant health status (Drane & Logemann, 2000), race or ethnicity, parenting behavior and attitude, the home environment, and paternal characteristics (Anderson et al., 1999). The child's genetic predisposition has yet to be adequately controlled in any study (Anderson, et al., 1999; Lucas, et al., 1992). At best, proxy measurements of genetic predisposition may be obtained by measures of maternal and paternal intelligence (Johnson et al., 1996), however this is rarely attempted. Furthermore, when maternal intelligence (measured by verbal IQ), is controlled, the benefit of breastfeeding is substantially reduced (Jacobson & Jacobson, 2002). Of even greater interest, but poorly addressed to date, is the amount and quality of stimulation provided by the breastfeeding relationship (Burgard, 2003) as well as the quality of parenting in general (Jacobson & Jacobson, 2002).

1.7.4 Sources of Error and Statistical Analysis

Poor study design introduced significant error in many studies of breastfeeding and neurodevelopment. Some studies involved testers who were "not specifically blind to feeding method," (Jorgensen et al., 1996; Rogan & Gladen, 1993). Retrospective studies often rely on 5-year or longer recall (Hoefer & Hardy, 1929; Pollock, 1994) or incomplete medical records of breastfeeding duration and exclusivity (Gale & Martyn, 1996), leading to potential misclassification of participants (Rey, 2003). However, some studies have found an adequate correlation of mother's recall with information on breastfeeding duration from medical records (Lanting et al., 1998).

Statistical weaknesses also reduce the validity of many studies. Frequently there is inadequate statistical power, either through small sample sizes or misclassification of participants, to detect small differences between groups (Pollock, 1994). Researchers rarely conduct power analyses to identify sample sizes that could lead to significant results (Anderson, et al., 1999). Reporting of statistical parameters (rather than just determining "significant" or "non-significant" differences) and descriptive statistics of confounders are often missing or sub-optimal (Burgard, 2003). As well, effect sizes calculated differently cannot be compared across studies (Burgard, 2003). Finally, there is often a strong correlation between the confounding variables (e.g., birth weight and gestational age) included in regression analysis. This collinearity of data may result in magnified error terms and reduced statistical power (Drane & Logemann, 2000).

1.7.5 Interpretation of Results

The ultimate question in this research is of what clinical importance are the small but significant advantages in neurodevelopment that accrue from longer breastfeeding? Opinions vary considerably on this issue (Burgard, 2003). For a healthy infant, very small improvements in scores on standardized tests may not provide a significant advantage for later success in education, career or social adaptation (Drane & Logemann, 2000). However when small increases in neurodevelopment are applied to a whole population, assuming breastfeeding will convey the same benefits to every child and not only to specific groups, the effect on society might be considerable (Burgard, 2003; Drane & Logemann, 2000). There is more agreement on the clinical importance of the benefits of breastfeeding to the neurodevelopment of pre-term infants, a group in which a considerable proportion will require special education services later in life (Burgard, 2003). An increase of 8 points on cognitive tests is thought to be extremely important (Drane & Logemann, 2000).

Drane and Logemann (2000) attempted a preliminary calculation of the economic benefits to breastfeeding at the population level. They suggested that a 3-point increase in cognitive development would shift a proportion of the population above the cut-off level for mental retardation, subsequently reducing the cost of special education (Drane & Logemann, 2000). However, this must be interpreted cautiously as it is still unclear if breastfeeding will act uniformly on all members of the population.

Another controversial conclusion relates to the durability of the neurodevelopmental benefits of breastfeeding. Although cognitive development in breastfed children has been reported to be greater at 1 to 18 years of age, it is not uncommon for the effects of early childhood to persist into adulthood. What may be at work is a favourable family environment rather than biochemical effects of breastfeeding (Burgard, 2003). There is no simple answer to the clinical importance of breastfeeding. There are possibly multiple interacting factors for different groups of mothers and children (Burgard, 2003).

1.8 Suggestions for Future Studies

Even after 75 years of study, we still do not adequately understand the relationship of breastfeeding to neurodevelopment. As Jacobson and Jacobson (2002) wrote:

> The controversy in this literature is not about whether there is an enhanced [neurodevelopment] among the breastfed children, but whether this difference reflects a nutritional advantage or a difference in socio-environmental factors that are generally more optimal among women who breastfeed for an extended period of time." (p. 258)

Future studies should include a dose-type classification of infant feeding that separates exclusively breastfed from partially breastfed groups, including longer durations of breastfeeding. Statistical reporting must include the values of the test parameters to determine the magnitude as well as the significance of the effects, as well as a check for colinearity among the confounders studied. Confounders considered should include better measures of parental attitudes and behaviour, such as the HOME (Caldwell & Bradley, 1984), as well as direct measures of maternal verbal intelligence. As Jain and colleagues (2002) concluded:

> An ideal observational study to measure the true effect of breastfeeding on intelligence would follow full-term infants longitudinally, define and measure breastfeeding with sufficient detail and appropriate timing, control for socio-economic status and the stimulation a child receives, measure intelligence using a standardized instrument at age 2 or greater by observers unaware of feeding status, and report an effect size of some other metric to interpret the quantitative magnitude of results. (p. 1051).

In addition, we have much to learn about that goes on in the breastfeeding relationship of mother and child. As Burgard pointed out, we must address the question: "What do breastfeeding mothers do with their children?" (2003, p.7) before we can determine what it is about breastfeeding that leads to better neurodevelopment. Regardless of the debate on the neurodevelopmental benefits, breastfeeding has many other established benefits for the child, mother and society (American Academy of Pediatrics, 2005). We must all work to ensure that breastfeeding is the easiest and preferred choice, when possible, for mothers worldwide.

1.9 References

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CHAPTER 2

The Relationship of Breastfeeding to Mental and Motor Development in Children Under Two Years of Age[1]

2.1 Introduction

Breastfeeding involves the occupational performance of a mother-child dyad within a physical, social, economic and cultural environment and, for many mothers, constitutes the primary occupation of motherhood for the greater part of the child's first year. Occupational therapists are involved also in the rehabilitation of infants with feeding difficulties in a variety of health care and community settings (Caretto, Topolski, Linkous, Lowman & Murphy, 2000; Seabert, Eastwood & Harris, 2005). Occupational therapists are equally concerned with optimizing child developmental outcomes in order to enhance a person's health.

Mental development has been linked to greater educational and occupational success (McCall, 1977), job performance in "manual" and "mental" occupations (Hunter, 1986), and decreased criminality and delinquency (Moffitt, Gabrielli, Mednick, & Schulsinger, 1981). Mental impairment and disability have been associated with health indicators such as unemployment, poor housing, and low education (Epp, 1986). Mental development therefore contributes substantially to health status. Furthermore, the monetary costs to a society of sub-optimal cognitive development can be considerable if one investigates the costs related to special education, and other social services, for children falling into the range of learning disability or mental retardation (Drane & Logeman, 2000). As occupational therapists develop their role in health promotion and community health (American Occupational Therapy Association, 2001; Baum & Law, 1998; Canadian Association of Occupational Therapists, 1998; Finlayson & Edwards, 1995), a compelling argument exists for their study of breastfeeding to enhance health and occupational performance of children and mothers (Law, Polatajko, Baptiste, & Townsend, 2002). As a multi-faceted and broadly influential component of a child's early years, breastfeeding is best studied from the holistic perspective that is characteristic of occupational therapy.

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Breastfeeding has been strongly associated with improved infant health, growth, and development (American Academy of Pediatrics, 2005). A dose-response pattern with longer breastfeeding duration correlated with greater intelligence has been suggested (Horwood & Fergusson, 1998). However, the relationship between breastfeeding and motor development has not been shown to be as strong (Angelsen, Vik, Jacobsen & Bakketeig, 2001; Florey, Leech & Blackhall, 1995).

Three main theories support the relationship of breastfeeding to a child's mental and motor development. A behavioral theory implies that a child's development is enhanced by the promotion of child-mother bonding, stimulation and interaction, through the experience of suckling a child at the breast (Pollock, 1994). A physiological theory, involving the role of long chain polyunsaturated fatty acids (LCPUFA) or some other substance of breast milk in the development of the infant nervous system, has also been supported in the literature (Cockburn, 2003; Donovan & Odle, 1994; Lucas, 1998). Finally, a genetic theory suggests that children who are innately better off neurologically will show better performance in many behaviors, including breastfeeding.

Although the protective effect of breastfeeding on mental development of those who were breastfed has been studied for the past 50 years, many studies have been inadequately designed to appropriately address this relationship (Burgard, 2003). Mothers who breastfeed are typically, older, married, more educated, have higher incomes and participate in more health-related behaviors than mothers who do not breastfeed (Maclean, 1998; Pesa & Shelton, 1999). A child's development results from the interplay of their genetic predisposition and multi-factorial environmental influences (Bee et al, 1982). Because it would be unethical to conduct randomized controlled trials to examine the effects of breastfeeding, numerous confounding variables must be addressed. Past studies have not always controlled adequately for the socio-economic status of the family and the quality of the child's stimulation, which have been found to influence child development (Jain, Concato & Leventhal, 2002). As well, breastfeeding definitions in previous studies have often failed to capture a dose- response relationship by separating children into breastfed and non-breastfed groups, rather than the duration of breastfeeding.

This study addressed the question: Is the duration of maternal breastfeeding related to mental and motor development at 18 months in healthy, full-term children?

2.2 Methods

2.2.1 Study Design

Only recently has a dose-response relationship between the duration of breastfeeding and mental and motor development been more frequently investigated (Horwood & Fergusson, 1998; Mortensen, Michaelsen, Sanders & Reinisch, 2001; Quinn et al., 2001). Some studies still group children of different breastfeeding durations together into the same categories, thus diluting the effect of longer breastfeeding (Angelsen et al., 2001; Wigg et al., 1998).

This descriptive study examined the relationship between the duration of exclusive and partial breastfeeding (dose) and a child's mental and motor development (response). Relationships of several possible confounding variables to mental and motor development were examined also.

2.2.2 Sample Size

In previous studies, power analysis was rarely conducted to ensure that a sample could produce significant results (Anderson, Johnstone, & Remley, 1999; Pollock, 1994). To avoid a type II statistical error in this study, a power analysis was conducted to estimate the sample size needed to achieve a power of 80% (i.e. there is a 20% chance of committing a type II statistical error or rejecting a hypothesis that is true) in a multiple regression analysis. Effect size (r^2) was estimated to be a regression coefficient of 0.15, based on results of a previous study (Paine, Makrides, & Gibson, 1999). The number of significant independent variables was estimated to be five (Anderson et al., 1999; Paine et al., 1999). Using the equation for sample size (N) from Portney and Watkins (2000):

$$N = (\lambda\ (1 - r^2))/\ r^2$$

The sample size required to achieve a power of 80% was determined to be 79 subjects. A sample of 80 mother-child dyads was recruited to enhance the potential for obtaining a significant result.

2.2.3 Operational Definitions

Data on both exclusive and partial breastfeeding duration were obtained for this study. Using definitions from the Breastfeeding Committee for Canada, exclusive breastfeeding was the time in months, from birth, that a child received "no food or liquid other than breast milk, not even water…" (2004; p.1). Partial breastfeeding included both the Breastfeeding Committee for Canada (2004) definitions of "predominant breast milk" feeding (breast milk plus 1-2 feedings of foods or milks during the last 7 days) and "partial breast milk" feeding (breast milk plus 3 or more feedings of other foods or milks during the past 7 days). Thus, partial breastfeeding in this study was defined as the duration of breastfeeding in months including the time that formula, other milks or foods were introduced into the child's diet.

Mental development was defined as the standard score on the Mental Development Index (MDI) of the Bayley Scales of Infant Development, Second Edition (BSID-II; Bayley, 1993). Motor development was defined as the standard score on the Psychomotor Development Index (PDI) of the BSID-II.

2.2.4 Confounding Variables

Development is influenced by multiple, sometimes interrelated, factors (confounding variables or covariates), all of which must be controlled in some way in order to examine the true relationship between infant development and breastfeeding. A mother's choice to provide breast milk to her child has been found to be associated with other parenting factors and "positive health behaviors" (Lucas, Morley, Cole, Lister, & Leeson-Payne, 1992, p. 263). Breastfeeding mothers are typically older, more educated, with higher family income and more social support. Breastfed children may experience what Pollock (1994) termed the "healthy worker" effect: infants who succeed at breastfeeding constitute an advantaged group based on the absence of childhood illness, stress, or other biological and environmental factors which would have led to the failure of breastfeeding.

Environmental factors, such as economic deprivation (Duncan, Brooks-Gunn, & Klebanov, 1994), family ecology, mother-child interaction, environmental quality (Bee et al., 1982), housing quality (Ozmert, et al., 2005), parental smoking (Niemela & Jarvenpaa, 1996), postpartum depression (Murray, 1992), maternal education, ethnic background (Ivanans, 1975) and parental life change (Bee, Hammond, Eyers, Barnard, & Snyder, 1986), have all been shown to relate significantly to a child's development.

Because it would be unethical to randomly assign groups to breastfeeding vs. non-breastfeeding, potential confounding factors must be addressed by statistical means. Most studies include 5 to 12 covariates (Anderson et al., 1999). Covariates most frequently controlled were socioeconomic status, child's sex, maternal education, birth weight, parity, gestational age, maternal intelligence, and maternal smoking (Anderson et al., 1999). Less frequent covariates were race or ethnicity, parenting behavior, childhood experiences, family size, and paternal characteristics (Anderson et al., 1999).

Mothers' diet during pregnancy and breastfeeding is not usually considered because, while breast milk composition may vary significantly within a day or week, a mother will meet her child's nutritional needs by increasing or decreasing volume (Mitoulas et al., 2002; Picciano, 1998). In the case of significant malnutrition, the child will receive the nutrients needed from breast milk at the expense of the mother (Azizi, Sadeghipour, Siahkolah & Rezaei-Ghaleh, 2004; Rogers, Golding & Emmett, 1997).

Due to study design and ethical implications, adequate control has yet to be achieved for the child's genetic predisposition or the amount of stimulation provided by the breastfeeding relationship (Burgard, 2003; Drane & Logemann, 2000; Rey, 2003). Proxy measurements of genetic predisposition have been obtained by measures of maternal and paternal education (Quinn et al., 2001).

For this study, data for a number of possible confounding variables were collected: prenatal and birth characteristics, child characteristics, parent characteristics, environmental characteristics and feeding characteristics. See Table 2.1 for a list of the possible confounding variables collected in this study.

2.2.5 Instrumentation

A self-report questionnaire (Appendix I), developed by the first author (AP), was used to gather information on breastfeeding duration, feeding practices, and the home environment. A mother's 5-year recall has been correlated moderately with information on breastfeeding duration from medical records (Lanting, Patandin, Weisgals-Kuperus, Touwen, & Boersma, 1998).

A score for the quality of the home environment was calculated from 39 questions based on the Home Observation for Measurement of the Environment (HOME, Caldwell and Bradley, 1984), infant-toddler (IT) version, for children from birth to 3 years of age. The HOME has been used to control for aspects of the home environment (Jacobson, Chiodo & Jacobson, 2002; Wigg, et al., 1998). Questions cover the emotional and verbal responses of the caregiver, avoidance or restriction and punishment, organization of the physical and temporal environment, provision of appropriate play materials, caregiver involvement with the child, and opportunities for variety in daily stimulation (Caldwell & Bradley, 1984). The number of incorrect answers was totaled to produce the raw score. The IT-HOME is a measure of the physical environment and child-caregiver relationship based on observation of the child in his/her home environment with a primary caregiver. Thus, the home environment score obtained from parent completion of the questionnaire does not provide a validated score but rather a simple measure of the adequacy of the home environment.

A second questionnaire (Appendix II) was used to collect other background information on pregnancy and birth, child health and parent demographics. This questionnaire, developed by the second author (SRH), in the previous study, from which the data for the Phase I sample were collected.

The BSID-II consists of three scales: Mental Development, Psychomotor Development and the Behavior Rating Scale, which measures the child's behavior during testing. The BSID-II was derived from a number of infant development scales and has been characterized as "theoretically eclectic" (Bayley, 1993). It can be used as a diagnostic tool, a measure of progress, a teaching tool for parents and caregivers, or a research tool (Bayley, 1993).

Mental development was measured by scores on the MDI (Bayley, 1993), designed to assess memory, habituation, problem solving, number concepts, generalization, classification, vocalizations, language and social skills in children aged 1 to 42 months of age (Bayley, 1993). The MDI consists of 24 to 30 items (depending on the child's age). Motor development was measured by scores on the PDI, designed to assess control of gross and fine muscle groups (Bayley, 1993). The PDI consists of 14 to 21 items (depending on the child's age).

Both the MDI and PDI must be administered according to standard procedures, and together take approximately 25 to 60 minutes to administer (Bayley, 1993). Standard scores for the BSID-II were derived from a sample of 1700 children from the United States (Bayley, 1993). The sample was stratified according to race, gender, geographic region, and parental education. Both the MDI and PDI standard scores have means of 100 and standard deviations of 15.

2.2.6 Reliability and Validity of MDI and PDI Scores

Inter-rater reliability was examined for MDI and PDI scores. Five testing sessions were videotaped (with parental permission) by the first author (AP) and labeled according to a code, which did not reveal characteristics of the child or parents. A second research assistant, who was familiar with 18-month BSID-II testing, scored the MDI and PDI from the videotapes. Agreement of scores was determined by paired samples correlation (r).

The validity of the MDI, as a measure of infant intelligence, and PDI, as a measure of motor skills, are described extensively in the administration manual (Bayley, 1993). Content validity by consultation with a group of experts, construct validity by correlations among items and factor analysis, and discriminant validity of developmentally "normal " and "at risk" children have been established (Bayley, 1993). Concurrent validity has been investigated by comparison with other tests of cognitive development in children. Moderate to strong correlations were found between BSID-II scores and the McCarthy Scales of Children's Abilities ($r = 0.79$ for mental abilities and $r = 0.59$ for motor abilities) as well as the Wechsler Preschool and Primary Scale of Intelligence-Revised ($r = 0.73$; Bayley, 1993).

2.2.7 Recruitment and Data Collection

This study consisted of two phases of data collection. Both phases received ethics approval from the Behavioral Research Ethics Board of the University of British Columbia (Appendix III and Appendix IV). Phase II was approved also by the Vancouver Coastal Health Research Institute, Vancouver Community (Appendix V).

Phase I

A volunteer sample was recruited from a group of children assessed on the BSID-II (MDI and PDI) in a previous study (conducted by the second author, SRH). This sample consisted of children tested from 2000 to 2002 who resided in British Columbia's Lower Mainland. A convenience sample of children known to the investigator was used, plus some "snowball sampling". In December 2003, 66 families were sent a letter (Appendix VI and Appendix VII) and the breastfeeding questionnaire described above and asked to return the questionnaire by mail as consent to participate in the study. Background information on these children was available from the previous study's database.

Phase II

A volunteer sample of children was recruited from a variety of health units and community groups, in British Columbia's Lower Mainland Area, from February 2005 to April 2006 (Appendix VIII and Appendix IX). Snowball sampling was also attempted by inviting participants to recruit families they knew. The child's family was asked not to discuss their method of feeding with the investigator or research assistant to preserve blinding to breastfeeding duration.

A single research assistant collected all the data for Phase II. After contacting the child's family by phone and arranging a testing time, she traveled to the family home and administered the MDI and PDI according to the standard procedures outlined in the test manual (Bayley, 1993). The parent then completed the background information as well as the breastfeeding and home environment questionnaires while the research assistant scored the tests and put away materials. To ensure that the research assistant remained blinded to the duration of breastfeeding, questionnaires were not reviewed prior to scoring the BSID-II. Although the BSID-II manual discourages using the home as the testing environment due to the difficulty in minimizing distractions (Bayley, 1993), all children were tested in their homes, making the effect of distractions similar for all participants.

Written consent to participate in the study was obtained at the time of testing (Appendix X) and parents were paid an honorarium for their participation (Appendix XI). When needed, the first author (AP) obtained missing questionnaire data through a follow-up phone call. Information for each participant was placed in a separate file, which was kept in locked storage to ensure confidentiality.

2.2.8 Data Analysis

Data collected from mother-child dyads were entered into a computer spreadsheet kept under the same secure conditions as the individual files and protected by a password. Descriptive statistics were computed on all variables in the study. Correlations for exclusive or partial breastfeeding duration and mental or motor development were calculated. The relationships of covariates with mental and motor development were investigated to identify variables that could confound the primary relationship of interest (i.e., between breastfeeding duration and mental and motor development). The relationship of covariates with breastfeeding duration was conducted to eliminate those that co-varied, in preparation for multiple regression analysis. Multiple regression analysis was planned to examine the relative influences of exclusive or partial breastfeeding duration and the covariates on mental and motor development. Intraclass correlation coefficient was calculated using model 2, for rater representative of a population of similar raters (Protney & Watkins, 2000). Level of significance was set at $p \leq 0.05$. Statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS) for Windows version 13 (SPSS Inc., Chicago, IL USA).

2.3 Results

Eighty mother-child dyads were recruited for this study. In Phase I, 45 of the 66 families (68%) who were sent participation letters returned completed questionnaires. In Phase II, 35 children were recruited and tested. Table 2.1 shows the descriptive characteristics of the total sample as well as those for the Phase I and II groups. Differences between characteristics of participants in the Phase I and II groups were calculated with a chi-square test for categorical variables and *t*-tests for continuous variables.

Participant dyads from Phases I and II differed significantly in some variables. More mothers from Phase I reported alcohol consumption during pregnancy than mothers in Phase II (p=0.02). Mothers in Phase I were on average 2 years younger (p=0.02) and fathers 2.3 years younger (p=0.05) than their counterparts in Phase II. A greater proportion of Phase I fathers had a university degree (77%) than those in Phase 2 (49%). Duration of partial breastfeeding was, on average, 2.1 months shorter by mothers in Phase I than by those in Phase II (p=0.04).

TABLE 2.1: Descriptive Characteristics of the Sample

Mean ± standard deviation or number of subjects and (percentage) for Phase I, Phase II and Total sample groups. Probability (p) the difference between Phase I and Phase II is due to chance (Chi^2 or t-test).

Prenatal/Birth Characteristics	**Total (n = 80)**	**Phase I (n = 45)**	**Phase II (n = 35)**	***p***
Birth Weight (grams)	3620 ± 405	3665 ± 406	3560 ± 403	0.25
C-section birth	20 (25%)	11 (24%)	9 (26%)	0.90
Pregnancy Nicotine	3 (4%)	3 (7%)	0	0.12
Pregnancy Alcohol	22 (28%)	17 (38%)	5 (14%)	**0.02**
Pregnancy Rx/OTC Drugs	15 (19%)	11 (24%)	4 (11%)	0.14
Child Characteristics				
Gender (girls)	37 (46%)	21 (47%)	16 (46%)	0.93
Age at testing (months)	18.6 ± 1.3	18.6 ± 1.0	18.7 ±1.6	0.65
MDI standard score	102 ± 10	102 ± 11	102 ±10	0.92
PDI standard score	96 ± 8	95 ± 8	97 ± 9	0.41
Ear infections	4 (5%)	1 (2%)	3 (9%)	0.20
Visual Impairment	2 (2%)	2 (4%)	0	0.21

TABLE 2.1 (Continued): Descriptive Characteristics of the Sample

Mean ± standard deviation or number of subjects and (percentage) for Phase I, Phase II and Total sample groups. Probability (p) the difference between Phase I and Phase II is due to chance (Chi^2 or t-test).

Parent Characteristics	**Total (n = 80)**	**Phase I (n = 45)**	**Phase II (n = 35)**	***p***
Mother's Age (years)	33.3 ± 3.8	32.4 ± 3.2	34.4 ± 4.2	**0.02**
Mother's Education				
High School	4 (5%)	2 (4%)	2 (6%)	
Technical Diploma	15 (19%)	5 (11%)	10 (29%)	
University Degree	61 (76%)	38 (84%)	23 (66%)	0.12
Mother's Race				
Caucasian	73 (91%)	41 (91%)	32 (91%)	
Asian	6 (8%)	3 (7%)	3 (9%)	
East Indian	1 (1%)	1 (2%)	0	0.65
Mother's Marital Status				
Married	77 (96%)	44 (98%)	33 (94%)	
Common-law	2 (3%)	1 (2%)	1 (3%)	
Single	1 (1%)	0	1 (3%)	0.51
Father's Age (years)	35.8 ± 5.1	34.8 ± 4.0	37.1 ± 6.1	**0.05**
Father's Education				
High School	8 (10%)	3(7%)	5 (14%)	
Technical Diploma	21 (26%)	8 (18%)	13 (37%)	
University Degree	51 (64%)	34 (77%)	17 (49%)	**0.04**
Father's Race				
Caucasian	70 (88%)	38 (84%)	32 (91%)	
Asian	4 (5%)	2 (4%)	2 (6%)	
East Indian	2 (3%)	2 (4%)	0	
Native American	1 (1%)	0	1 (3%)	
Other	3 (4%)	3 (7%)	0	0.25

TABLE 2.1 (Continued): Descriptive Characteristics of the Sample

Mean ± standard deviation or number of subjects and (percentage) for Phase I, Phase II and Total sample groups. Probability (*p*) the difference between Phase I and Phase II is due to chance (Chi^2 or t-test).

Environment Characteristics	**Total (n = 80)**	**Phase I (n = 45)**	**Phase II (n = 35)**	***p***
Modified HOME raw score (failures)	4.3 ± 1.9	4.5 ± 1.7	4.1 ± 2.1	0.28
Birth order				
First	51 (64%)	26 (58%)	25(71%)	
Second	23 (29%)	16 (36%)	7(20%)	
Third	6 (7%)	3 (7%)	3 (9%)	0.31
Mother smokes	3 (4%)	2 (4%)	1 (3%)	0.71
Father (or others) smoke	1 (1%)	0	1 (3%)	0.25
Feeding Characteristics				
Feeding breast milk in bottle				
Never	15 (19%)	6 (13%)	9 (26%)	
Rarely	32 (40%)	20 (44%)	12 (34%)	
Once a week	10 (12%)	4 (9%)	6 (17%)	
Once a day	16 (20%)	10 (22%)	6 (17%)	
Several times a day	6 (8%)	4 (9%)	2 (6%)	
For all feedings	1 (1%)	1 (2%)	0 (0%)	0.48
Age at introduction of other food	5.2 ±1.0	5.1 ± 1.1	5.3 ± 0.9	0.41
Exclusive Breastfeeding (months)	4.3 ± 1.9	4.2 ± 2.0	4.5 ± 1.7	0.39
Partial Breastfeeding (months)	13.1 ± 4.8	12.2 ± 4.5	14.3 ± 4.8	**0.04**

2.3.1 Breastfeeding Duration and Mental and Motor Development

Correlations of exclusive and partial breastfeeding duration with mental and motor development, determined by the Pearson product-moment correlation coefficient (Pearson *r*), are reported in Table 2.2. None were statistically significant.

TABLE 2.2: Relationships of Breastfeeding Duration and Mental and Motor Development on Bayley II

Correlations (Pearson *r*) of mental development (MDI) and motor development (PDI) with exclusive breastfeeding and partial breastfeeding durations. Probability (*p*) the correlation is due to chance.

	Exclusive Breastfeeding	**Partial Breastfeeding**
Mental Development	$r = 0.142$ $p = 0.21$	$r = 0.162$ $p = 0.15$
Motor Development	$r = 0.155$ $p = 0.17$	$r = 0.211$ $p = 0.06$

The relationships of breastfeeding with mental and motor development are represented graphically in Figures 2.1 to 2.4. Those data points in Figures 2.1 to 2.4 falling below MDI or PDI scores of 80 were considered as possible outliers. However, removal of these points did not significantly change the correlation coefficients. Furthermore, one would expect 16% of a sample to fall outside 1 standard deviation in a normally distributed variable such as MDI and PDI (Bayley, 1993).

A correlation coefficient above 0.8, for raters representative of other similar raters, was deemed acceptable for inter-rater reliability (Portney & Watkins, 2000). Inter-rater correlation coefficients were 0.91 for MDI scores and 0.83 for PDI scores.

Figure 2.1: The Relationship of Exclusive Breastfeeding and Mental Development

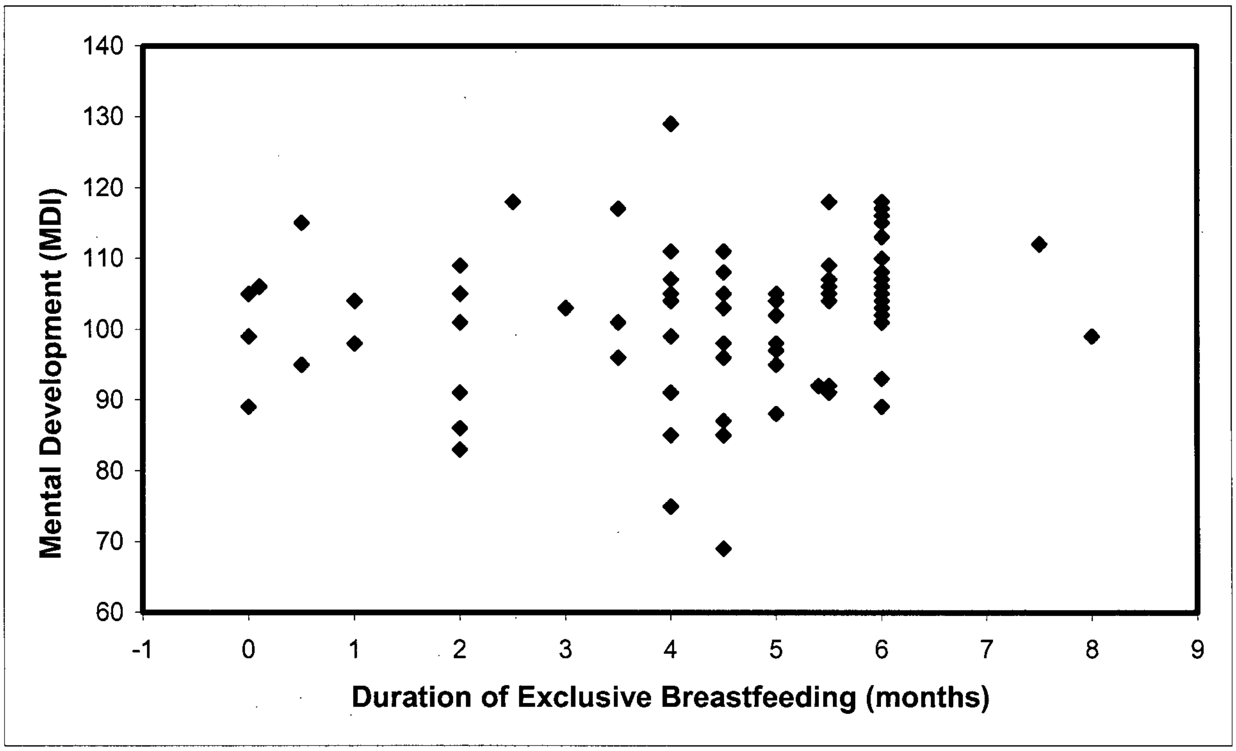


Figure 2.2: The Relationship of Partial Breastfeeding and Mental Development

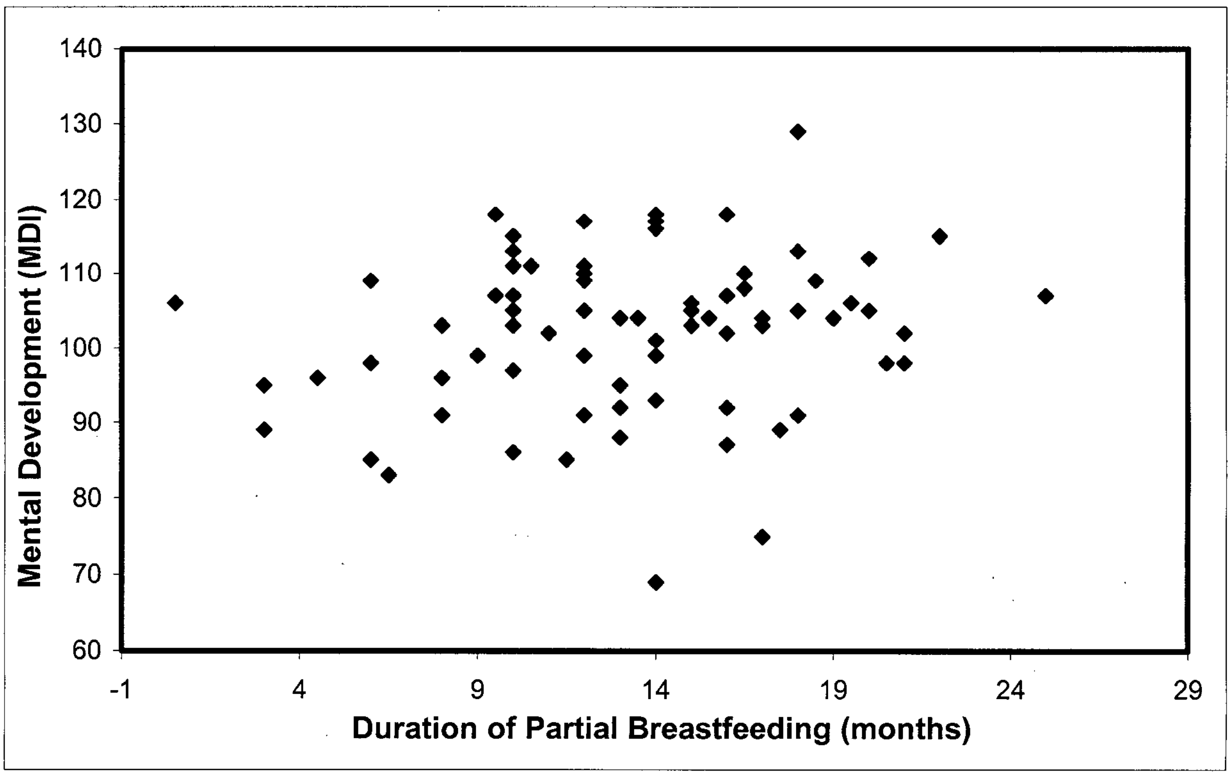


Figure 2.3: The Relationship of Exclusive Breastfeeding and Motor Development

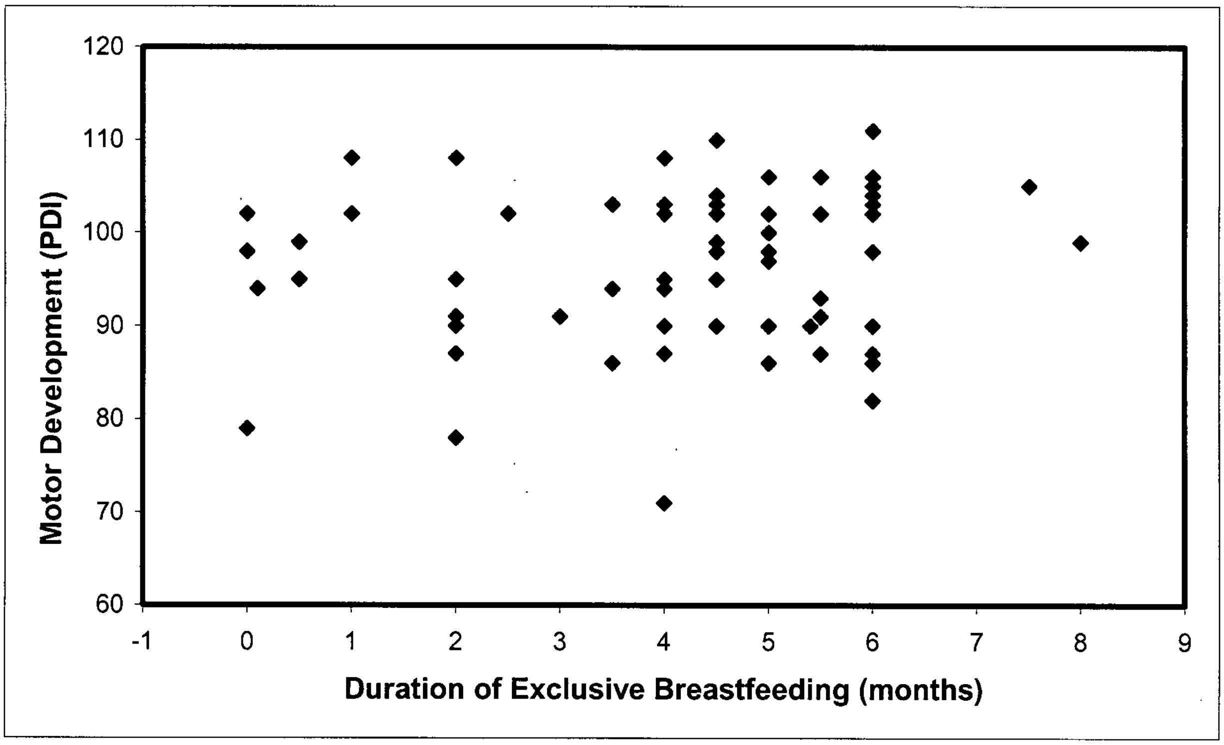
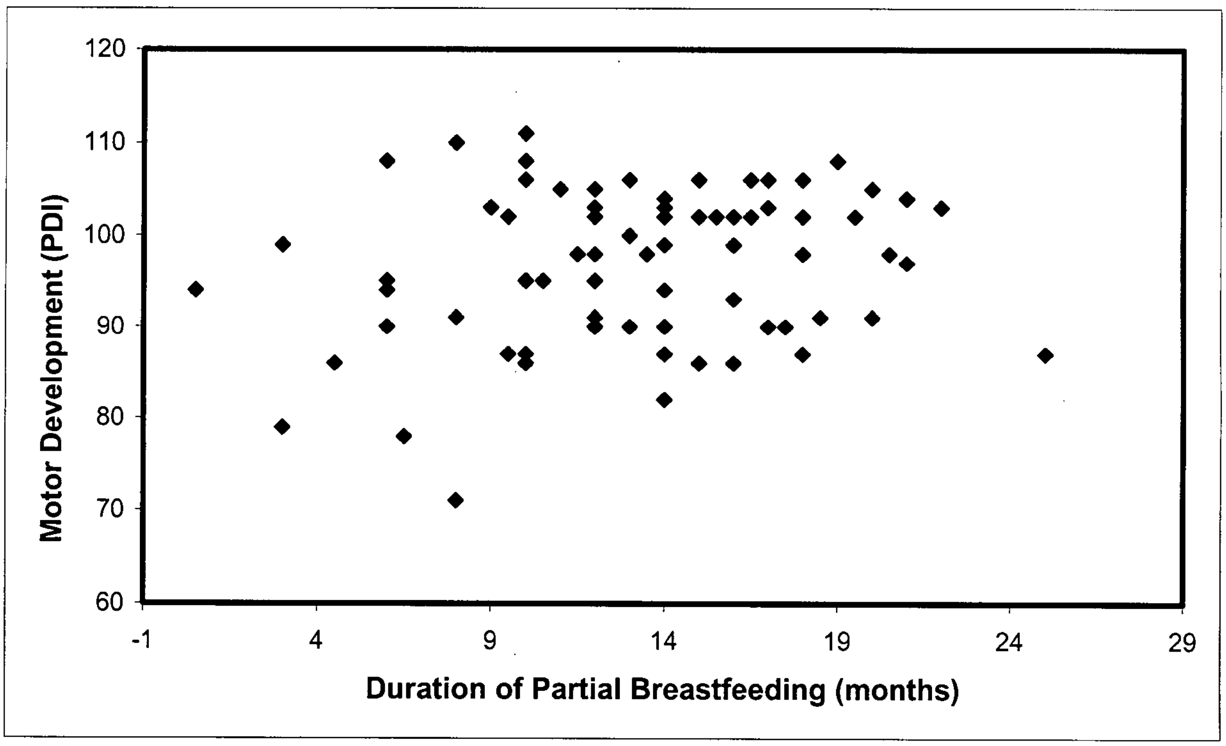


Figure 2.4: The Relationship of Partial Breastfeeding and Motor Development



2.3.2 Covariates and Mental and Motor Development

The relationships of covariates to mental and motor development were calculated also using Pearson *r* for the continuous variables and ANOVA (F) for categorical variables (Table 2.3). None of these variables was significantly related to mental development. Only, the frequency of feeding breast milk in a bottle was significantly related to infant motor development ($F=2.852$, $p=0.02$). Therefore, only feeding breast milk in a bottle would have confounded any relationship between breastfeeding duration and motor development.

2.3.3 Breastfeeding Duration and Covariates

The relationships of exclusive and partial breastfeeding duration with covariates were calculated using the Pearson *r* for continuous variables and ANOVA (F) for categorical variables (Table 2.4). Exclusive breastfeeding duration was significantly related to father's race ($F = 5.701$, $p<0.01$) and child's age at introduction of other foods ($r = 0.500$, $p<0.01$). Partial breastfeeding duration was significantly related to maternal nicotine use during pregnancy ($F = 4.303$, $p = 0.04$), maternal alcohol consumption during pregnancy ($F = 12.419$, $p<0.01$), father's age ($r= 0.292$, $p<0.01$), frequency of drinking breast milk from a bottle ($F = 2.367$, $p = 0.05$), and child's age at introduction of other foods ($r = 0.260$, $p = 0.02$).

2.3.4 Multiple Regression Analysis

Although initially planned, multiple regression analysis was not necessary in this study. The only variable (frequency of drinking breast milk from a bottle) that related significantly to motor development was also a covariate of partial breastfeeding and would, therefore, be redundant in the regression equation.

TABLE 2.3: Relationships of Covariates and Mental and Motor Development on Bayley II
ANOVA (F) or Correlation (Pearson *r*) of other variables with excusive breastfeeding and partial breastfeeding durations. Probability (*p*) the relationship is due to chance.

	Mental Development		Motor Development	
Prenatal/Birth Characteristics	F or *r*	*p*	F or *r*	*p*
Birth Weight	-0.091	0.42	-0.030	0.79
C-section birth	0.462	0.50	0.135	0.72
Pregnancy Nicotine (mother)	0.403	0.53	0.356	0.55
Pregnancy Alcohol (mother)	0.918	0.34	1.047	0.31
Pregnancy Rx/OTC Drugs	0.004	0.95	0.928	0.34
Child Characteristics				
Gender	1.421	0.24	0.796	0.38
Age at testing	-0.117	0.30	0.122	0.28
Ear infections	0.015	0.90	0.001	0.98
Visual Impairment	2.111	0.15	0.159	0.69
Parent Characteristics				
Mother's Age	0.079	0.48	0.061	0.59
Mother's Education	0.234	0.79	2.565	0.08
Mother's Race	0.113	0.89	0.471	0.63
Mother's Marital Status	0.703	0.50	0.187	0.83
Father's Age	0.038	0.74	-0.041	0.72
Father's Education	1.673	0.19	0.208	0.81
Father's Race	0.262	0.90	0.631	0.64
Environment Characteristics				
Modified HOME score	-0.115	0.31	0.166	0.14
Birth order	0.840	0.44	1.747	0.18
Mother smokes	0.011	0.92	0.772	0.38
Father (or others) smoke	2.610	0.11	2.044	0.16
Feeding Characteristics				
Feeding breast milk in bottle	0.847	0.52	2.852	**0.02**
Age at introduction of other food	0.197	0.08	0.102	0.37

TABLE 2.4: Relationships of Covariates and Breastfeeding Duration

ANOVA (F) or Correlation (Pearson *r*) of other variables with excusive breastfeeding and partial breastfeeding durations. Probability (*p*) the relationship is due to chance.

	Exclusive Breastfeeding		Partial Breastfeeding	
Prenatal/Birth Characteristics	F or *r*	*p*	F or *r*	*p*
Birth Weight	0.117	0.30	0.018	0.88
C-section birth	0.015	0.90	0.096	0.76
Pregnancy Nicotine (mother)	0.609	0.44	4.303	**0.04**
Pregnancy Alcohol (mother)	1.846	0.18	12.419	**<0.01**
Pregnancy Rx/OTC Drugs	0.003	0.95	0.132	0.72
Child Characteristics				
Gender	0.586	0.45	1.224	0.27
Age at testing	0.148	0.19	0.204	0.07
Ear infections	2.080	0.15	0.018	0.67
Visual Impairment	2.226	0.14	0.013	0.91
Parent Characteristics				
Mother's Age	-0.161	0.16	0.160	0.16
Mother's Education	2.093	0.13	2.647	0.08
Mother's Race	1.206	0.30	0.076	0.93
Mother's Marital Status	2.587	0.08	0.810	0.45
Father's Age	0.072	0.53	0.292	**<0.01**
Father's Education	0.180	0.84	0.591	0.56
Father's Race	5.701	**<0.01**	0.665	0.62
Environment Characteristics				
Modified HOME score	-0.057	0.62	-0.111	0.33
Birth order	0.773	0.46	0.904	0.41
Mother smokes	0.215	0.64	0.055	0.82
Father (or others) smoke	1.590	0.21	0.438	0.51
Feeding Characteristics				
Feeding breast milk in bottle	1.450	0.22	2.367	**0.05**
Age at introduction of other food	0.500	**<0.01**	0.260	**0.02**

2.4 Discussion

In this study, no significant relationships were found between exclusive or partial breastfeeding and mental or motor development. Although it is conceivable that a larger sample could lead to significant correlations, one must not over-interpret significance in correlations because it is the strength of the correlation coefficient that is more meaningful. None of our correlation coefficients exceeded $r = 0.211$, suggesting weak relationships. Because published research tends to be biased toward positive results, reporting a negative finding is important. Others have also deemed this to be true and a number of studies support our negative findings (Jacobson et al., 1999; Slykerman et al., 2005; Wigg et al., 1998).

What is different about this study is the absence of a relationship between breastfeeding and mental and motor development prior to consideration of confounding variables. Elsewhere, the significant relationship between breastfeeding and mental or motor development is eliminated when the effect of confounding variables is removed (Jacobson et al., 1999; Wigg et al., 1998). The older age of parents, higher education and number of positive health behaviors observed in our sample of parents may eliminate the effects of these variables since they are at the optimal level for child development.

It must be noted that our findings are opposite to those of other studies supporting a significant relationship between breastfeeding and child neurodevelopment (Angelsen et al., 2001; Gustafsson, Duchen, Birberg, & Karlsson, 2004; Quinn et al., 2001) and debate remains debate over the general conclusion from the numerous studies to date as to whether this relationship is direct or mediated by socio-environmental confounders (Drane & Logemann, 2000; Jain et al., 2002; McCann & Ames, 2005; Rey, 2003).

Our results also confirmed previous findings about the social and environmental variables associated with breastfeeding. In this study, longer duration of partial breastfeeding was related to not smoking, a positive health behavior that has been reported in other studies (Angelsen et al., 2001; Bouwstra et al., 2003; Wigg et al., 1998). Longer partial breastfeeding was also related to not drinking during pregnancy and introducing solid foods at an older age, which may also be interpreted as parental positive health behaviors. The American Academy of Pediatrics (2005) recommends waiting until 6 months to introduce foods other than breast milk. Lastly, our finding that a lower maternal education related to better motor development has also been reported elsewhere (Petterson & Albers, 2001).

Surprisingly, maternal age, education, and marital status were not significantly related to exclusive or partial breastfeeding as reported in another study (Anderson et al., 1999). As suggested earlier, our homogeneous sample may have served to control the effect of these variables, which can confound the relationship between breastfeeding and mental and motor development (Jacobson et al., 1999; Wigg et al.,1998).

2.4.1 Limitations

Between-phase differences in the two groups of data collected at different times could be attributed either to the study design or have little meaning. The differences in mean parental ages were small (fathers' = 2.3 years, mothers' = 2.0 years) and may not be important since most parents were over 30 years of age. Paternal education differences were due mostly to having a technical diploma versus a university degree. The between-phase difference in reported alcohol consumption during pregnancy may have been due to the method of data collection, i.e. Phase I background data were collected by interview whereas Phase II parents completed a background questionnaire (in writing) with help if needed. Thus Phase I parents might have been more accurate in their answers. Phase differences in the duration of partial breastfeeding may have represented a study artifact. That is, Phase II mothers reported breastfeeding at the time of testing (when children were approximately 18 months of age) and may still have been breastfeeding, whereas Phase I participants had to recall breastfeeding duration when the child was about 3 years of age. Thus, mothers in Phase I reported longer periods of partial breastfeeding.

Overall, the sample appears to be a homogeneous group of children from older, educated, Caucasian parents of children who were breastfed according to AAP guidelines, i.e., exclusively to 6 months and partially to 1 year or more (AAP, 2005). A more heterogeneous sample would be more representative of a larger population and provide more variability for analysis. ANOVA is particularly sensitive to lack of variability and showed significant differences in categorical variables that were mostly homogeneous in this sample (e.g. father's race).

Another consideration is the correlational design of this study. One study suggested the relationship follows a non-linear pattern, where no additional positive effects on mental development are seen after 9 months of breastfeeding (Mortensen, et al., 2002).

Covariates

The potential for identifying confounding factors in this study was limited to the background information collected in the previous study from which the Phase I dyads were recruited. Variables may have been better operationally defined. For example, genetic predisposition of a child is not necessarily represented by maternal education. Maternal intelligence could better approximate a child's potential for cognitive development (Johnson, Swank, Howe, Baldwin & Owen, 1996). One study including maternal intelligence as a proxy of the child's genetic potential found it eliminates completely the prior beneficial effect of breastfeeding on child development (Jacobson et al., 1999).

Similarly, the choice of the HOME as a measure of the child's social and physical environment, including parenting behavior, may not have adequately captured reality. The HOME is a valid and reliable tool when administered in the standardized manner as an observational measure. As a self-report questionnaire, it can potentially screen for high-risk environments but cannot detect meaningful subtleties in a child's environment that may influence neurodevelopment. Even in its standardized form, the HOME does not capture significant life events (e.g. divorce, new baby, moving to a new home) that may impact upon a child's development (Bee et al., 1986).

Other variables that may influence child development were not considered in this study. The quality of a mother's diet during pregnancy can have some influence on later developmental outcomes. In particular, supplementation with DHA has been shown to improve children mental processing (Decsi & Koletzko, 2005) and motor development (Jensen, C.L., et al., 2005) and it is still unclear whether environmental neurotoxins, such as methylmercury and dioxins, negatively affect child development (Jensen, T.K., et al., 2005; Koppe, 1995).

Also, a mother's emotional status and stress level during pregnancy and in the post-partum period influences child development as well as breastfeeding duration (McLearn, Minkovitz, Strobino, Marks, & Hou, 2006). At an incidence of 10 to 15%, depression is one of the most common complications of pregnancy (Lattimore, et al., 2005). Cortisol and other stress hormones, as well as the mother's behavior towards her child, are altered in mothers who are clinically depressed (Lattimore, et al., 2005; McLearn et al., 2006). If a mother chooses to undertake medical treatment for depression during pregnancy, it is still unclear if antidepressants, such as selective serotonin reuptake inhibitors (SSRIs), negatively affect a child's neurological development (Gentile, 2005; Lattimore, et al., 2005). Furthermore, two studies have shown that children of mothers who were depressed post-partum are vulnerable to developmental delays (Hay et al., 2001; Lattimore et al., 2005).

Breastfeeding Definitions

In this study, by definition, exclusive breastfeeding ended when other foods were introduced into the child's diet (Breastfeeding Committee for Canada, 2004). Firstly, the relationship of exclusive breastfeeding duration to age at introduction of solids is likely an artifact of the study design since the definition of exclusive breastfeeding is limited by the age at which a child would typically begin to need foods other than breast milk (i.e. 6 months). Secondly, the amount of other food ingested (formula, puree, etc) can vary greatly among children since some transition quickly to a table diet and others can take several months to get used to the texture of pureed foods. Feeding behavior when a child is being weaned is particularly variable (Parkinson & Drewett, 2001). Thus, the amount of breast milk consumed may have been different even among children breastfeeding partially for the same amount of time, an important factor when considering the physiological theory that a substance of breast milk contributes to better neurodevelopment. To stop exclusive breastfeeding at introduction of other foods (Breastfeeding Committee for Canada, 2004) does not provide an adequate picture of a child's breastfeeding intensity during the first year of life.

2.4.2 Future Directions

Continued efforts to improve study design, especially in the areas of confounders included and dose-response formulations, are needed. New approaches to methodology are also needed such as Evenhouse and Reilly's (2005) use of a sample of siblings to reduce selection bias in their study on breastfeeding and 15 indicators of health. Standard definitions of breastfeeding and other variables would allow for combination of data sets and meta-analyses as well as more conclusive systematic reviews of studies on the relationship of breastfeeding to mental and motor development.

While mothers have gathered personal knowledge over centuries, very little has been reported in the literature on what actually goes on in the relationship of a mother and child who is breastfed. For an occupation that can occur 12 to 15 times per day in the early months, breastfeeding has been considerably under-investigated. Furthermore, it is possible that mental and motor development do not adequately capture the adaptive advantage for breastfed children. It is said that mothers develop a greater sensitivity to their child through breastfeeding (La Leche League International, 1997). Could this lead to a more emotionally adapted child, better able to create and sustain relationships and thus succeed in areas beyond intelligence, such as empathy, social responsibility, and self-acceptance (La Leche League International, 1997; Sears & Sears, 1995)? While this theory resonates with mothers, little research has been devoted to the topic.

Breastfeeding appears to be an overlooked "occupation of motherhood" in need of the attention of occupational therapists. If occupational therapists are to become involved increasingly in health promotion, breastfeeding must be an interest and a focus for those working in environments in which there are infants, children and their families. As a partner with national and international organizations (Breastfeeding Committee for Canada, 1999; UNICEF, 1990), occupational therapists have a unique role in the study and promotion of this "preventative occupation" (American Occupational Therapy Association, 2001).

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CHAPTER 3

Conclusion and Recommendations for Further Work

3.1 Overview and Conclusions

3.1.1 Chapter Overviews

This thesis consisted of an extensive examination of the existing literature on breastfeeding and neurodevelopment in Chapter 1 and a new study on the relationship of breastfeeding duration to mental and motor development in children less than 2 years of age in Chapter 2.

In Chapter 1, we looked at the evidence for relationships between breastfeeding and several aspects of neurodevelopment from infancy to adulthood, in the population of born at term and those neurologically at risk. Most studies concluded that neuromotor development was generally not improved by breastfeeding, with the exception of a few studies that suggest breastfeeding may positively influence quality and fluency of infant movements (Bouwstra et al., 2003; Lanting, Patandin, Weisgals-Kuperus, Touwen, & Boersma, 1998). Some studies have reported better visual development in children who were breastfed compared to children who were formula-fed (Birch, Birch, Hoffman, & Uauy, 1992; Birch et al., 1993; Williams et al., 2001). However, most of these studies lack control of confounding variables. Increased duration of breastfeeding is significantly associated with better performance on academic achievement measures both in middle school and at age 18 (Horwood & Fergusson, 1998). The outcome that has been least studied is psychosocial adaptation. Some positive benefits have been reported (Lundqvist-Persson, 2001) but others were inconclusive (Fergusson, Horwood, & Shannon, 1987; Fergusson & Woodward, 1999). Finally, cognitive development is generally thought to improve with increasing duration of breastfeeding (Gustafsson, Duchen, Birberg & Karlsson, 2004), more pronouncedly in children born premature (Lucas, Morley & Cole, 1998). In conclusion, it is likely that breastfeeding improves overall brain function. However, it is still unknown if this is a direct relationship or one mediated by the physical, social, economic environment and genetic contribution of the child (Jain, Concato, & Leventhal, 2002).

In Chapter 2, a novel study was reported on the relationship of exclusive and partial breastfeeding duration to mental and motor development, as measured by the Mental Development Index (MDI) and the Psychomotor Development Index of the Bayley Scales of Infant Development, Revised (BSID-II, Bayley, 1993). This study replicated and improved upon previous study designs. Limitations to the study included, inadequate control of confounders such as use of the HOME as a measure of environment and parenting behaviour, maternal intelligence, maternal diet during pregnancy, and stress and depression during pregnancy and post partum. This study of a fairly homogeneous sample of white, married, older, educated mothers, failed to find a relationship between breastfeeding and mental or motor development.

3.1.2 Chapter Cohesion and Conclusions

Chapter 1 served as an essential background study for the development and completion of the study in Chapter 2 in three ways. First, the broad range of designs attempted in previous studies (randomized controlled trial, descriptive correlation, descriptive case-control, cohort) were reviewed in Chapter 1 (Anderson, Johnstone, & Remley, 1999) and the most appropriate, descriptive correlation, was chosen for Chapter 2. Second, a wide range of covariates was examined in previous studies in Chapter 1 and the most important were chosen for the study in Chapter 2 (within feasibility). Third, explanatory theories studied in Chapter 1 guided the development of the research question in Chapter 2. This thesis attempted to replicate and improve upon past studies on breastfeeding and mental and motor development. This proved to be a complicated question to formulate and test in Chapter 2. Ultimately, the evidence in Chapter 2 does not support a relationship between duration of exclusive or partial breastfeeding and mental or motor development.

3.2 Strengths and Weakness of this Thesis

This thesis provides a comprehensive overview of the current and past literature on breastfeeding and neurodevelopment. We focused not only on mental and motor development but on a variety of observations of neurological functioning. This provides a balanced and complete picture of the effects of breastfeeding. In Chapter 2, the study was designed based on the recommendations and knowledge of study design in this area and avoids repeating past mistakes. A weakness of this thesis is not undertaking a systematic review of studies but rather an historic and topical overview of the field. This was constrained by the time available to complete this thesis since a systematic review of studies in five areas is a considerable amount of work. However, previous studies have been critiqued in detail elsewhere (Burgard, 2003; Jacobson & Jacobson, 2002; Rey, 2003).

3.3 Current Knowledge

With the abundance of studies on breastfeeding and cognitive development in term infants, it is surprising that the Cochrane Collaboration (Starr & Chalmers, 2003) has yet to undertake a systematic review of this question. It may point to the extreme variability of study methodology, especially prior to 2000 (Anderson, et al., 1999). However, five different critical reviews have been conducted on subsets of studies on breastfeeding and cognitive development with contradictory conclusions (Anderson et al., 1999; Drane & Logemann, 2000; Jain et al., 2002; McCann & Ames, 2005; Reynolds, 2001). It is generally agreed that most studies find a significant relationship between breastfeeding and cognitive development and that numerous covariates confound the relationship (McCann & Ames, 2005). While some reviewers conclude that few studies meet adequate design standards and those that do, fail to show a conclusive relationship (Drane & Logemann, 2000; Jain et al., 2002), others believe that there is adequate evidence to endorse breastfeeding as a positive influence on cognitive development (Anderson et al., 1999; McCann & Ames, 2005). However, no one can answer the question of whether this relationship is direct or mediated by aspects of the child's genetic make-up or environment (Jacobson & Jacobson, 2002; Rey, 2003).

3.4 Significance and Application

3.4.1 Significance

The significance of this thesis is two-fold. Firstly, it provides an extensive and up to date background exploration of the topic of breastfeeding and human neurodevelopment, which can serve as a reference or an introduction to those unfamiliar with the field of study. Secondly, the study undertaken in Chapter 2 informs the argument for a causal link between breastfeeding and cognitive development. Five criteria for establishing causality have been outlined (McCann & Ames, 2005): 1) there must be a consistent association between the two factors; 2) it must be biologically plausible that one can cause the other; 3) there must be an ability to manipulate the dose experimentally; 4) the relationship must follow a dose-response pattern; and 5) the cause and effect must be specifically defined. Considering studies related to breastfeeding, LCPUFA supplementation and animal studies, some evidence exists to fulfill the first, second, and third criteria (McCann & Ames, 2005). The present study fails to support the presence of a dose-response relationship between breastfeeding and mental development, thus weakening the argument for causality. Furthermore, it is still unknown if LCPUFAs are the influential ingredients of breastfeeding or that improved cognitive and motor development are the direct effects (McCann & Ames, 2005).

3.4.2 Potential Application for Occupational Therapists

Occupational therapists (OTs) have a role in health promotion (American Occupational Therapy Association (AOTA), 2001; Canadian Association of Occupational Therapists, 1998). However, OTs have been typically involved in tertiary prevention programs in which "treatment or services [are] designed to arrest the progression of a condition, prevent further disability, and promote social opportunity, " (p. 657, AOTA, 2001). Work on enhancing breastfeeding environments and practices involve primary health promotion (avoiding the onset of disease or disability) and secondary health promotion (early detection and treatment). These less conventional, health promotion roles may force occupational therapists into an area that may seem beyond their scope of practice. Breastfeeding research and intervention can bridge this gap for occupational therapists and encourage them to partner with other health professionals (Breastfeeding Committee for Canada, 1999) already working in this area to the greater benefit of mothers, children and those who care for them.

3.5 Future Research in the Field

3.5.1 Studies on Breastfeeding and Mental and Motor Development

Future studies of the relationship of breastfeeding and mental and motor development must become more uniform in terminology and design in order to be able to compare and combine results. Firstly, the most sensitive study design appears to be the one that tests a dose-response relationship between breastfeeding and neurodevelopment since other designs will dilute the effects of longer breastfeeding (Drane and Logemann, 2000). Secondly, confounders studied must be shown to be associated with the exposure and the outcome (Victora, Barros, Horta & Lima, 2005). Of particular importance would be a measure of the mother's intelligence, which is highly related to child mental development, as well as a measure of child stimulation, such as the HOME (Caldwell & Bradley, 1984; Jain, et al., 2002). More study of the factors influencing child mental and motor development would clarify further the question of confounders. Finally, neurodevelopmental tests must be specific to the behaviour of interest and breastfeeding definitions must be sensitive enough to capture significant variations in the dose.

It is also encouraging that new methodological approaches have been attempted that may provide a better way of framing and answering the question of breastfeeding and mental and motor development. Two examples are a study of siblings (Evenhouse & Reilly, 2005) and a study of a Brazilian population in which socio-economic status was not associated with breastfeeding duration (Victora et al., 2005).

3.5.2 Other Questions to Ask

Core concepts within occupational therapy, i.e. occupational performance and the environment of occupation (Law, Polatajko, Baptiste, & Townsend, 2002), provide a new perspective from which to ask questions about breastfeeding and neurodevelopment. What goes on during breastfeeding that is unique to that activity or similar to other occupations of motherhood? More studies like Maclean's (1989) on "women's experience of breastfeeding" would generate new research hypotheses about the breastfeeding relationship and the mother-child environmental context that would have a unique occupational therapy perspective.

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APPENDIX I

BREASTFEEDING QUESTIONNAIRE

January, 2004

Date of Completing Questionnaire:

Child's Birth Date:

Participant Number:

Section 1: Feeding History

Did your child receive breast milk? ________yes ________no

If yes, how long did your child receive breast milk? ________________weeks

While receiving breast milk, did your child receive any infant formula or other types of milk? If yes, I am interested in knowing how frequently your child received formula or other milk as he or she became older. The next questions may help you remember how frequently your child was fed milk other than breast milk. (Please check the one statement that applies.)

While in hospital, my infant had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ________________________

At 2 weeks, my infant had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ________________________

At 1 month, my infant had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ____________________

At 2 months, my infant had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ____________________

At 4 months, my child had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ____________________

At 6 months, my child had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ____________________

At 8 months, my child had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ____________________

At 10 months, my child had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ____________________

At 12 months, my child had:
__breast milk only
__breast milk plus formula once a day
__breast milk plus formula twice a day
__breast milk plus formula more than once a day
__more formula than breast milk
__only formula (please indicate which kind ____________________

Has you child ever received breast milk in a bottle or other feeding method?
If yes, how often?
__not at all
__rarely
__once a week
__once a day
__several times a day
__for all feedings

What age did you child start taking solid foods? ________months

Section 2: Home Environment

Do you smoke? ________yes ________no
If yes, how many cigarettes per day? ____________

Does anyone else smoke in your home? ________yes ________no
If yes, how many cigarettes per day? ____________

The next questions are about your child's environment from infancy.
Please answer what was true on average from the time your child was born (or adopted) to the present.

	Yes	No
Do you talk with your child frequently during the day?		
Do you try to speak to your child in a clear and distinct voice?		
Do you respond to your child's talking by saying something back?		
Do you teach your child the names of objects?		
Do you sometimes let your child be messy in play?		
Do you praise your child's qualities or behaviour often?		
Do you try to speak positively to your child?		
Do you kiss or caress your child often?		
Do you like other people to praise your child?		

	Yes	No
Do you shout at your child more than once a week?		
Do you express annoyance at your child?		
Do you slap or spank your child more than once per week?		
Does your family have a pet?		
Does your family have 10 or more books visible in your home?		
Do you scold your child more than once a week?		
Is your child free to play and move at his or her own will?		

	Yes	No
Do you leave your child with a familiar caregiver when you are away?		
Does your child go to the grocery store at least once a week?		
Does your child go out 4 or more times per week?		
Does your child go to the doctor regularly?		
Does your child have his own place in your home for toys?		
Is your home child safe?		

	Yes	No
Does your child have toys for large muscle play (e.g. rolling, crawling)?		
Does your child have a push or pull toy?		
Does your child have a scooter, kiddie car or tricycle?		
Did your child play with different toys at different ages?		

	Yes	No
Does your child have toys like things to go in and out of a container, fit together toys or beads?		
Does your child have stacking or nesting toys, blocks or building toys?		
Does your child have musical toys or listen to music daily?		

	Yes	No
Do you keep your child in sight at all times?		
Do you talk to your child about the things you are doing?		
Do you encourage your child to develop his or her skills?		
Do you encourage your child to play with more mature toys?		
Do you structure your child's play periods?		

	Yes	No
Does your child's father or other guardian provide some care taking everyday		
Do you read stories to your child at least 3 times per week?		
Do you eat at least one meal per day as a family?		
Do you visit or receive visits from relatives once a month or more?		
Does your child have at least 3 books of his or her own?		

Thank you for your participation in completing this questionnaire. Please insert it into the envelope provided with your package and mail it to :

Dr Susan R. Harris
School of Rehabilitation Sciences - UBC
T325-2211 Westbrook Mall
Vancouver, BC
V6T 2B5

APPENDIX II

BACKGROUND INFORMATION

HARRIS INFANT NEUROMOTOR TEST
(Development Edition #2: November, 1993; rev. 9/97)

Background Information: Child

Child's Name:
Assessment Date:
Birth Date:
Birth Weight (grams):
Current Head Circumference (cms):
Examiner:
Test Location:

Chronological Age:
Corrected Age:
Gender:
Gestational Age: (weeks):
Medical Record No.
General Health:

Bayley-II Mental Scores:	Raw	MDI	Developmental Age
Bayley-II Motor Scores:	Raw	PDI	Developmental Age

Other Test Scores:

Background Information: Birth Parents

Marital Status (mother):
1=married; 2=single; 3=divorced; 4=separated; 5=widowed; 6=common-law
Mother's Age:
Father's Age:
Maternal Occupation:
Maternal Education (highest grade completed):
Paternal Occupation:
Paternal Education (highest grade completed):

Race of Mother:	1=Caucasian	5=Hispanic
Race of Father:	2=Black	6=East Indian
	3=Asian	7=Other
	4=Native American/Native Indian	

Birth order of child being assessed:
Number of other children in the family:

Background Information: Primary Caregivers

(Note: Complete this section only if primary caregiver is not a birth parent.)
Relationship of primary caregiver to the child:

1=adoptive parent	2=maternal grandparent
3=paternal grandparent	4=maternal aunt/uncle
5=paternal aunt/uncle	6=foster parent

7=other (please specify):

Risk Factors

(Check all items that apply. Supply additional information as requested.)

Birth Weight:	Low Birth Weight:	SGA:	
Mode of Delivery:	Vaginal:	C-section:	Breech:
Multiple Birth:	Number:	Birth order:	
Intaventricular Hemorrhage:	Grade:	PVL:	
Bronchopulmonary Dysplasia (BPD):		Severity:	
Respiratory Distress Syndrome:	Grade:		
Ventilator Use:	(length of ventilator use):		
Oxygen Use:	(length of oxygen use):		
ECMO:	Bradycardia:		

Additional Risk Factors:

Asphyxia:	Seizures:	Apnea:
Hydrocephalus:	Microcephaly:	PDA:
Chromosomal Abnormalities:	Musculoskeletal Anomalies:	
Ear Infections:	(list frequency):	
Hearing Loss:	Visual Impairment:	
Feeding Problems:		

Number of hospitalizations since birth:
Length of total hospitalizations (in days):

Prenatal Drugs (check all that apply and provide information about length and timing during gestation, if available):

Alcohol:
Cocaine:
Heroin:
Methadone:
Nicotine:
Ritalin:
Talwin:
Valium:
Other (please list):

PROCEDURE (continued)

During this meeting, your child's cognitive (thinking) and motor (moving) development will be assessed using a standard test for babies. During the test, the co-investigator or research assistant presents toys to your child while sitting on your lap or interests your child in moving around the room. You will then be asked to answer a questionnaire about breastfeeding, your parenting practices and home environment. Your child's testing may be videotaped for future reference. If you wish, the co-investigator or research assistant will discuss the results of the intelligence test with you following the assessment.

RISKS AND DISCOMFORTS

The procedures involved in this study will cause no physical or emotional pain or discomfort to yourself or your child. You will be asked to give your time to answer questions. The testing will not upset your child in any way.

BENEFITS

Your participation in the study will bring you more knowledge of your child's development. The findings of the study may benefit you indirectly by helping the medical community understand the role of breastfeeding. You will receive $25 honorarium for your participation in this study.

ALTERNATIVES

The testing your child receives will not take the place of other developmental intervention or support he or she may need in the future. If the research assistant has concerns about your child's development, you will receive information about where to go for a more detailed assessment.

CONFIDENTIALITY

All personal information gathered by the co-investigator or research assistant about yourself and your family will be kept confidential and private according to the code of ethics of the University of British Columbia (UBC) and of the College of Occupational Therapists of BC. All files and videotapes will be kept in a locked storage area. Computer files with your information will be protected by a password.

Your name or your child's name or any identifying information (such as where you live or your spouse's name) will not appear on any information shared with faculty at UBC. If the information should be published or used for teaching purposes, your name or other identifying information will not be used.

APPENDIX XI

HONORARIUM FORM

Invoice for Honorarium

Name: ______________________________

Address: ____________________________________

City: _______________ Province: ______________ Postal Code: __________

SIN: ________________________

Are you a current student or employee of UBC? ☐ Yes ☐ No

Billing Period: _____________________

Total: $______25.00______

Account Number:

Signature: ____________________________ Date: _____________

Approved By: ___Andrea Petryk_______________________