# Does Independent Locomotion Influence the Age-of-Attainment of Proto-Declarative Pointing?

by

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

**Master of Arts**

Department of Psychology

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Winnipeg, Manitoba, Canada

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
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Abstract

A baby's ability to move her body through space by crawling may facilitate the development of joint attention. To test the hypothesis that earlier crawling onset would predict one aspect of joint attention skills, pointing, we analyzed prospective daily checklist parent reports. Proto-declarative pointing or "pointing to share interest with another" was selected as a good measure of joint attentional competence in infancy, and hands-and-knees crawling was selected as a measure of locomotor ability. Ages of attainment for these two competences were studied by using different threshold definitions for estimating when attainment occurred. The reliabilities for the various definitions were estimated with a split-half procedure and found to range from .95 - .99. The age of first crawling attainment was then used to predict age of first pointing in a survival analysis, along with other factors (age of sitting, gender, family income, mother's age, gestational age, children in the household, Ponderal Index, and mother's education). Age of sitting was included as a baseline measure of prior non-locomotor development and was a significant predictor of pointing. Mother's education and Ponderal index also predicted age of pointing. Most importantly, age of crawling was a significant positive predictor of pointing, above and beyond the predictive influence of all other predictors. The finding that earlier crawling uniquely predicts earlier pointing highlights the contribution of infant motor experience and attainment to the early aspects of joint attention.

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I sincerely thank my advisor, Dr Warren Eaton for his commitment, patience, support, careful feedback, his tremendous kindness, especially during my many humiliating SAS moments, and his great wit while working with me to complete this thesis. I would like to thank my thesis committee members Dr Rosemary Mills and Dr Judy Chipperfield for their thoughtful ideas and great enthusiasm for my work. In addition, I want to express my sincere gratitude to Dr Rosemary Mills for her ongoing encouragement and support for me. Thank you Dr Michelle Corley, my dearest friend, you stayed on the telephone with me for hours from Virgina State, to listen to my oral defense rehearsals. Thank you Dr Kimberley Arbeau for your cheerful support and endless words of encouragement during this time. Also, I would like to thank my lab members, Amy De Jaeger, Samantha Lewycky and Jennifer Schultz for their generous comments. Thank you Manitoba Health Research Council for awarding me a Graduate Studentship, which funded my Master's degree. Finally, I thank Dr. Timothy Racine, for his encouragement, genuine feedback, and for caring about psychological theories of development, as much as I do.

# Dedication

This thesis is dedicated to my mother Merlyn Lall, my beloved grandmothers, Roni and Rachael, and my Aunty Ena.

Thank you for your love, support and encouragement over the years. In order to complete this degree, I had to spend time away from you, which was never easy.

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# CHAPTER I

# INTRODUCTION

The ability to share and coordinate one's attention with another person's is a critical developmental achievement. An early form of joint attention is first observed in typically developing 3-month-old infants (Scaife & Bruner, 1975), and more complex forms appear to emerge reliably in a particular developmental order (Carpenter, Nagell & Tomasello, 1998; Carpenter, Pennington & Rogers, 2002). First, around two or three months of age, infants share attention by meeting their caregivers' gaze (Scaife & Bruner, 1975), and by around six months, infants start to follow their caregiver's changing visual focus of attention (Scaife & Bruner, 1975). Eventually, infants begin to engage with their social partners around a common object or experience. These later triadic interactions include behaviours such as object-based imitation (Carpenter et al., 1998), referential pointing and social referencing. Referential pointing includes pointing to request an object (the so-called proto-*imperative* point), and pointing to share interest in an object (the so-called proto-*declarative* point). Referential pointing and object-based imitation emerge sometime between 9 to 14 months (Butterworth, 2003; Butterworth & Morrissette, 1996; Camaioni, Perucchini, Bellagamba & Colonnesi, 2004; Murphy 1978); whereas, social referencing emerges closer to 14 months of age (Walden & Ogan, 1988). An infant's ability to initiate and engage in triadic social interactions is considered a robust indicator of the emergence of early social understanding and a "necessary" prerequisite for the development of language (Morales, Mundy, Delgado, et al., 2000), and social and cultural pragmatics (Tomasello, Carpenter, Call, Behne & Moll, 2005).

In particular, the proto-declarative point (Bates, Camaioni & Volterra, 1975), or pointing to engage another's attention to an object or event of interest to the infant, is of considerable developmental importance. Researchers have linked the proto-declarative point to children's later advanced social cognition or theory-of-mind (Camaioni, et al., 2004), children's later language acquisition (Butterworth, 2003; Butterworth & Morissette; 1996; Tomasello, et al., 2005), and language competence (Morales, et al., 2000; Tomasello et al., 2005). Moreover, the absence of, or low frequencies of, proto-declarative pointing, has been linked to the childhood psychopathology of autism (Baron-Cohen, 1989; Bruinsma, Koegel, & Koegel, 2004), and the order of development of joint attention skills for children with autism is different than that of typically developing children (Carpenter et al., 2002). Furthermore, deficits in joint attentional skills are associated with poor infant mental health (Trevarthen & Aitken, 2001), and deficits in both joint attention and theory of mind are present in persons with schizophrenia (Brune, 2005). Because impairment in proto-declarative pointing is associated with at-risk health trajectories, understanding how the proto-declarative point develops has important health-related implications.

Recently, theory suggests that the onset of independent locomotion in infancy may influence when babies start using proto-declarative pointing. However, this relationship has not yet been examined by developmental researchers. Thus, the primary goal of this study is to investigate the influence of an earlier form of independent locomotion, crawling, on the developmental timing of the proto-declarative point.

*Theories of Joint Attention*

Several theoretical explanations for the development of joint attention have been proposed. Some center on the following themes: evolutionary endowment (Baron-Cohen, 1995; 1999; Butterworth, 2003), the presence of an innate capacity (Meltzoff, 2002; 2006; Trevarthen & Aitken, 2001), the neuro-biological perspective (Gallese, 2005) and infant-cognitive factors (Tomasello, 1995). Other theories propose that the infant is able to process and understand environmental influences, which in turn leads to the development of joint attention (Barresi & Moore, 1996; Moore & Corkum, 1994). Although these theories differ, they emphasize maturational, evolutionary, biological or cognitive causes "within" the individual infant to explain the development of joint attention. More recently, explanations of joint attention moved beyond infant-specific factors to consider other developmental processes, such as parent-infant socio-emotional interactions (Carpendale & Lewis, 2004; Greenspan & Shankar, 2004; Hobson & Hobson, 2008; Racine & Carpendale, 2007; Reddy, 2003; Rodriguez & Moro, 2008), and the influence of independent locomotion (Campos, Anderson, Barbu-Roth, Hubbard, Hertenstein, & Witherington, 2000; Lindbolm & Ziemke, 2006; Racine & Carpendale, 2008), the main focus of this current project, on the development of joint attention. Before elaborating on how independent locomotion may influence the development of joint attention, I will discuss the various theoretical frameworks proposed to explain the development of joint attention.

*Individualistic Theories of Joint Attention*

The following theories were grouped under the heading individualistic theories of joint attention because they explain the development of joint attention by looking for causal factors within the infant. The evolutionary perspective on joint attention argues that pointing is an innate ability uniquely evolved in humans (Baron-Cohen, 1995; 1999; Butterworth & Franco, 1993), and that there are four evolution-based modules responsible for the development of joint attention. These modules are the intentionality detector (ID), the eye-direction detector (EDD), the shared/attention mechanism (SAM), which facilitates early triadic social interactions, such as pointing, and the theory-of-mind module (TOMM), which facilitates the onset of perspective taking in early childhood. These various modules are activated sequentially at different ages as the infant matures (Baron-Cohen, 1995).

The neuro-biological explanation for social understanding is based on the discovery of mirror neurons in the premotor cortex of monkeys. Research with rhesus macaque monkeys *(Macaca Mulatta)* revealed that their mirror neurons will fire in the same manner when an action is performed by them, and when that identical action is performed by another (Gallese, 2005). The neuro-biological explanation for social understanding argues that we understand another's behaviour because their behaviour will resonate within us in the same manner, and using the same neural mechanisms through which we process our own emotions and perceptions (Gallese, 2005). Because of the similarity in how self-behaviour and other-behaviour trigger the neural system, the neuro-biological perspective on joint attention proposes that mirror neurons may explain both how we come to understand shared attention, and our capacity to take another person's perspective (Gallese, 2005). Wolf, Gales, Shane and Shane (2000) claim that mirror neurons are also present in humans. However, although the mirror neural systems are involved in joint attention, the field is still unclear about whether mirror neurons underlie and cause joint attention, or whether mirror neuron pathways are established from early infant experiences (Shankar, 2004).

Trevarthen proposes an innate-cognitive explanation for the development of joint attention (see Beebe, Sorter, Rustin & Knoblauch, 2003; Gallager, 2004 for reviews; Trevarthen & Aitken, 2001). Trevarthen argues that joint attention is explained by the development of "primary intersubjectivity," followed by "secondary intersubjectivity." Primary intersubjectivity is the newborn's ability to use her rudimentary perceptual capacities to coordinate her innate awareness of her social partner's intention to interact, when engaged in one-to-one interactions. Thus, the infant is predisposed to an innate awareness of others, and the biological capacities that the infant is born with, for example, her eyes, will facilitate joint attention. Then, at around 9 months-of-age, the infant will demonstrate her capacity for secondary intersubjectivity, which includes competence in triadic joint interactions. Trevarthen claims that competence in triadic interactions first originates from the infant's innate ability to sense and understand another person's subjective states, for example, their motives and desires (Beebe et al., 2003), and is next reflected in the infant's capabilities for agency in her environment (Gallager, 2004). Agency is the infant's control over her "bodily movements," which enables her to engage in triadic interactions. Trevarthen's biologically based, cognitive explanation for joint attention, attempts to integrate the infant's biological capacities, which first enable primary intersubjectivity, with her later abilities to interact with others, and her environment (secondary intersubjectivity). Trevarthen sees the newborn as biologically predisposed to be an involved learner, with innate capabilities for understanding her own, as well as another's desires and intentions (Trevarthen & Aitken, 2001).

Tomasello proposes another cognitive-based explanation for the development of joint interactions (Tomasello, 1995; Tomasello, et al., 2005). According to him, an infant develops social understanding by first gaining insight into the effects of her own behaviours on her environment. By first understanding her own direct effect on objects in her environment, the baby will learn about cause and effect. And from the understanding that in order to achieve her goals she needs to take certain actions, she will begin to develop an understanding of her own intentions to act. Following from her understanding of her own intentions to act, and by comparing others' observed behaviours to her understanding of her own goal-directed behaviours, the infant comes to understand other people's behaviours and intentions. According to Tomasello's explanation, it appears that joint attention reflects the infant's ability to introspect upon her own behaviours, and then apply these self-reflections to others during shared interactions (Tomasello et al., 2005).

The final proponent of the cognitive-analogical argument for joint attention is Andrew Meltzoff. According to Meltzoff (2006), the infant gains an understanding that another is "like me," because of her innate ability to imitate. The baby is able to understand the meaning behind another person's behaviours, by imitating that person's behaviours. Thus, social understanding develops because the infant makes an inference from her own subjective feelings about these imitated behaviours to understand another's intentions (Beebe et al., 2003) during bouts of joint attention.

Other theoretical approaches focus on environmental influences on the infant that facilitate the development of joint attention (Barresi & Moore, 1996; Moore & Corkum, 1994). For example, Moore and Corkum (1994) propose that social conditioning explains the development of gaze following, while Barresi & Moore (1996) attempt to explain the development of social understanding in its entirety. Moore and Corkum (1994) challenge the innate perspectives on joint attention, and propose instead that infants develop expectations of other people's behaviour during social interactions that are reinforcing to the infant. Thus, the infant will follow the direction of another's gaze because the infant has learnt that by looking where someone else is looking, she will eventually see some interesting things (Moore & Corkum, 1994).

Finally, Barresi and Moore (1996) propose a four-level framework for social understanding that they refer to as Intentional Relations Theory (IRT). According to IRT, only adults will attain the highest level of social understanding, while typically developing children will attain up to the third level. Children with autism on the other hand, will not be able to reach the third level of development as would typically developing children. IRT proposes that during infancy, information about another's intentions is available to an infant as he observes the spatiotemporal movements of himself, in relation to the spatiotemporal movements of another person. Thus, the infant gains both a first-person and a third-person perspective of events. And by "matching" these "world-caused and self-caused" perceptions of movement (Barresi & Moore, 1996, p.14), the infant is able to understand self in relation to other.

*Relational Theories of Joint Attention*

Relational theories of joint attention adopt a social-constructivist perspective (Vygotsky, 1978). The social-constructivist perspective on joint attention emphasizes the importance of everyday infant-caregiver interactions. They suggest for example, intimate moments during which infants and their caregivers play, or snuggle together, as they express their affection for each other (Greenspan & Shankar, 2004). It is specifically argued that these parent-infant moments are the "opportunities" for children to develop complex forms of emotional understanding and expression, which in turn is the developmental pathway to age-appropriate, communicative gestures, such as pointing, language, theory of mind, and general long-term healthy development (Greenspan & Shanker, 2004). Key to the relational based account of joint attention are everyday caregiver-infant interactions and the meaning of these interactions for the dyad (Carpendale & Lewis, 2004; Racine & Carpendale, 2007; Reddy, 2003; Rodriquez & Moro, 2008).

As a consequence of considering the role of the caregiver and the infant in the development of joint attention, it becomes necessary to account for the emotional functioning of the parent-infant dyad and the infant's emotional development (Greenspan & Shanker, 2004; Hobson & Hobson, 2008; Reddy, 2003). For example, Racine and Carpendale (2007) suggest that infant-caregiver attachment patterns may influence the development of joint attention. In fact, there is some preliminary evidence substantiating this claim. Scholmerich, Lamb, Leyendecker and Fracasso (1997) found that secure infants maintained more social attention towards their parents compared to resistant, avoidant and disorganized infants. Thus, according to the relational theories of joint attention, the quality of the parent-infant dyad's emotional engagement may be a primary mediating influence on the development of early social understanding.

The importance of joint attention is reflected by the amount of theoretical attention it has received. However, the previously discussed theoretical explanations share little common ground with respect to the developmental pathway that leads to successful joint attention abilities. In summary, the mirror-neural system provides us with the necessary neural basis for triadic social interactions, whereas the evolutionary modular perspective provides a possible explanation for why a healthy infant will developmentally first gaze follow before engaging in referential pointing. From the cognitive perspectives, we have Tomasello who argues for the emergence of innate cognitive capacities to understand other's intentions, Trevarthen who argues that innate, biological predispositions are responsible for infants' social competence, and Meltzoff who argues that the ability for joint attention begins with the innate ability to imitate another. Meanwhile, Moore and Corkum (1994) argue that the positive reinforcing aspects of the environment encourage infants to engage more often in gaze following. IRT (Barresi & Moore, 1996) argues that joint attention begins with the infant's understanding of the spatiotemporal components of social interaction. Finally, as described above, relational theories of joint attention suggest that the quality of the parent-infant emotional relationship leads to the development of healthy joint attention capacities. To recapitulate, the development of joint attention in infancy is an important developmental achievement that is the building block for children's later theory of mind ability, language acquisition and language competence. Also, of the various joint attentional abilities identified, proto-declarative pointing is considered by most in the developmental literature to be the clearest indicator of joint attentional competence.

*Independent Locomotion and Joint Attention*

Recently, however, Lindblom and Ziemke (2006) suggest that another factor may influence the development of joint attention. They point out that current explanations for joint attention fail to consider the influence of self-produced locomotion on the development of joint attention abilities. According to Lindblom and Ziemke, it is possible that developmental changes, such as the onset of self-produced locomotion, may provide perceptual opportunities and perspective changing experiences that advance joint attention abilities. Others (e.g., Campos et al., 2000; Racine & Carpendale, 2008; Smith, 2005) support this position, and argue that social understanding in itself is not only relational and contextual, but is also embodied. Social understanding is considered embodied because social-cognition is thought to develop as the infant physically interacts with the environment through sensory-motor activities like touching, seeing and movement.

There is some preliminary research evidence indicating that independent locomotion may be a "sufficient" mechanism providing experiences that advance the development of one type of joint attention ability, that of proto-declarative pointing. In this regard, Campos et al., (2000) cite empirical evidence indicating that infants who had earlier locomotor experience were advanced in their understanding of referential gestures and socio-emotional interactions, compared to same-aged infants with no prior locomotor experience. Their evidence does suggest that independent locomotion facilitates infants' understanding and the production of proto-declarative pointing (Campos, Kermoian, Witherington, Chen & Dong, 1996; Campos et al., 2000), but systematic examination of this relationship is still required (Campos et al., 2000; Lindbolm & Ziemke, 2006). In the present study I begin that examination by extracting locomotion and pointing attainments from longitudinal data.

# CHAPTER II

# LITERATURE REVIEW

### *Proto-Declarative Pointing*

An infant's ability to express himself using communicative gestures is considered an important developmental milestone that indicates healthy development. In particular, pointing has received greater interest in the developmental literature, than other communicative gestures (Blake et al., 1994). The proto-declarative point is considered an essential aspect of communication (Masataka, 2003), and a vehicle for the development of social cognition and language (Franco, Perucchini, & March, 2008). Physically, the proto-declarative point is "characterized by an arm and index finger extended in the direction of the interesting object, with the other fingers curled under the hand and the thumb held down and to the side" (Masataka, 2003; p.69). Proto-declarative pointing occurs in conjunction with alternating visual monitoring of the social partner and the object of interest (Tomasello, 1995). Functional definitions of proto-declarative pointing encountered in the literature state that the proto-declarative point: (a) is a "vehicle" for communication (Bates et al., 1975), and (b) an intentional act used to change the contents of another's mind (Baron-Cohen, 1989, 1995). Generally, the consensus in the literature is that the onset of proto-declarative pointing in infancy demonstrates an early ability to coordinate visual attention with another, around an object or event of interest to both parties.

Proto-declarative pointing is evident in typically developing infants sometime between 9 and 14 months of age (Baron-Cohen 1989, Bates et al., 1975; Blake et al., 1994; Butterworth and Morrissette, 1996; Camioni et al., 2004; Eaton & Lall, 2008; Leung & Rheingold, 1981; Murphy, 1978; Rodrigue, 2006). The age-of-onset of proto-declarative pointing has been extensively studied (Blake et al., 1994; Baron-Cohen 1989, Bates et al., 1975; Butterworth and Morrissette, 1996; Camioni et al., 2004; Eaton & Lall, 2008; Leung & Rheingold, 1981; Murphy, 1978; Rodrigue, 2006). However, the age at which the proto-declarative point is reported to emerge show significant variation. For example, according to Murphy (1978) the average age-of-pointing in their sample was at 9 months; Leung and Reingold (1981) observed that on average, pointing started at 12.5 months; Blake et al., (1994) found that pointing occurred in the majority of 12-month-old infants in their sample; while Butterworth and Morrissette, (1996) reported that pointing emerged at a mean age of 11 months, 10 days. Camioni et al., (2004) reported that the infants in their study ($N$=133) pointed on average at 11 months, with a gender difference in favour of girls pointing at a younger age. Eaton and Lall (2008) found in a large sample study ($N$=330) that the mean age-of-pointing was 10.5 months, with a gender difference consistent with Camioni and colleagues. It is possible that the variation in mean ages of pointing listed above may have been influenced by differences in definitions and sample sizes across these studies. Small sample sizes are associated with larger standard errors, which may have lead to the apparent fluctuation in estimates of ages of pointing observed in the existing literature.

*What factors are related to the development of proto-declarative pointing?*

The development of pointing has largely been accounted for in the literature as a by-product of the infant's "failed reaching" for an object (Leung & Rheingold, 1981), and by static variables, such as family socioeconomic status, education, age and gender (Eaton & Lall, 2008; Leung & Rheingold, 1981; Murphy, 1978; Rodrigue, 2006), which are not likely to reveal causal factors. Some theoretical perspectives (Campos et al., 2000; Lindbolm & Ziemke, 2006; Racine & Carpendale, 2008; Smith, 2005) reviewed earlier suggest that other developmental factors like the onset of independent locomotion, may accelerate the development of proto-declarative pointing and joint attention abilities in general. It is to the possible role of independent locomotion in the development of pointing to which I now turn.

*Independent Locomotion and Proto-declarative Pointing*

The need for researchers to systematically investigate the relationship between the onset of self-produced locomotion and social understanding during the first year of life is being strongly advocated (Campos et al., 2000; Lindbolm & Ziemke, 2006; Racine & Carpendale, 2008). Researchers feel that individual differences in infant motor systems may influence the age-of-onset of independent locomotion (Thelen & Smith, 1994), and the onset of independent locomotion in turn may bring about perspective changing opportunities to an infant (Campos et al., 2000; Lindbolm & Ziemke, 2006; Racine & Carpendale, 2008). Thus, individual differences in the age-of-onset of independent locomotion may be one factor that explains variations in the ages-of-onset of proto-declarative pointing reported in the literature. Moreover, there is some prior research evidence linking joint attention behaviours to the onset of independent locomotion in infancy.

Using Gibson and Walk's (1960) visual cliff paradigm, Sorce, Emde, Campos & Klinnert's (1985) study examined the relationship between social referencing and infant motor action. They found that 12-month-old infants checked in with their mothers first and based their decision to cross the visual cliff on their mother's expression. In other words, 12-month-old infants used their parent's encouraging or discouraging emotional expression as a reference to decide if they should cross the cliff or not. Tamis-LeMonda and Adolph (2005) also argue that the development of social understanding and motor development in infancy may be interrelated. For example, they argue that the ability for joint attention, in particular, may be extremely useful in infant motor activities that pose a risk to the infant's well being. It should be noted that in the Sorce and colleague's study discussed above, the infant's decision for motor action was based on their already present abilities for joint attention.

In contrast, others (Campos et al., 1992; 2000; Campos et al., 1996; p.396) argue that the prior onset of "self-produced locomotion lies not so much in the act of crawling itself, but in its experiential consequences" for social cognitive abilities. In other words, crawling is not a direct causal factor in the development of joint attention, but crawling results in a wide range of changes in the infant's experiences, which in turn facilitate the development of joint attention. One experiential consequence of the onset of independent locomotion is a new and broader perspective on the world, because infants are no longer restricted to lying on their backs in their cribs. Campos and colleagues (1992) point out that the onset of crawling results in greater freedom for infants to turn their heads to look at the objects and people in their environment. In their study they found that with the onset of crawling, infants began to pay more attention to their parents and more interest towards objects and events in their environment. There was also an increase in the number of parent-infant interactions, infants began to monitor their parents' presence even more, and they started to express greater degrees of displeasure if their parents left them alone.

Other studies found that the onset of self-produced locomotion facilitated the development of optic flow or the visual control of posture (Higgins, Campos & Kermoian, 1996), which seems necessary for engaging in social interactions involving the proto-declarative point. In addition, Telrow and colleagues in a series of longitudinal studies found that infants with spina bifida developed an understanding of gaze and point following relative to their delayed acquisition of locomotion (as cited in Campos et al., 2000). Tao and Dong (1997) investigated the relationship between crawling and gaze following by comparing infants whose movement was physically restricted and thus had less opportunities to crawl, to a second group who had more freedom to crawl and explore their environment (as cited in Campos et al., 2000). They found that infants with more crawling opportunities performed better on joint attention trials. Finally, Campos et al., (1996) found that prelocomotor infants with walker experience and older infants with hands-and-knees crawling experience, correctly followed the experimenter's pointing gesture significantly more often, than prelocomotor infants without locomotor experience. It is Campos and colleagues' (1992; 1996; 2000) belief that it is not the act of crawling itself that facilitates the development of joint attention, but the resulting changes in infant experiences resulting from the onset of locomotion that facilitates the infant's understanding of referential gestures.

To summarize, crawling it is argued, brings with it perceptual and emotional advantages that may facilitate the development of joint attention. For example, locomotion may facilitate the infant's orientation to distant objects and events in the environment, which in turn may facilitate their understanding of, and production of referential gestures towards these objects (Campos et al., 2000). As earlier noted, the influence of independent locomotion on the production of proto-declarative pointing during infancy has not been systematically studied (Lindbolm & Ziemke, 2006). Furthermore, Sorce and colleague's study suggest that joint attention influences the planning and coordination of motor activities, while other studies suggest that prior motor development influences joint-attention abilities. In the present research literature, the direction of influence between the development of joint attention and independent locomotion is unclear, and needs to be disentangled.

Both Campos et al., (2000) and Lindbolm and Ziemke (2006) are suggesting a dynamic system approach to understand the development of joint attention. A dynamic systems approach (Shankar, 2004; Thelen & Smith, 1994) to understanding joint attention could account for how other developmental processes occurring prior to, and concurrently with, proto-declarative pointing enhance the infant's ability to engage in triadic interactions. Self-produced locomotion is considered a dynamic influence because it helps to organize the infant's biological, perceptual, environmental, relational and emotional interactions, which in turn facilitate the infant's ability to engage in early forms of social interactions (Thelen, 2000). Thus, one way of understanding how these dynamic processes influence the development of proto-declarative pointing in the first year of life is to consider the influence of the earlier onset of independent locomotion on the age when pointing first emerges in infancy. In light of the fact that there appears to be no consensus in the literature on the age when proto-declarative pointing should typically emerge (Blake et al., 1994; Butterworth and Morrissette, 1996; Camioni et al., 2004; Eaton & Lall, 2008; Leung and Reingold, 1981; Murphy, 1978), adopting a dynamic developmental systems approach to understand causal factors associated with the development of proto-declarative pointing is overdue.

*Assessing Rates of Development of Proto-Declarative Pointing and Crawling*

According to theory, if crawling facilitates proto-declarative pointing, then earlier crawling should lead to earlier pointing. Therefore, we need to consider the best solution to measure individual differences in rate of development of both crawling and pointing. The age-of-attainment (AOA) method is one approach that can be used once we are dealing with an age-related event, whereby the age attained can be specified for each individual. In development, there are many such individual attainments: first steps, walking, menarche, and parenthood. These events are developmental milestones, and "distance" is measured with chronological age or time from birth. Individuals will vary in their ages-of-attainment, and this variation in age-of-attainment is the key outcome variable of interest, showing how long it takes the individual to reach a defined event. Thus, age becomes our outcome variable of interest, and we predict that babies, who crawl at an earlier age, will point at an earlier age as well.

Because age-of-attainments are our events of interest, we first needed to identify appropriate criteria to define these events. For example, a non-walking baby might walk one day and then not do so again for many days. How is a milestone attainment to be determined if a milestone transition is not abrupt and consistent? What exactly is the date of attainment for a milestone? An obvious choice as an event definition would be the first day a baby crawls or points. However, a single observation will be more vulnerable to errors than an event criteria based on multiple days of observations (Epstein, 1979). At the same time, aggregation over multiple days would make the estimate of AOA less precise and more prone to loss due to missing observations. The point to note is that the first day of attainment is not the only way to define an event, and we considered different criteria for deciding that a milestone had been reached in this study.

In order to measure age-of-attainment, we employed a longitudinal design to obtain specific AOAs for both proto-declarative pointing and crawling. A longitudinal design in which parents are recruited and utilized to watch for specific milestones events, which they can easily observe, was optimal. Parents spend more time with their infants than we the researchers can. Therefore, it is likely that they are in a better position to observe these events when they occur. Thus, with parents' help, a longitudinal study of observable milestones, and our AOA approach to differences in rate of development became an attractive method to determine the relationship between crawling and pointing.

*The Present Study*

As described above, some theoretical explanations of joint attention mainly favour neuro-biological maturation, evolved modules of social understanding, innate-cognitive abilities or social conditioning theories to explain the development of joint attention. These competing theoretical explanations in most instances only emphasize a single feature of the circumstances that influence the development of proto-declarative pointing. For example, the infant's biological or genetic inheritance as some theories argue, while "necessary" for the development of joint attention, is “insufficient” to facilitate the development of pointing on its own.

Instead, we argue that the development of pointing is embedded within these distinct, but interdependent relationships that influence each other over time. Therefore, this study took a novel approach to investigate one of these relationships by emphasizing the influence of self-produced locomotion on the development of proto-declarative pointing. The investigation of this dynamic developmental factor also insured that we accounted for the influence of the infant’s own biological constitution, as well as the influence of their experiences. If we are to identify causal processes that influence the variation in the different ages of onset of proto-declarative pointing in the literature, we needed to simultaneously examine the relationship between the onset of pointing and the other variables that could be associated with pointing as a developmental system.

We predicted that individual differences in the age-of-crawling attainment would predict the age of first point. Investigating the relationship between pointing and crawling in a longitudinal study was an opportunity to better understand from a developmental systems perspective the role of early locomotor experience on later joint attention abilities, a relationship to which prior research has alluded. Therefore, we expect that babies who crawl at younger ages will point earlier than late crawlers. Additionally, age of first crawling will be an indicator of the accumulated influence of both prior experiential and prior biological factors on gross motor development.

Individual differences in the age-of-onset of crawling and pointing reflect differences in timing elements. The timing of these events may be reflected in how we measure the AOA of pointing and crawling. The choice of an appropriate event definition also depends on the nature of the milestone and how abruptly it is attained. For some milestones the transitions from one status to another may be more gradual; for others the transition may be sudden (Bushnell & Boudreau, 1993). In part, then, we argue that the appropriateness of an event threshold definition is an empirical question, and one that we addressed in this study by considering different event definitions and their reliabilities. For example, along with considering the first instance of an event occurrence, we also considered other definitions (e.g., the mid-point of the first 3-day window that encompasses two appearances of a milestone). Once a reliable AOA definition is determined for pointing and crawling, we will use the best defined AOAs to assess my core hypothesis, namely that earlier crawling predicts earlier pointing, after appropriately controlling for other known predictors of pointing, such as SES, education, age and gender.

# CHAPTER III

# METHOD AND MATERIALS

Before testing the hypothesis that age-of-onset of crawling predicts the age-of-onset of pointing, we considered onset definitions for the two developmental events (crawling and pointing) in question. These definitions were applied to the observations for each baby in our data set, to determine the best definition to use to describe each baby's age of milestone attainment. Before describing our method of attainment event definition in more detail, I will describe the dataset that will be used in this study. The data for this study are from a large, existing longitudinal dataset. Below, I describe how the data were collected.

### *Recruitment and Procedure*

Participating parents were recruited primarily by distributing a brochure to new mothers at a major hospital maternity ward in the city of Winnipeg. The brochures were also included in a "Welcome Wagon" packet for new mothers at a second hospital in the city. This brochure invited parents to call the study office. The research was also advertised in a number of other ways: a newspaper article about the study, a news segment on the local television news program, publicity booths at parenting and birth fairs, and friends and relatives. When interested parents ($N$=784) contacted the researchers, they were advised about the general nature of the study. If they agreed to participate, they were asked for their infant's date of birth. Then, when the infant was two-months old, the researchers mailed a packet to the parent containing a consent form, a checklist and postage-paid envelopes for returning the consent and information forms and the checklists. Parents were asked to mail back the completed checklist forms on a monthly basis. At the end of the study, they were sent a small gift and a *Baby of Science* diploma.

*Participants*

General information about the participants ($N$=613) was obtained using questions drawn from the National Longitudinal Survey of Children (Statistics Canada, 1995). These questions covered family income, mother education, smoking and alcohol use during pregnancy, birth order, birth weight, birth length and gestational age. Although infants entered the study at different ages, most began at 2 or 3 months, which is before crawling typically occurs; approximately 90 percent of infants first crawl between 5-to-11 months (Bayley, 1969). Because crawling is a key predictor for testing the influence of independent locomotion on the age-of-onset of proto-declarative pointing, we first needed accurate reports of when infants in our study first crawled. Secondly, by using data in which most infants were recruited before they crawled, we ensured that we could test our hypothesis with prospectively collected data.

After recruitment, infants were followed until they walked or until their parent stopped returning monthly milestone forms. According to the literature, most babies are reported to point on average between 9 – 13 months (Blake et al., 1994; Butterworth and Morrissette, 1996; Camioni et al., 2004; Eaton & Lall, 2008; Leung and Reingold, 1981; Murphy, 1978), which meant the data were appropriate to test for a link between crawling and pointing.

*Exclusions*

In determining the final sample to be included in our analysis, we needed to identify and exclude any cases where the age for first pointing was implausible. According to the established developmental timeline for which motor milestones appear, sitting is expected to emerge before crawling, which is expected to emerge before pointing. In our data, we found 11 of 613 cases where parents reported that their infant pointed before sitting, and based on existing literature, we decided to exclude these infants from the analyses. This exclusion reduced the sample to 602. We also excluded from the analysis all infants ($N$ =171) from the final analysis whose parents reported that their infant had previously passed any of the milestones of interest (sitting, crawling, pointing) before they joined the study.

*Checklist data*

The daily parent checklist was easy for parents to use, and contained a number of items related to infant milestones. An example of the daily checklist recording sheet is included as Appendix A. A set of 31 easily observable milestones were developed from infant assessment tools, such as the Denver Developmental Screening Test II (Frankenburg, Dodds, Archer, Shapiro, & Bresnick, 1990), the Bayley Scales of Infant Development (Bayley, 1969), and the Alberta Infant Motor Scale (Piper & Darrah, 1994). A crucial issue for a study on age of attainment is the identification of the day when a milestone is first reached. Thus, I evaluated the reliability of different onset definitions.

One could argue that using parent reports for scientific research may lead to inaccuracies because of reporting biases and memory lapses. The memory-lapse criticism is not relevant in this situation because the recordings were being made daily. Moreover, as Stiles points out (see Fenson, Dale, Reznick, Bates, Thal & Pethick, 1994), most family doctors invariably depend on parents for information about children's illness before they decide on a treatment for a child. In addition, parent reports have been used in the construction of the widely used MacArthur Communicative Development Inventories (CDIs) (Fenson, et al., 1994). Thus, for this study, the prospective longitudinal data obtained from parent participants will likely yield reliable sources of information. Moreover, parents spend much more time with their infants than we, the researchers, possibly could. Therefore, they are in a better position to notice any subtle developmental changes occurring in their child, and are able to capture their infants' developmental events on a daily basis, when "even weekly observations may miss these critical transitions" (Thelen & Smith, 1998, p. 602).

There is evidence for the validity of such parent checklist reports. Bodnarchuk and Eaton (2004) compared parent report checklists to the scores kept by researchers who visited the home and found good convergence between parent and visitor attainment reports. Bodnarchuk and Eaton (2004) found that parents provided reliable reports on sitting, crawling and walking milestone attainment indicating that parents do recognize developmental changes in their infant and accurately report on them.

*Outcome Variable*

In the present study, the main outcome variable of interest was the age-of-onset of proto-declarative pointing, which was described to parents as follows: "Baby points or reaches towards an object or event they're interested in and wants you to notice (baby wants to share interest or enjoyment with you)." This definition conveys to parents in a simple and clear manner the infant's physical actions as well as the underlying intention behind an act of proto-declarative pointing as defined in the literature. That is, the baby wants to communicate his own interest to the parent, as well as to draw the parent's attention to the object of interest so that the parent can also share interest in the object with them. This definition is similar to the definitions used by others (Bates et al., 1975; Baron-Cohen, 1989; Masataka, 2003).

*Attainment Event Definition*

We used in the analyses only those babies whose records began before they were able to sit, so we expected that parents would initially report that their baby had not yet sat, crawled or pointed. Next it was necessary to explicitly define how an age of attainment is determined. There are several possibilities to which we now turn.

*Age of First Attainment*

The simplest attainment event definition is the day of the first reported observation of a milestone, and this age of first attainment (AOF) is calculated by subtracting the baby's birth date from the day of first observation and converting to weeks of age. It was possible that the milestone may have been reached prior to the start of observation, which would have meant that the first day of parent observation would have been mistaken for the AOF. To avoid that mistake, we established from the checklist that a milestone had not been previously seen in the seven days prior to the first reported attainment; at least four or more of those seven days had to have been recorded as "not observed" (up to three days of the seven days could have missing observations).

*More Stringent Attainment Criteria*

The AOF is not the only possible event definition of milestone attainment, and one of our goals was to assess the reliability of alternative threshold definitions. Specifically we evaluated three other event definitions that use increasingly larger observational windows from which the attainment is determined. A window is an established number of days that is successively applied to the ordered array of daily observations for a given baby using a SAS program called *Proc Expand.* In other words, the SAS program looked at one window after another until it found one that met the criteria. Thus for a 3-day window, we required that at least 2 passes of the milestone by the baby be observed by the parents. Once two passes are observed, only then is the baby judged to have reached the milestone. Then, to establish an exact age we needed to select a specific day from the window; we used the middle day of the first three-day window when this occurred. In a similar fashion, five- and seven-day windows with three- and four-pass thresholds were also considered. Thus, in addition to AOF, which is a 1-of-1-day criterion, we had a 2-of-3-day criterion, 3-of-5-day criterion, and a 4-of-7-day criterion. To illustrate, different hypothetical patterns of observations are addressed by the four different definitions in Figure 1.

In Figure 1, four different patterns of observations are displayed (e.g. Saltatory Change, Early Outlier, Missing Data and Infrequently Seen). To the right of each pattern is a row of hypothetical outcomes, where 0 = not observed, 1 = observed, - = missing data. For example, Saltatory Change is abrupt change and is characterized by an uninterrupted series of 0's followed by an uninterrupted series of 1's. Such a pattern of observations indicates that change is sudden (or Saltatory) and consistent, as opposed to one that is intermittent or episodic. However, in reality, we needed to be prepared to deal with data patterns containing more varied patterns of observations and missing data. Some of these possibilities are represented by hypothetical sequences of 0's, 1's and –'s for the other four patterns. Figure 1 also depicts window sizes that vary from one to seven as shown by the shaded part of the row. The X in each row represents the deemed day of attainment for each definition. In the case of Saltatory Change, all definitions return the same day of attainment, Observation Day 9. However, it can be seen with other data patterns, that the deemed day of attainment will differ from definition to definition. For example, for the Early Outlier pattern, a first observation criterion identifies Observation Day 2, whereas the other definitions pick Day 7 or 8. Consequently, it is necessary to empirically evaluate the different definitions' reliability as they interact with actual data from real babies. We applied each of these 4 criteria using the *Proc Expand* program to the actual observations for the babies to establish the reliability of different age-of attainment decision rules.

*Figure 1.* Illustrations of four event attainment criteria as applied to four different patterns of daily checklist observations.

| Pattern & Criteria | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Saltatory Change** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **First** | | | | | | | | | X | | | | | | | |
| **2 of 3** | | | | | | | | | X | | | | | | | |
| **3 of 5** | | | | | | | | | X | | | | | | | |
| **4 of 7** | | | | | | | | | X | | | | | | | |
| **Early Outlier** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **First** | | X | | | | | | | | | | | | | | |
| **2 of 3** | | | | | | | | X | | | | | | | | |
| **3 of 5** | | | | | | | X | | | | | | | | | |
| **4 of 7** | | | | | | | | X | | | | | | | | |
| **Missing Data** | 0 | 0 | 0 | 0 | – | – | 1 | – | 0 | – | 1 | 1 | 1 | 1 | 1 | 1 |
| **First** | | | | | | | X | | | | | | | | | |
| **2 of 3** | | | | | | | | | | | X | | | | | |
| **3 of 5** | | | | | | | | | | | X | | | | | |
| **4 of 7** | | | | | | | | | | X | | | | | | |
| **Infrequently Seen** | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| **First** | | | X | | | | | | | | | | | | | |
| **2 of 3** | | | | X | | | | | | | | | | | | |
| **3 of 5** | | | | | X | | | | | | | | | | | |
| **4 of 7** | | | | | | | | | n/a | | | | | | | |

Note. 0 = Not observed; 1= Observed; – = missing data; X = Attainment; ▒ = Window.

## *Predictors*

Several important predictors were included in the analysis model to ensure that the predictive value of crawling or pointing is independent of other variables that could influence when babies first point. Crawling, the core predictor of proto-declarative pointing was described to parents as follows: "Baby uses only hands and knees for support. Baby's back is straight and doesn't sag. The knees are under the hips, and the elbows are under the shoulders. Only check this skill if you see your baby continuously go 10 feet or more (this will involve several consecutive crawling steps)."

Crawling is one of many, related motor milestones, and the main hypothesis is based on the idea that experience in self-propelled locomotion is a key contributor to the onset of pointing. In order to differentiate locomotion from related milestone accomplishments, we sought to include another, non-locomotor, gross motor milestone that could serve as a proxy for general motor development that was distinct from self-propelled locomotion. Sitting is a milestone that fit these requirements nicely because it is nearly universal and involves gross motor skills and balance, but does not include locomotion.

Sitting develops earlier than crawling. Sitting was described to parents as follows: Baby sits up alone *without using hands for support* for at least 30 seconds (is not propped with pillows or other supports). Back is straight. Baby often uses hands to play with a toy." By including sitting as a predictor, a milestone that infants typically would have attained prior to both crawling and pointing, we could remove the effects of prior gross motor development from the influence of locomotor experience on the age when babies point.

Along with crawling and sitting, we considered 13 individual differences variables that are widely known predictors of infant development, including mother's age, gestational age, sibling, ponderal index, mother education, household income, smoking, alcohol, gender, birth position, birth weight, birth length and caesarian versus vaginal birth (see Table 1). These variables were derived from questions taken from the National Longitudinal Survey of Children (Statistics Canada, 1995). Age-of-attainment of pointing, sitting and crawling were measured in weeks. In this analysis, all covariates were centered. In some cases, 0 represented a baseline situation. In others, predictors were centered on their approximate mean value. For example, gestational age was recoded so that 40 weeks would be reset to zero. Thus the default model estimate of age at first point would be for an infant with zeroes on all the centered variables.

Demographic characteristics such as income and mother education are related to individual differences in the development of theory-of-mind in preschool-aged children (Pears & Moses, 2003). The relationship between socio-economic status (SES) and mother education on the development of motor milestones in infancy is not that clear in the literature. Some studies show a positive relationship between SES and the attainment of milestones; whereas, others show the opposite relationship (Lejarraga, Pasucci, Krupitzky, Kelmansky, Bianco, Martinez et al., 2002). Gestational age is a known predictor of when all milestones appear (Peter, Vainder, & Livshits, (1999), in that earlier gestational age is associated with delays in motor abilities. Finally, researchers found that infants born to older mothers were delayed in gross motor development compared to infants born to younger mothers (Eaton, Bodnarchuk, Mckeen, & De Jaeger, 2007).

*Table 1.* List of possible predictors of infant development included in the analysis.

| *Predictor* | *Centered/Reference* |
|---|---|
| Gender | Male=0, Female = 1 |
| Gestational Age (weeks) | 0 centered on 40 weeks |
| Caesarian | Vaginal=0, Caesarian = 1 |
| Smoking | No=0, Yes = 1 |
| Alcohol | No=0, Yes = 1 |
| Mother's Age (years) | Centered on 31 years |
| Ponderal Index | Centered on 2.4 |
| Education | 0 centered on Trade School Diploma |
| Income | 0 centered on $40K-$59K |
| Sibling | No =0, 1= Sibling |
| Birth Weight (g) | Centered on 3560 grams |
| Birth Length (cm) | Centered on 54 cm |
| Birth Position | First Born = 0, Second Born = 1 |

# CHAPTER IV

## Results

*Reliability*

The appropriate form of reliability for our longitudinal data would be split half reliability, where the elements of each half are drawn from across the observation days. Therefore, we assessed reliability by dividing an infant's daily records into two samples, one from all even-numbered calendar days, and the other from all odd-numbered days. We then applied each of the four event definitions discussed above to each sample, that is, first to the even-days' recordings and second to the odd-days' recordings. We then had two samples of observations for each infant, to which we could apply our four different AOF definitions. Our estimate of split-half reliability was the intraclass correlation (ICC), which estimates the percentage of shared variance from one sample to the other. ICC is analogous to a squared Pearson *r*. With two estimated dates of attainment for each definition for each baby, we were able to estimate a split-half reliability coefficient for the various attainment definitions for both crawling and pointing.

A second consideration in choosing the best definition was sample size. These could differ because definitions requiring more days of observations are more likely to have missing values. For example, in Figure 1, the 4-of-7 day definition could not be calculated for the Infrequently Seen pattern because of missing data. For these reasons we needed to select the definition that maximized reliability while minimizing missing data for AOA estimates. Table 2 presents the various attainment definitions and their calculated split-half ICC reliabilities. Examination of *n*'s shows that sample size drops as the number of days in the threshold definition increases.

*Table 2.* Intraclass correlation (ICC) reliability estimates and sample sizes for crawling and pointing by age of attainment definition.

| Age of Attainment Definition | N | ICC |
|---|---|---|
| | Crawling | |
| Age of First (AOF) | 359 | 0.994 |
| 2-of-3 Day Criterion | 354 | 0.988 |
| 3-of-5 Day Criterion | 350 | 0.989 |
| 4-of-7 Day Criterion | 338 | 0.980 |
| | Pointing | |
| Age of First (AOF) | 224 | 0.964 |
| 2-of-3 Day Criterion | 217 | 0.956 |
| 3-of-5 Day Criterion | 212 | 0.966 |
| 4-of-7 Day Criterion | 207 | 0.947 |

As seen in Table 2, there was little meaningful difference in the reliabilities calculated from the AOF criterion through to the 4-of-7 day criterion for crawling and pointing, with one exception. For pointing, the 3-of-5 day criterion resulted in a slightly higher reliability than the AOF of pointing. However, the number of participants present for this criterion was less than the number of participants in the AOF criterion. Thus, to maximize the number of participants in our study, we chose to use the AOF definition for pointing instead of the 3-of-5 day criterion. We also decided to use AOF as the event definition for crawling. We noted from our ICC calculations that the sample size for AOF of pointing ($N$=224), was less than the sample size for AOF of crawling ($N$=359), indicating that some participants were missing data for the variables required for our hypothesis-test analysis. Because meaningful differences in reliability were not observed, the decision was to use the definition that resulted in the largest sample size, AOF.

*Survival Analysis*

The main goal of this study was to determine whether the age of onset of crawling was predictive of the age when babies use proto-declarative pointing. Survival analysis, also called event history analysis, was used to analyze the influence of crawling on pointing. Survival analysis was originally developed to predict people's survival rate (Singer & Willett, 2003) and was primarily used by life insurance companies, but as Allison (1995) pointed out, it can be used for all sorts of time-defined events. Unlike most studies, age was not an independent variable, but rather an outcome variable. More specifically, the age-of-attainment of proto-declarative pointing was the outcome variable, which was predicted by age of crawling and other predictors. Therefore, survival analysis has the ability to address our research question of how much time (age) has elapsed before the target event occurred. That is, is the length of time to achieve pointing shorter for the infants who crawled at a younger age compared to later crawlers?

Survival analysis is similar to multiple regression analysis because it can accommodate multiple predictors of proto-declarative pointing, such as family socio-economic status and gender, and covariates of interest to us like infant gestational age, and mother's age in our analysis. In addition, there is a key advantage of survival analysis over multiple regression analysis, namely survival analysis does not require that all participants have non-missing values for the outcome variable of interest, in this case proto-declarative pointing. This is an important advantage because in longitudinal studies, participant attrition is inevitable, and late pointers would be more likely to be missing than early pointers. This leads to bias in longitudinal studies toward younger age estimates for when babies first point. The attrition problem is addressed with survival analysis because study dropouts can still provide information on pointing attainment. For example, if an infant has not pointed before leaving the study, survival analysis takes this into account because it uses the information that the baby had not pointed prior to the date of dropping out. Thus, survival analysis is more appropriate for addressing our hypothesis because late pointers who left the study were included, not excluded, as would have been the case with multiple regression analysis (Singer & Willett, 2003).

*Censoring variables for survival analysis*

In order for survival analysis to take into account the timing of an event occurrence in our study, two variables in addition to the age-of-attainment AOA variable must be created. These new variables indicate to survival analysis whether the events of interest occurred within the duration of the study, or not. Only AOA variables are entered into the survival analysis program, *Proc Lifereg*, as predictors. The two additional variables enter the *Proc Lifereg* program as outcome variables. These variables reflect a lower bound and an upper bound for the outcome variable. In our particular situation, if a baby reached a milestone before the start of study, then the lower bound for the attainment is unknown, and we only know the upper bound, which is the start date of the study. The upper bound indicates that the milestone was attained; however, we do not know the exact date when the milestone was attained because this event occurred prior to the start of the study. On the other hand, if the baby did not attain the milestone or during the study, then we only know the lower bound, that is the last day of participation in the study. When the baby is reported to have attained the milestone during the study, we know the exact date when the milestone emerged, and both the lower age-of-attainment (lower bound) and the upper age-of-attainment (upper bound) are equal to the AOA. By utilizing these "censored' (upper and lower bound) variables, survival analysis provides a better estimation of the timing of an event.

*Multicollinearity*

Before entering the predictors in the final survival analysis, we conducted multicollinearity analysis to ensure that our predictors were not significantly correlated with each other. For the full sample we intercorrelated all predictors and examined the size of the correlations. Large correlations signal multicollinearity problems, and one of the highly correlated predictors should be considered for removal. Correlations for all of our variables were in a reasonable range, except for birth weight and birth length, which were correlated at $r > .70$, so these two variables were excluded after they were combined into a useful alternative, Ponderal Index (indicator of infant growth and chubbiness). Ponderal Index (PI) = 100 x (Birth Weight in grams/ Birth Length in $cm^3$. Birth position was also highly correlated with the number of siblings in the household ($r = .83$), so birth position was also excluded from the analyses. We opted to keep the number of children in the household in our model because this was a key variable of interest. After making these changes, we subsequently calculated two collinearity indices, the tolerance test and the VIF test. Tolerance values < 0.2 (that is, closer to 0) indicates multicollinearity, but tolerance values for our variables were all larger than 0.77. A VIF value > 4.0 indicates a multicollinearity problem, and our VIFs for all variables were less than 2, which was in an acceptable range.

*Survival Analysis Results*

*Infant Demographics.* Table 3 describes the percentage of infants in our sample as a function of the levels of categorical variables in our model. Table 4 provides summary information for the continuously distributed variables in the sample.

*Table 3.* Summary information for categorical predictor variables

| Demographic Variables | Percentage |
|---|---|
| Gender | |
| Male | 55 |
| Female | 45 |
| Delivery Type | |
| Caesarian | 19 |
| Vaginal | 81 |
| Smoking During Pregnancy | |
| Yes | 11 |
| No | 89 |
| Alcohol Use During Pregnancy | |
| Yes | 19 |
| No | 81 |
| Other Sibling in Household | |
| Yes | 47 |
| No | 53 |
| Mother Education | |
| High School | 13 |
| Community College | 16 |
| Trade School Diploma | 22 |
| Bachelor | 39 |
| Masters | 10 |
| Family Income | |
| Less than $20K | 7 |
| Between $21K to $39K | 15 |
| Between $40K to $59K | 24 |
| Between $60K to $79K | 29 |

*N*=277

The final sample size after the survival analysis was *N*=277 which is the number of infants with complete data for all predictor variables. As noted earlier, the outcome variable, pointing, could have missing values.

*Table 4.* Summary information for continuously distributed predictor and outcome variables.

| Analysis Variables | Mean | STD | Minimum | Maximum |
|---|---|---|---|---|
| Gestational Age (weeks) | 39.7 | 1.4 | 34.4 | 42.9 |
| Mother's Age (years) | 31.5 | 4.5 | 1.9 | 43.9 |
| Ponderal Index | 2.4 | 0.3 | 1.8 | 3.9 |
| Sit | 25.4 | 3.9 | 9.7 | 39.1 |
| Crawl | 37.4 | 6.4 | 20.4 | 64.7 |
| Point | 39.4 | 8.5 | 12.7 | 59.1 |

*N*=277

A total of 12 predictors were entered into the SAS *Proc Lifereg* program using a gamma distribution. The algorithm converged with a Log Likelihood of -153.7. Table 5 provides a summary of all predictors entered into the survival analysis. A positive significant coefficient for a predictor means that an increase of one unit for a predictor is associated with an increase (i.e., later) in age-of-attainment of pointing (i.e., more of the predictor is associated with more age). In the final survival analysis, the significance of each predictor was evaluated after the effects of the other predictors in the model had been removed. Wald $\chi^2$ for significant predictors of pointing are highlighted in italics. The Wald $\chi^2$ statistic reflects Type III analysis effects, which indicates the significance of each predictor above and beyond the effects of the other predictors on the age of pointing. Four of the twelve predictors entered into the survival analysis were significant, Ponderal Index, Mother's Education, Sit and Crawl.

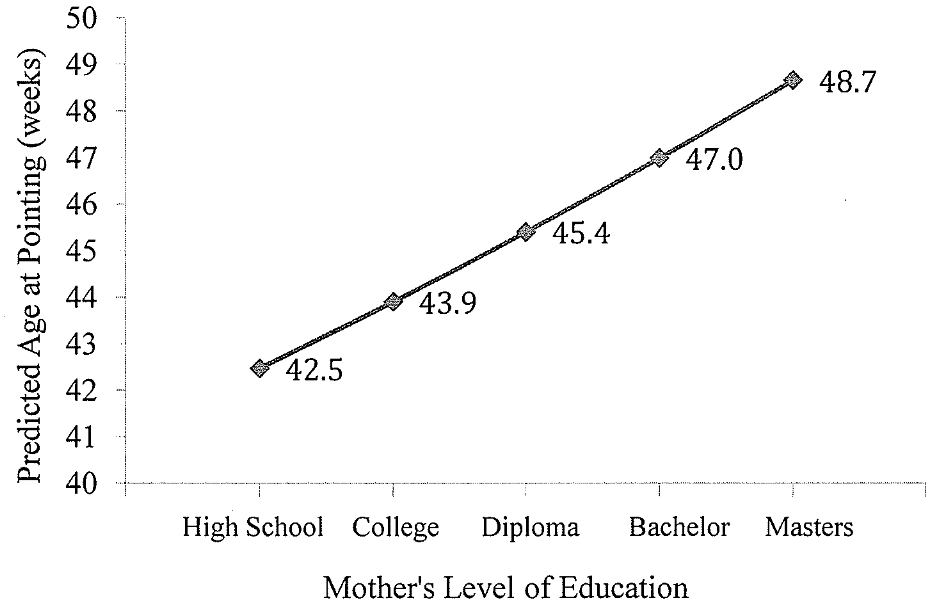
*Table 5.* Summary of survival analysis model

| Predictors | Wald $\chi^2$ | Parameter Estimates |
|---|---|---|
| Mother's Age (years) | 0.181 | 0.002 |
| Gestational Age (weeks) | 0.392 | 0.013 |
| Ponderal Index | *4.435* * | 0.187 |
| Mother Education | *4.212* * | 0.051 |
| Household Income | 0.005 | -0.002 |
| Smoking | 0.302 | 0.057 |
| Alcohol | 0.277 | 0.037 |
| Gender | 1.610 | -0.070 |
| Caesarian birth | 1.636 | 0.092 |
| Sibling | 0.353 | 0.036 |
| Sit | *10.582* ** | 0.025 |
| Crawl | *6.252* * | 0.012 |

$p < .05^{*}$ $p < .01^{**}$

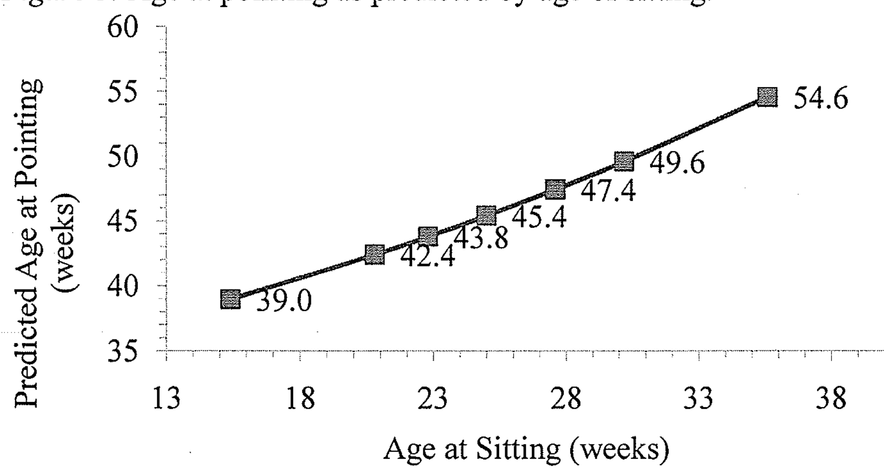
Age of pointing was positively related to mother's education, that is, babies whose mothers reported lower levels of education pointed earlier than babies whose mothers reported higher levels of education, see Figure 2. For example, mothers with high school level of education reported that their mothers pointed on average at 42 weeks whereas mothers with a university degree reported that their infants pointed at 47 weeks, a difference of 5 weeks.

*Figure 2.* Age at pointing as predicted by mother's education



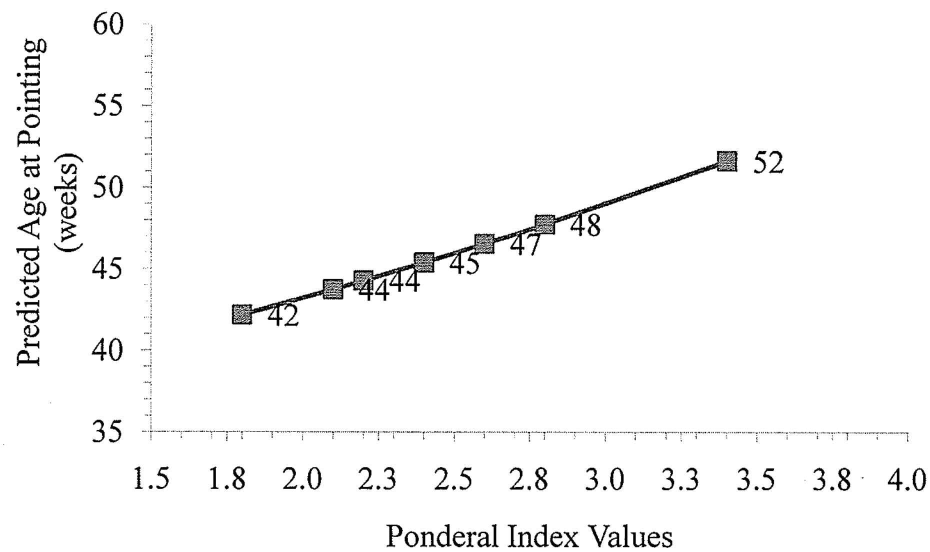

Babies who sat earlier pointed earlier (see Figure 3). That is, infants who sat at 28 weeks pointed at 47 weeks and infants who sat at 38 weeks pointed at 54 weeks.

*Figure 3.* Age at pointing as predicted by age of sitting.



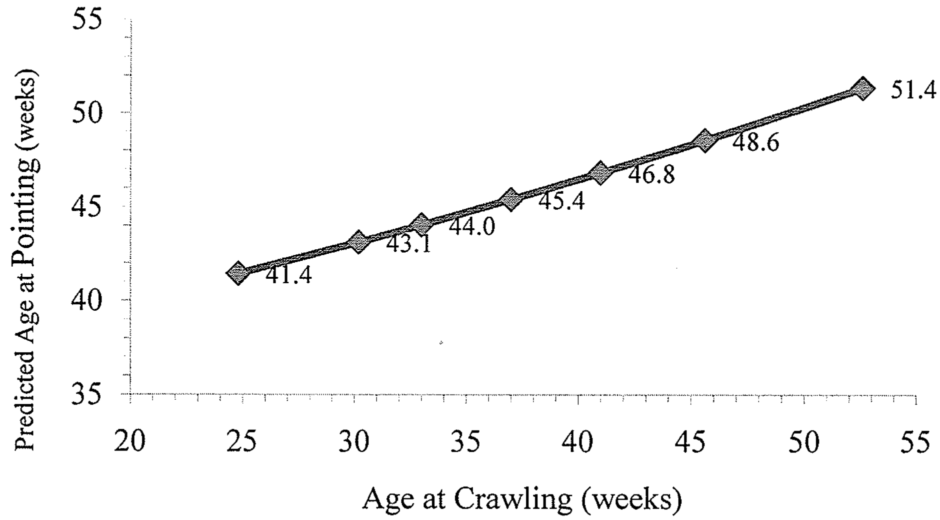
In addition, infants who were chubbier, those who had higher Ponderal Index values at birth, pointed later, compared to infants with lower values on the Ponderal Index. An infant with a Ponderal Index of 2.3 pointed at 44 weeks compared to an infant with a Ponderal Index value of 3.0 who pointed at 48 weeks (see Figure 4).

*Figure 4.* Age at pointing as predicted by Ponderal Index




Finally, age of crawling, the main predictor of interest in this study significantly predicted the age when babies first point, above and beyond the influence of other important predictors. Infants who crawled at 35 weeks pointed at 44 weeks compared to infants who crawled at 45 weeks and pointed at 47 weeks.

*Figure 5.* Age at pointing as predicted by crawling.




*Multiple Imputation*

After completion of the survival analysis, we noted that only $N$=277 participants were included in final analysis, although the number of participants entering the model was $N$ = 602. We were concerned about the possibility that the significant results we obtained from the survival analysis were a function of missing data, and decided that perhaps we could not be too confident about the robustness and interpretation these results. We decided that we needed to come up with a strategy for dealing with missing data and to conduct supplementary analyses.

Multiple imputation (MI) was the chosen method for replacing missing values, and we only imputed values for the continuous variables in our model (gestational age, mother's age, Ponderal Index, sitting and crawling). We chose MI because unlike other existing methods for replacing missing values, MI will replace each missing value with a set of plausible values, instead of simply replacing each missing observation with a single value. A plausible set of values will reflect the "uncertainty about the right value to impute" (Yuan, 2009; p.1). MI also considers the relationships among the variables in the dataset, as it computes replacement values as opposed to dealing with them in isolation. Finally, MI will take into consideration the patterns of missingness in the dataset before computing the replacement values. MI is able to determine whether the pattern of missingness in the data is monotone or random.

MI was conducted using the *Proc MI* function in SAS. We selected the Markov chain Monte Carlo mode for generating missing values because the pattern of missingness in our data was random. *Proc MI* involved several runs to create multiple imputed data sets, of which, the standard number of datasets created is five. After these five imputed data sets were created, they were re-entered into a survival analysis. Then, the parameter estimates from each of the five analyses were combined using the *Proc Mianalyze* program in SAS to obtain general results. Table 6 displays a summary of the parameter estimates in the original survival analysis and results from the survival analysis after MI. Survival analysis using the five multiple imputed data sets indicated that all non-significant predictors remained non-significant. All significant predictors remained significant with the exception of Ponderal Index, for which the *p-value* increased from $p = .035$ to $p = .094$. Although the increase in the *p-value* was small, we still felt the need to be cautious about the robustness of Ponderal Index as a predictor of proto-declarative pointing. We also concluded that the parameter estimates resulting for the original standard survival analysis results did not reflect bias due to missing data.

*Table 6.* Summary of significant survival analysis parameter estimates before and after multiple imputation.

| Predictors | Standard Analysis *p-value* | Multiple Imputation *p-value* |
|---|---|---|
| Ponderal Index | .035 | .094 |
| Mother Education | .040 | .002 |
| Sit | .001 | .013 |
| Crawl | .012 | .034 |

# CHAPTER V

## Discussion

### *Age of Attainment Definitions*

This study first set out to examine an age-of-attainment method of data collection using the *Proc Expand* program in SAS to define a framework for collecting age-of-attainment data, and to determine the best way of measuring the age-of-onset of motor milestone events. These measurements were subsequently entered into survival analysis to test our predictive model. Data for this study were gathered from a longitudinal, prospectively collected data set. Parents were previously asked to make daily recordings of whether or not they saw their baby display a series of milestones. We felt that parent participants were extremely important to our study because they could more readily observe their babies' development than could visiting researchers, and at far less cost.

After data collection, we first wanted to ensure that parent reports yielded reliable as opposed to biased data. Our intention in this study was to obtain from a large sample of infants, the age of first attainment for a variety of developmental milestones. To ensure that our checklist data collection method would provide reliable age of attainment estimates, we decided that instead of simply using the date that a parent reported that they had first observed a milestone, that is, the age-of-first attainment (AOF); we would instead evaluate multiple threshold definitions to define age-of-attainment. The use of AOF is based on an implicit assumption that once a milestone appears it is consistently present. This may not be the case, and other threshold definitions may be more appropriate when a milestone makes a fleeting inconsistent appearance. These threshold definitions were then applied to the date-ordered array of observations for the infants in our sample. Thus, along with using the first day of attainment of a motor milestone as the age-of-attainment in our analysis, we considered three additional event definitions to determine the best way for estimating the age of crawling and pointing onset.

Split-half reliability for these data was calculated using the ICC, by comparing the odd-days of observations to the even-days observation for each baby. Odd and even day observations were reliable across the various definitions, and ranged from .95 to .99 for both crawling and pointing. We found that when the 4 different criteria definitions were applied to the longitudinal observations, they returned similar reliability estimates across definitions for crawling and pointing. Similar ICCs across the various event onset definitions using different window sizes (three, five or seven days) indicate that the onset of pointing and crawling are fairly abrupt events, and once seen, they seem to be consistently present, at least for seven days (the size of the largest window). Although we chose to use the AOF in our final analysis, similar ICCs across definitions implies that we could have chosen any one of the 4 event definition criteria to determine AOA, for testing the main hypothesis of the study with survival analysis.

*Independent Locomotion and Proto-Declarative Pointing*

The main purpose of this study was to examine the development of proto-declarative pointing from a dynamic developmental systems approach. A dynamic development systems explanation for pointing would argue that an infant's ability for proto-declarative pointing emerges from an interaction of biological, social, emotional and environmental factors. This contrasts with more dominant theories of joint attention, which consider the development of pointing to be either an innate, maturational or cognitively determined phenomenon. Theoretical arguments state that the onset of crawling brings about a "reorganization" of the infant's perspective taking abilities, as well as changes in the types of social and emotional interactions infants begin to encounter (Campos et al., 2000; Thelen, 2000). The onset of independent locomotion is expected to result in changes in parent-infant relationships as a result of the infant's new found freedom to pursue his own goals and activities. For example, parents would need to now actively supervise their crawling infants to keep them out of harm's way. Thus, crawling is considered one of the dynamic factors that could influence the later development of proto-declarative pointing, and joint attention. As a result, our main hypothesis was that infants who crawl at a younger age will also point at a younger age.

To test the influence of crawling on pointing, we included multiple predictors of pointing, not just one or two. We found that an influence of age-of-crawling on the age of onset of proto-declarative pointing above the effects of other predictors. In particular, we included age of sitting in our model to account for the influence of generic maturational effects on the age of attainment of pointing. It is possible that any predictive relationship between crawling and pointing may simply be a reflection of the influence of a general developmental rate on various aspects of development, such as crawling and pointing. That is, the relationship between crawling and pointing could be simply reflecting a third variable, general rate of development. To get a better assessment of the influence of the age-of-onset of crawling on when babies first point declaratively that is distinct from general developmental rate, we removed the influence of AOA of sitting on the development of proto-declarative pointing.

*Theoretical Implications of the Association between Crawling and Pointing*

We tested the hypothesis that the onset of independent locomotion predicts the development of proto-declarative pointing. This hypothesis was confirmed and provides support for recent theoretical arguments that the development of proto-declarative pointing and early social understanding could be influenced by the age of onset of independent locomotion. These results also provide some preliminary support for a dynamic systems perspective on the development of joint attention. According to dynamic systems theory, the onset of crawling not only represents the infant's attainment of gross motor development, it represents many other dynamic changes in the infant's developmental arena that are not limited to physical growth. These changes include a new perspective on the world, environmental changes, and changes in infant-caregiver emotional relationship and interactions that could play a role in the development of joint attention. For example, relational theories of joint attention argue that the quality of parent-infant relationships may influence joint attention attainment. Crawling in turn may influence how these relationships play out, which in turn may influence the development of pointing. Another significant theoretical contribution of this study is brought about by the longitudinal nature of this study. We were able to find a significant relationship between crawling and pointing that persisted over developmental time. Finding a relationship that persisted over time supports a developmental systems approach to understanding proto-declarative pointing.

*Additional Contributions*

The significant predictive relationship we found between crawling and pointing is consistent with findings from earlier studies. However, when these earlier studies examined the relationship between pointing and crawling, they only examined and reported on the relationship between the onset of crawling and infants' ability to point or gaze follow. That is, they examined the difference between crawlers and non-crawling ability to successfully follow an experimenter's point (see Campos et al., 2000 for a review of these studies). In this study, we went further on to examine the relationship between the onset of crawling and the infant's *production* of proto-declarative points with prospective longitudinal data as opposed to cross-sectional data.

Another contribution of the present study was the use of stringent techniques to examine the relationship between crawling and pointing. We decided to use more stringent techniques to identify the ages of attainment of crawling and pointing, before attempting to identify the difference in the amount of crawling experience measured in weeks that is required to predict proto-declarative pointing. Previous empirical studies on the other hand only examined the relationship between independent locomotion and joint attention by looking at differences in joint attention abilities between two groups of infants, crawlers and non-crawlers.

*Sitting, Ponderal Index, Mother's Education and Proto-Declarative Pointing*

This study provides additional support for a dynamic systems perspective on pointing because aside from only looking at the influence of crawling on pointing, we also considered several other variables to explain the development of pointing, of which four including crawling were significant.

Three non-crawling predictors in our survival analysis model were significant, Age of Sitting, Ponderal Index and Mother's Education. As discussed earlier, Age of Sitting was included to account for general developmental rate. Ponderal Index at birth was a significant predictor of age of pointing indicating that infants who scored in the higher range of the index pointed later than infants with lower scores. Ponderal Index is an index of chubbiness, and high scores tend to indicate heavier babies. According to our results, babies who were chubbier at birth tend to point later than thinner babies. Perhaps it is easier to move a thinner body in space than to move a heavier one. And Thelen and Smith (1998) succinctly explain here how an infant's unique developing motor system may underlie her ability to successfully engage in joint attention behaviours. In the following excerpt, they describe how individual differences in infant motor systems influence motor-action:

> "The task for all babies was the same: to get their hands in the vicinities of the desired objects. But they had different problems to do this: Gabriel and Nathan had to damp down their forceful movements to gain control; Hannah and Justin had to produce more muscle force to extend their arms forward in space and hold them stiffly against gravity" (p.608).

It is inferred from Thelen and Smith's observations, that individual differences in the development of infant motor systems may influence variations in the age-of-onset of independent locomotion, which in turn may influence the perspective changing opportunities that independent locomotion brings to an infant (Lindbolm & Ziemke, 2006). In turn, individual differences in the onset of independent locomotion may be one factor that explains variations in the ages-of-onset of proto-declarative pointing, reported in the literature (Blake, O'Rourke and Borzellino (1994); Butterworth and Morrissette, 1996; Camioni et al., 2004; Eaton & Lall, 2008; Leung and Reingold, 1981; Murphy, 1978). These individual differences in motor systems or body type (thinner or bigger), as reflected by infant's Ponderal Index value could influence when babies point declaratively. These particular findings reflect a relationship between measures on Ponderal Index that were taken at the infant's birth and crawling, so these results should be carefully interpreted, because we had no way of verifying that these values remained consistent across time.

Mother's Education was also a significant predictor of age of pointing. Results from survival analysis indicate that infants of more educated mothers produced declarative pointing at older ages. It is possible that this finding may simply reflect that more educated mothers are quite likely to be away from their home more often, and therefore were unable to interact with their infants often enough to observe infant's pointing behaviours and to reinforce their babies pointing. But, it is possible that more educated mothers were more discriminating in their observations of what constitutes a proto-declarative point based on the definition we provided them with. It is also possible that more educated mothers may use language more often when interacting with their infant, as opposed to gestures. Rodrigues (2006) observed that mothers with less education used gestures more often than more educated mothers. She also found that the number of gestures infants produced was related to the number of gestures that mothers used in parent-infant interactions.

*Strengths, Limitations and Conclusion*

A major strength of this study was the use of parent checklist diaries that facilitated the collection of milestone data because it used observable facets of behaviour, based on simple and clear descriptions. This meant that the task of recording milestone onset was simple enough for parents to understand. A second strength of the milestone checklist was that in order to prevent the possibility of parental bias in their observations, the milestone checklist was designed to focus on overt behaviours, used low-inference coding definitions and same-day observations. The success of this easy-to-use parent report checklist may also provide a format for other researchers to regularly and reliably track children's development from central as well as remote locations in an economical way. Finally, parents used these checklists to observe and record the presence of the milestones prospectively.

However, there were some limitations to this study. First of all, we depended on parental observations of the onset of the milestones in question, instead of observing them ourselves. We had no way of knowing whether parents filled in the checklists several days at a time, and whether they may have been biased by the ordering of the checklist items. For example, crawling was listed prior to pointing on the checklist. It was possible that parents assumed that crawling developed prior to pointing. Secondly, this study was not based on a random sample of parents and infants, but instead on a convenience sample. Also, we did not measure any other factors related to infant development, which current theory suggests may have an influence on the development of joint attention abilities. Additional measures we could have included in our study were measures of infant secure attachment, infant emotional development and infant temperament. Finally, we did not measure the amount of freedom infants had to explore their environment nor did we attempt to get a sense of individual differences in parental restrictiveness due to safety concerns, which together could have influenced infants' ability to locomote.

To conclude, in this study, we attempted to answer this question: "Does Independent Locomotion Influence the Age-of-Attainment of Proto-Declarative Pointing?" But now we must ask ourselves how well we addressed this question. First, in order to answer this question, which dealt with the attainment of an age related event, we outlined an efficient way of collecting age-of-attainment data. Then we discussed a method of establishing the appropriate age of first attainment of the milestones in question. After obtaining appropriate ages of attainment, analyses revealed that our main hypothesis was supported. That is, differences in crawling experience predicted when babies begin to produce proto-declarative pointing. These results were in line with current theoretical arguments that a relationship exists between the experience of self-produced locomotion and the development of joint attention.

The empirical findings that the age a baby crawls predicts when they will begin to produce declarative pointing also supported preliminary empirical findings of this relationship in the current literature. But beyond this, we established a very interesting linkage between earlier crawling and pointing, one that may explain other findings in the research literature. Mainly we refer to two separate studies. One study established links between crawling and cognitive development at 2 years of age (Mckeen, Eaton, Bodnarchuk & Lewycky, 2007), while the other has established a relationship between pointing and cognitive abilities at 2 years (Lall, Eaton, McKeen & Bodnarchuk, 2009). It is possible that the relationship between age of crawling and later cognitive abilities may in fact be mediated by the age when an infant points, but this relationship warrants further investigation.

Although we encountered many interesting findings in our study, we feel that we have only just begun to answer the question "Does Independent Locomotion Influence the Age-of-Attainment of Proto-Declarative Pointing?" We arrived to this conclusion mainly because theory suggests that it is the influence of the "experiential consequences" of independent locomotion and not the act of crawling itself that influences the development of joint attention abilities. In our study, we only examined the influence of independent locomotion on the development of crawling, assuming the presence of greater amounts of "experiential consequences" if crawling was attained earlier. We did not go on to measure and examine any of the possible theorized mediating "experiential consequences" of independent locomotion on the later development of proto-declarative pointing. However, we still conclude that this study provides some exciting results, and we suggest that future studies examine the factors that may mediate the relationship between independent locomotion and proto-declarative pointing.

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APPENDIX A

## October 2004

Each day, mark every item with one of the following: observed (o) not observed (--) don't know (?)

| Milestones | Fr 1 | Sa 2 | Su 3 | Mo 4 | Tu 5 | W 6 | Th 7 | Fr 8 | Sa 9 | Su 10 | Mo 11 | Tu 12 | W 13 | Th 14 | Fr 15 | Sa 16 | Su 17 | Mo 18 | Tu 19 | W 20 | Th 21 | Fr 22 | Sa 23 | Su 24 | Mo 25 | Tu 26 | W 27 | Th 28 | Fr 29 | Sa 30 | Su 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grasps and holds a rattle or toy | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Reaches for object | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Passes from hand to hand | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sits using own hand support  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sits without support (5 secs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Sits without support (30 secs)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rolls over | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rocks on hands and knees | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Shifts weight from 4 limbs to 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Feeds self finger food | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Crawls **less** than 10ft (3m): | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| belly crawl | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| other crawl | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| hands-and-knees crawl | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Crawls **more** than 10ft (3m): | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| belly crawl  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| other crawl | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **hands-and-knees crawl** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Drinks from cup by self | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Says "mama" or "dada" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Stacks toys or other objects | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Points or reaches: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |