MOTOR TRAINING AND ATTENTION ENGAGEMENT IN EARLY INFANCY: A PILOT STUDY

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Abstract

The following study evaluated the long-term effects of motor training on 3-month-old infants regarding motor development and attentional development in a natural setting (i.e., when interacting with parents). Infants were trained daily for two weeks by their parents. Motor activity and attention were assessed prior to and after training, and at 5 months of age. Infants were either actively (received opportunities to grasp objects) or passively (received no such opportunities) trained. Overall, results did not reveal a difference in motor or attentional tendencies between the active and passive training groups, although actively trained infants showed tendencies towards increased motor behaviour relative to passively trained infants. Infants in both groups demonstrated increased motor behaviour across assessments, and results were inconclusive regarding attentional tendencies during parent-infant interactions in each group. Findings from the present study provide an important first step from which future studies can determine the long-term effects of motor training.

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Motor Training and Attention Engagement in Early Infancy: A Pilot Study

Introduction

From the moment they are born, infants are presented with a wealth of information from their environment. Early interactions with the environment provide learning opportunities for infants, as each new encounter offers new avenues from which to draw information about the world. Research has explored infant development across a variety of domains. One particular developmental domain that has received considerable attention is motor development (e.g., Bushnell & Boudreau, 1993; Cratty, 1979; Frick & Möhring, 2013; Von Hofsten, 2003; Thelen, Kelso, & Fogel, 1987). Throughout early development, a major mode by which infants learn is through the physical exploration of their environment with their body and hands (Jouen & Molina, 2005; Ruff, 1984); thus, acquiring an understanding of how motor processes develop and function has been of interest to many. The following introduction will discuss various aspects of infant development, including theories of development, motor development and the development of attention, developmental cascades and milestones, neurological development, motor training, the role of parental involvement, and joint attention.

Theories of Motor Development

As researchers gained an increased understanding of infant development, varying theories were established to describe the process of motor development. An early ecological approach to infant development emphasizes the concept of affordances in linking perception and action as they relate to motor processes (Gibson, 1988; 1991). According to this framework, infants perceive different objects in their environment as providing certain capabilities and limitations (affordances) on which they can or cannot act. For example, a perceived affordance of a shelter is that it can protect us from harsh climates. The concept of affordances is related to both perception and action because it is linked to how one understands and explores their environment. (Gibson, 1988, 1991). The appraisal of objects' affordances also impacts upon cognition, as this leads infants to think about their surroundings in a novel way (i.e. to consider the practical utility of surrounding objects).

The ecological theory of development links perception and action because it is proposed that they guide one another in the detection of object invariants (the characteristics of objects that do not change, for example, upon object movement; Gibson, 1988, 1991). As an infant comes to learn about invariants, this furthers their understanding of an object's affordance and facilitates motor interaction with that object. Thus, according to this theory, as infants come to understand an object's invariants and affordances, their motor activity develops and increases accordingly (Gibson, 1988, 1991). While infants are still learning about affordances, motor exploration is essential in aiding this process (Gibson, 1991).

Another theory of development that builds on the ecological approach, the dynamic systems theory, views development as being continuous in time, nonlinear (can be both predictable and unpredictable), and complex (determined by multiple factors such as the brain, the body, the environment, and their interactions; Thelen, 2005). In the context of this model, the term dynamic means that the state of an infant's developmental system at every point in time depends on its previous states. It also means that the current state of an infant's developmental system is the starting point for future states (Thelen, 2005). According to this theory, development has a quality of dynamic stability. For example, once infants master a new behaviour, this behaviour becomes stable for some time. Then, as other new behaviours emerge, the old behaviours become less available or less favourable to the infant (Thelen, 2005). Development as seen from this perspective, is the result of infants' everyday experiences and continuous attempts to benefit the most from their ever-changing collection of abilities (Thelen, 2005). One example that illuminates the key components of this theory is the development of walking. At birth, infants engage in reflexive newborn ‘stepping’ motions with their feet. However, the development of walking is dependent on many factors (e.g., physical strength, muscle tone, motivation, environmental factors such as the surface upon which the infant is placed) as opposed to simply an inborn reflex. Further, as infants learn to walk, they revert back to crawling at times until walking becomes easily achievable in both simple and complex scenarios (e.g., walking on new surfaces, moving at different speeds; Thelen, 2005).

When applied to motor development, the dynamical systems approach theorizes that each new action learned by the infant will become stable and commonly used until a newer and more favourable behaviour is learned. For example, pre-grasping infants may bring a toy up to their bodies by dragging it on the floor towards themselves using their arms and hands. Then, as the infant learns how to grasp objects with their hands, they will no longer need to drag toys toward themselves, as they will be able to reach forward and pick them up. In their everyday encounters with objects, infants learn new, more efficient ways to organize and achieve these interactions.

Motor Development and the Development of Attention

In addition to establishing an understanding of motor development, researchers have investigated the relationship between motor and other areas of infant development. Interestingly, motor development is associated with development in many other domains, and can even propel other areas of developmental change (e.g., cognitive function; Murray, Jones, Kuj, & Richards, 2007). Studies have found that motor development is associated with language development (Iverson, 2010; Iverson & Braddock, 2011; Wang et al., 2014), perception (Bushnell & Boudreau, 1993), attention (Libertus & Needham, 2011; Sommerville, Woodward, & Needham, 2005; Tamis-Lemonda & Bornstein, 1993), cognition (Diamond, 2000; Piek, Dawson, Smith, & Gasson, 2008), and academic performance (Bornstein, Hahn, & Suwalsky, 2013). Recent research on infant development has also begun to recognize the important role of fine-motor experiences early in life on later development in other domains (Libertus & Needham, 2011; Ozonoff et al., 2008; Piek et al., 2008). Thus, while motor development is significant in its own right, it also has very important implications in regards to other areas of infant development.

For the purposes of this literature review, a further discussion of the association between fine-motor development and attention skills is particularly relevant. Through interactions with objects (and, often simultaneously, with other people), infants learn about the physical and the social world (Brandone, 2015; Libertus & Needham, 2010). In a study assessing the frequency with which infants look at others' faces, Libertus and Needham (2010) found that motor training by use of a sticky mitten paradigm increased the tendency to look at faces in infants as young as 3 months old. *Sticky mittens* are mittens that have Velcro attached to their palms, and are worn by infants during training sessions in which an adult draws the infant's attention toward a set of toys. A complementary set of toys contain the corresponding piece of Velcro, so that when the infant contacts the object, the Velcro pieces on the mittens and the toy will stick together and a successful grasp will be achieved.

In another study, Tamis-Lemonda and Bornstein (1993) found that 5-month-old infants' exploratory behaviours and motor maturity were predictive of their attention skills at 13 months of age. More specifically, increased exploratory behaviour at 5 months of age predicted increased levels of exploratory competence (play and attention) at 13 months old (Tamis-LeMonda & Bornstein, 1993). Research has also shown that increased motor activity at 3 months of age is associated with attentional gains at 15.5 months old (Libertus, Joh and Needham, 2015).

Thus, motor development appears to have important implications in regards to attentional development and may also have a predictive value.

Developmental cascades: Motor development and attention connections. Earlier in this literature review, studies were presented demonstrating that motor development is associated with outcomes in a variety of other developmental domains, a process that has come to be understood by some researchers through the concept of developmental cascades (Masten & Cicchetti, 2010). Developmental cascades refer to the delayed, cumulative effects of experiences in one area of behaviour that emerge either later in development, in other areas of development, or both (Masten & Cicchetti, 2010). When applied to a motor context, new skills that are learned by the infant may alter the way in which the infant interacts with the environment, and thus provide new and different learning opportunities. For example, once an infant is able to pick up toys, they then have more opportunities for new types of social engagement, as they can now share this toy (and their experience of this toy) with others (Karasik, Tamis-LeMonda & Adolph, 2014). Further, parents can invite their infant's attention toward various object features or functions as they become more salient to the infant. Thus, changes in motor ability appear to invite new experiences, initiating a developmental cascade that fosters learning and allows for new learning opportunities (Bornstein et al., 2006).

Motor and attentional developmental milestones in typically developing infants. In addition to understanding how different processes develop in infants, substantial research has provided a timeframe for the ages at which different abilities should appear in typically developing infants. At 2-months of age, infants are able to visually track events (e.g., a parent's activity, von Hofsten & Rosander, 1997), attempt to look at their caregivers, and begin to turn their heads to orient towards sound. In regards to motor activity, 2-month-olds can make smoother movements with their arms relative to when they were 1-month old (McDonnell, Corkum, & Wilson, 1989).

At 4 months of age, typically developing infants begin to reach towards a toy with one hand, and to coordinate action with vision. For example, an infant at this age learns to coordinate looking at a toy and then reaching towards it. Typically developing 4-month olds can also grasp and bimanually explore/manipulate objects (Rochat, 1989). They begin to pay more attention to faces (Frank, Vul, & Johnson, 2009), and begin to smoothly follow moving objects with their eyes (Rosander & von Hofsten, 2004).

When infants are 6 months old, most enjoy playing with their parents and begin to respond to others' emotions. They make important gains in regards to fine-motor coordination, learning to pick up and hold onto objects without assistance, hold an object with both hands, pass an object from one hand to another, and explore objects with their fingers (Eppler et al., 1995). They also engage in more sophisticated reaching and grasping (Heineman, Middelburg, & Hadders-Algra, 2010).

Because developmental guidelines have been established, caregivers are able to monitor their infants' behaviour to assess for early indication of developmental delays. Depending on the nature and severity of early developmental delays, these delays can range from being normative, to indicating that the infant may have an increased chance of developing a disability. Building on the knowledge of typical developmental milestones, if infants are at higher risk of developing a certain disability (e.g., increased likelihood due to heritability), preventative measures can be taken to try and elicit behaviours that low risk, typically developing infants would produce naturally (Hadders-Algra, 2013; Mahoney & Perales, 2006).

Neurological development in early infancy: Visual and motor development. In addition to the developmental milestones that have been established, research has identified the early neurodevelopmental trajectories for the visual and motor systems (Sampaio & Lifter, 2014). The visual system undergoes exponential growth within the first year of life, during which there is a proliferation in synapse density within the visual cortex (Sampaio & Lifter, 2014). This is particularly relevant to motor development given the influence of vision on inspiring motivation for object exploration in infancy (Morgante & Keen, 2008). Moreover, in concert with the development of the visual system, increased activity in additional brain regions (e.g., the primary sensorimotor cortex, thalamus, cerebellum) facilitate the development of pre-reaching movements within the first few months of life (Sampaio & Lifter, 2014). The growth and maturation of these various brain regions are influenced both by natural development as well as the infants' experiences (Sampaio & Lifter, 2014). Thus, infants undergo extensive neurodevelopment during infancy, and early experiences can further impact upon this development.

Sticky Mitten Research

Upon evaluating motor development in young infants, researchers have begun to design experiments in order to determine whether reaching and grasping behaviours can be elicited at an earlier stage of development than has been recognized thus far. In recent years, there has been an increasing focus on the use of training with sticky mittens, using the paradigm described above, to initiate infant reaching behaviours at an earlier age than is typically observed (Libertus & Needham, 2010, 2011, 2014; Needham, Barrett, & Peterman, 2002). A number of studies have shown that when 3-month-old infants are trained with sticky mittens for 10-minutes a day during a 2-week period, their reaching behaviours exceed those of their non-sticky mitten trained peers (Libertus & Needham, 2010, 2014; Libertus et al., 2015; Needham et al., 2002). The number of reaches made, time spent reaching, and time spent holding objects have all been shown to be enhanced by training with sticky mittens. Additionally, some sticky mitten studies have investigated looking behaviours and have found that infants who are trained with sticky mittens display more looking episodes (incidences of attention shifting) toward the caregiver and toy when compared to those without this training (Libertus & Needham, 2010; Libertus et al., 2015). The sticky mitten paradigm has been widely tested in the literature across several studies and the effect has proven robust in regards to motor exploration, reaching and grasping, attention engagement, and attention focusing in infants.

While there has been support for the effectiveness of sticky mittens, there has also been some related controversy in the literature. A study conducted by Williams, Corbetta and Guan (2015) did not find that the use of sticky mittens enhanced reaching behaviour or the attentional shifts noted in previous studies. In their study, they emphasize the importance of repeated task exposure, tactile feedback and social feedback of the parent as the mechanisms of change, as opposed to the sticky mitten training (Williams, Corbetta, & Guam, 2016). A response from Needham, Wiesen, and Libertus (2015) noted that some of the conflicting results were likely due to differences in methodology, and a recent study by Wiesen and colleagues acknowledged that the social role of the parent likely does contribute to the results (Wiesen et al., 2016). Thus, there is currently evidence supporting the value of sticky-mitten training for motor and attentional development, but there is some controversy regarding its specific effects as opposed to those cause by other factors (e.g., social interaction).

An additional consideration related to motor training paradigms is the practical utility of conducting training simply for the sake of motor training alone. Completing motor training in typically developing infants does not appear to offer immediate, tangible benefits, as all infants learn to reach and grasp. However, it does allow for an understanding of the flexibility/plasticity of the motor and attentional systems in the developing infant. While there are not immediate benefits in typically developing infants, sticky mitten training may offer unique learning experiences for atypically developing infants, as one study has found that active motor training led to increased reaching and grasping in infants who are at a high risk of developing Autism Spectrum Disorder (ASD; Libertus & Landa, 2014).

Motor Training and Attention Connections: Long-Term Effects

In addition to evaluating the immediate effects of motor training with sticky mittens, research has also followed infants on longer-term bases to evaluate whether two weeks of motor training with sticky mittens can produce lasting effects on reaching behaviour and attention (Libertus et al., 2015; Wiesen et al., 2016). Because typically developing infants do develop sophisticated reaching and grasping behaviours (at around 6-8 months of age; Heineman et al., 2010), one would expect that infants in both an active and a passive training group (being trained with or without the use of sticky mittens, respectively) would perform similarly once grasping is achieved through natural development. However, a study that followed up with infants when they were 15.5 months old found that those who were actively trained at 3 months of age initiated significantly more reaches and grasps than their peers who received passive training (Libertus et al., 2015). This study also found that training type (active versus passive training) acted as a predictor for subsequent object exploration one year after training, such that infants in the active training group demonstrated increased object exploration relative to their peers in the passive training group (Libertus et al., 2015).

In this study, Libertus and colleagues (2015) also found that active motor training had implications in regards to attentional development. The researchers investigated infants' visual toy engagement by use of a coding scheme that monitored whether the infant was attending to the toy, the caregiver, or elsewhere. Their results showed that at the age of 15.5 months old, infants in the active training group allocated significantly more attention toward the toys than did infants who were in the passive training group (Libertus et al., 2015). The authors concluded that the long-term effects of motor training provided further evidence for the role of motor development in the context of developmental cascades.

An additional study followed infants who received sticky mitten training at 3 months of age, to evaluate their motor activity and attention at 5.5 months of age (Wiesen et al., 2016). The researchers utilized an object exploration task, wherein an object was placed in the infant's hand, and evaluated looking, reaching, touching, and bimanual exploration. In addition to the object exploration assessment, a reaching assessment was also conducted (the typical measure used in sticky mitten studies) during which a rattle was placed at varying distances from the infant, and reaching behaviours or attention were coded at various distances (Wiesen et al., 2016). The results indicated that, at 5.5 months of age, infants who received active training demonstrated increased visual attention toward and manual contact with the object relative to their peers in the passive training condition. These results indicated, as the researchers interpreted, a cascading effect of the motor training (Wiesen et al., 2016). As the infants grew and continued to develop naturally, those who had additionally received active sticky mitten training at 3 months of age showed increased reaching behaviours relative to those without active motor training.

While research is starting to investigate the long-term gains of early active sticky mitten training, a closer examination of the benefits associated with this training is warranted. The previously discussed research indicates that there are benefits of active motor training in regards to reaching behaviours and, to some extent, attention skills. However, because the majority of studies that have demonstrated the benefits of sticky mitten training have been published within the context of one research lab or have used shared data in some capacity, it is important that these findings be replicated independently by other labs as well. Because a relationship has been established between motor and attention skills (e.g., Brandone, 2015; Libertus & Needham, 2010; Tamis-Lemonda and Bornstein 1993), a more thorough account of the long-term benefits of active motor training on attention engagement would provide novel information that would have interesting implications for understanding the flexibility of attentional processes during development.

Motor Development: The Role of Parental Involvement

As indicated by the studies previously discussed, and due to the nature of infant development more generally (largely influenced by interactions with others and with the environment), parents play a substantial role in infant development regarding object exploration and learning (Bruner, 1973; Fogel, 1993; Valsiner, 1978). When considering motor development and attention engagement, the specific role of parental contributions has been debated in the literature. Bruner (1973) proposed that parents stimulate joint activities with their infant, and that as their infants' abilities progress, parents then adjust the nature of their play in accordance with the infant's ability level. Thus, the parents scaffold tasks and games in which the infant will succeed, gradually increasing difficulty. In one of his studies, Bruner (1973) found that mothers interpret infants' attention and movements in regards to their underlying intention. If an infant is looking at an object or moving its arms in an effort to accomplish something, the mother will focus her attention to what she thinks the infant is aiming to achieve. Building on this, the mother will then assist the infant in completing the desired action. For example, a mother may hold a toy while the infant explores it (Bruner, 1973). Thus, from this perspective, the parent plays an active role in scaffolding their infant's motor skills.

In opposition to the idea of parents as scaffolders of infant activity, Valsiner (1978) suggested that parents have a more prominent role as instructors. Social interactions, then, are formed in accordance with the opportunities that parents provide for infant socialization. According to Valsiner (1978), parents guide their infants' actions within their environment, because parents set the structure of their environment. As opposed to adjusting behaviours in accordance with their infant's ability level, parents provide the context within which learning and socialization occur.

Whereas Bruner and Valsiner emphasized the role of parental guidance, Fogel (1993) emphasized that parents and infants co-construct the development of infant's motor abilities through their interactions, a framework known as the dynamic interactionist model. As the infant develops, the interaction between parent and infant is adjusted to accommodate these changes (Evans & Porter, 2009; Fogel, 1990; 1992; Lavelli & Fogel, 2005). This finding extends to both motor and postural development. For example, parents may shift from showing infants objects out of reach to holding objects within reach as the infant becomes capable of holding onto the object (Fogel, 1990). This model provides an alternative perspective on the role of the parent as one of a co-constructer of social interaction and motor development.

While there are many theories describing the caregiver role during infant development, it is clear that caregiver involvement is invaluable, especially during the first year of life. Because caregivers play a prominent role in supplementing infant development, it is important that they are actively included in infant training within a research setting as well. Doing so simulates a typical environment and interaction for the infant, and can assist in making a training paradigm fit better within the context of the infant's daily interactions. When parents are able to integrate early motor training into daily activities with their infants, motor experiences tend to be increasingly enriched, especially in infants who are at risk for experiencing reaching delays (Hadders-Algra, 2013; Heathcock, Lobo, & Galloway, 2008; Mahoney & Perales, 2006). Additionally, providing parents with skills by which to train their infants may provide a lasting resource that parents can use long after a period of training has ended.

Joint Attention

In light of the discussion above outlining the instrumental role of parents during infant development, research has also investigated the development of joint-attention, another process in which parents are actively involved. Joint attention occurs when an infant and another individual share an understanding that they are paying attention to the same object (Bigelow, MacLean, & Proctor, 2004). Thus far, there is evidence that joint attention abilities begin to emerge between 6 and 12 months of age (Bigelow et al., 2004; Corkum & Moore, 1995). The development of joint attention can be influenced by a number of different factors. For example, Osorio and colleagues found that infant responding to a mother's "bid" for joint attention (i.e., a mother's attempt to engage her infant in joint attention) was influenced by the total number of times that the mother attempted to share in joint attention with the infant (Osorio et al., 2011). More specifically, infants demonstrated increasing rates of responding to bids for joint attention as the mothers' total bids for joint attention increased. This indicates that an increase in prompting may promote infants' processing and understanding of these bids and subsequent responses to them (Osorio et al., 2011).

Alongside bids for join attention, another factor that can influence the development of joint attention is exposure to objects. With increasing active exposure to objects, infants demonstrate an increased preference for faces and eyes in a dynamic context (Libertus &

Needham, 2011; Libertus & Needham, 2014). Thus, infants begin to learn about social interaction as they are exposed to objects and as they develop the ability to handle objects. Furthermore, Bigelow and colleagues (2004) found that infants engaged in more advanced levels of play when they played with their mother and shared in joint attention relative to when they played with toys on their own. Because joint attention is rooted in simultaneous interactions with others and a third object, it follows that increased in object exposure would be linked to increased social awareness.

In a study investigating parents' role in infant visual and motor development, Danis and colleagues (2000) found that infants aged 2 – 4-months-old had significantly more interest in watching their caregiver present an object than they did in simply viewing an object on its own or attending to their caregiver. This tendency peaked at 3-months-old, indicating that at this age, infants tended to use passive exploration strategies (Danis, Bourdais, & Ruel, 2000). Interestingly, the researchers found that in 4-month-old infants, there was a significant decrease in fixations toward the mother presenting the object as well as a significant increase in fixations toward the object as the mother was manipulating it (Danis et al., 2000). In conjunction with these findings, infants at 4 months of age also spent a significantly greater amount of time grasping the objects than they did when they were 2- and 3-months-old. As infants grew to interact with objects more, the mothers recognized this change and adjusted their actions by holding the toys closer to the infant (Danis et al., 2000).

Levels of attention engagement: Precursors of joint attention. While fully developed joint attention abilities do not appear until around 9 months of age or later, researchers have been able to investigate developmental precursors to joint attention. One way that attention has been researched in the past is through assessment of the various levels of attention engagement exhibited during infant-parent interactions (Bakeman & Adamson, 1984; Perra & Gattis, 2012). Perra and Gattis (2012) assessed attention engagement in 2-, 3-, and 4-month-olds, wherein they outlined six states of engagement that were adapted from a study by Bakeman and Adamson (1984). The first state, *unengagement,* was defined as times when the infant was not engaged in any particular stimulus. Secondly, *onlooking* was coded when infants watched their caregiver interacting with a toy, but did not actively participate themselves. *Object engagement* occurred when infants played with objects alone. The fourth stage of engagement was called *person engagement*, and was defined as occurring when an infant actively interacted with an adult by responding to the adult, or attempting to initiate an interactional exchange. *Passive joint engagement* occurred when infants played with an object that was the focus of their attention as well as the caregiver's, but the infant did not acknowledge the caregiver's activity. Lastly, *coordinated joint attention* occurred when infants played with a toy that the adult was also focusing on, and the infant acknowledged that the adult was looking at the object. This was demonstrated when the infants actively coordinated their attention between the object and the adult (Bakeman & Adamson, 1984; Perra & Gattis, 2012). For example, coordinated joint attention would be coded when the infants would look back from the object to the parent (Perra & Gattis 2012). By observing free-play sessions when infants were 2-, 3- and 4-months-old, the researchers found that 4-month-olds were capable of maintaining simple joint attention, but not complex joint attention. After 3 months of age, infants were able to engage in a wider variety of attentional states. In particular, object engagement as well as passive joint engagement were seen to occur much more frequently than when the infants were 2- or 3-months-old (Perra & Gattis, 2012). The above outlined attentional states could provide further valuable information regarding the development of joint attention if applied to alternative research paradigms in addition to the study conducted by Perra and Gattis (2012).

Levels of attention engagement and motor training. As previously discussed, links have been established between increasing motor engagement and more sophisticated levels of attention engagement in part of the infant. While research has shown the development of differing levels of joint attention at around 4 months, this study did not actively manipulate any variables (Perra & Gattis, 2012). The sticky mitten paradigm could provide novel insights into the development of attention engagement. If infants are able to develop their reaching behaviour at an earlier age through training with sticky mittens, and research has shown that this training has impacted their attention engagement (e.g., Libertus et al., 2016; Wiesen et al., 2016), it follows that they should also be able to engage in more sophisticated levels of attention at an earlier age. As infants increase their interaction with objects, their gaze shifting should adjust accordingly, as their attention will shift between their parent and the toy that is placed front of them.

The Current Study

Purpose. Taken together, the research reviewed above and the diverse accounts of developmental explanations provide a compelling case for the importance of sticky mitten training in regards to motor development (e.g., Libertus & Needham 2010, Libertus et al., 2015), and in some studies, attention allocation (e.g., Libertus & Needham, 2010). However, sticky mitten studies to date have not evaluated the effects of this training on the development of shared attention with others. Additionally, research has not yet determined the generalizability of this training to a naturalistic setting in which an infant is interacting with the parent and the opportunity for free object exploration may stimulate an infant’s motivation to act instrumentally. The current study sought to address these gaps in the literature by evaluating how sticky mitten training impacts upon the immediate and long-term development of both motor and attentional development regarding shared attention as well as the generalizability of this training to a home-based setting.

Further developing an understanding of the link between motor training and changes in attention engagement is important not only to capture the flexibility of infant development, but to appreciate the implications of this training for clinical populations. If infants who receive active motor training engage in differential patterns of attention engagement relative to their passively-trained peers, these results could be important in the development of early interventions for infants who are at a high risk for developing autism spectrum disorder. Research has shown that high-risk infants (i.e., presence of a sibling with autism) who go on to develop autism tend to show very early delays in motor development (Bhat et al., 2011; Heathcock et al., 2015). If an understanding of how sticky mitten training affects attention engagement in a typically developing population can be established, this paradigm can then be applied to infants who are at a high risk for developing autism, in order to target delays in motor and attentional development (e.g., Libertus & Landa, 2014). The present study paradigm was discussed with Dr. Amy Needham, a primary investigator in a number of the sticky mitten studies completed to date (e.g., Libertus & Needham, 2010; 2011; 2014). Dr. Needham expressed interest in the new direction of this research and recognized the importance of building upon the sticky mitten paradigm to expand its applications, while also acknowledging the challenges of home-based research with very young infants (A. Needham, personal communication, May 27, 2016).

The current study was designed to investigate the effects of short-term motor training on both motor behaviour and attention allocation over time. Infants underwent two weeks of motor training that was administered by their parents. In keeping with a core methodological design of recent sticky mittens research, infants received either active (with use of sticky mittens) or passive (without the use of sticky mittens) motor training. Infants were assessed both before and immediately after the two-week training period was complete, and a follow-up reaching assessment was conducted when the infants were between 5 and 5.5 months old. In addition to the reaching assessment, infants also completed a parent-infant interaction task during which infants and their parent interacted with one another as well as with a toy for around 4 minutes (free-play instructions were provided, as delineated below). While implementing a training paradigm is fitting among Western communities, the existence of a broad range of child-rearing and parenting practices cross-culturally is important to acknowledge. The present study focused on a narrow, traditionally western-approach to child rearing wherein introducing training paradigms is commonly accepted and practiced among families.

Hypotheses. Based on the literature discussed above, three motor development hypotheses were proposed. Because an emphasis was placed on evaluating motor development during the reaching assessment, a priori hypotheses were not outlined regarding attentional tendencies during this interaction. The first hypothesis proposed that all infants, regardless of training group, would demonstrate increases in reaching behaviour (measured as the number of reaches made) at the third assessment due to natural development.

The second hypothesis was that during the reaching assessment, when the toy was placed within reach of the infants, all infants would i) contact the toy more frequently during the third and assessment than they did during the first and the second, ii) with infants in the active training group contacting the rattle for a longer duration than those in the passive training group. Additionally, when the toy was placed within reach, iii) infants in the active training group would grasp the toy more often, and for a longer duration of time, than infants in the passive training group.

Thirdly, it was hypothesized that, when the toy was placed in the infants' hands during the reaching assessment, i) infants in the active and passive training groups would have longer durations of bimanual exploration at the third assessment relative to the first two, and ii) infants in the active training group would demonstrate longer durations of bimanual exploration than infants in the passive training group.

In regard to levels of attention engagement during the parent-infant interaction, it was hypothesized that, at baseline testing, infants would spend most of their time either in an unengaged (i.e., not looking at anything in particular) attentional state or looking at a parent, relative to looking at the toy (Perra & Gattis, 2012). Because follow-up sticky mitten studies have not assessed attentional tendencies when interacting with parents in a home-based setting, this research evaluated attention during the parent-infant interaction in the same manner as the reaching assessment (i.e., infant looking at parent, toy, or something else). By first establishing an understanding of the effect of sticky mitten training on parent-infant interaction according to the coding scheme typically used for these studies, future research can incorporate the stages of attention engagement outlined by Perra and Gattis (2012). Exploratory analyses investigated the role of training type (active or passive) on attention (attending to the parent or the toy, instances of shared attention) at post-training (3.5-months-old) and follow up (5- to 5.5-months old).

Method

Participants

For the present study, data were collected from 20 typically developing infants aged 3-months-old (for participant descriptive information, please refer to Table 1). Participants were recruited from the *Ryerson Infant and Child Database*, a joint lab recruitment initiative between three developmental research labs housed in the Psychology Department at Ryerson University. Upon recruitment, participants were randomly assigned to receive either active or passive sticky mitten training. The motor training occurred when the infants were 3 months old (11-14 weeks old). The second assessment occurred two weeks after the first, and the follow-up assessment took place when they were 5- to 5.5-months-old. For information regarding the number of assessments that infants participated in as well as missed sessions, missed trials, and dropout information, please refer to Tables 1 and 2. All assessments took place at the infants' homes, and the researchers travelled throughout the Greater Toronto Area to complete the assessments (see Figure 1 for a map of the areas visited). This research protocol was approved by the Human Research Ethics Board at Ryerson University.

Table 1

Summary of participant characteristics.

Group	n	#Female	Total N assessments	Age 1st assessment	Age 2nd assessment	Age 3rd assessment
AT	10	4	28	3.04 (.26)	3.48 (.28)	5.19 (.18)
PT	10	5	29	3.00 (.39)	3.48 (.40)	5.44 (.35)

Note: AT = active training group; PT = passive training group. Total N assessments indicated the number of assessments completed by each group. Ages at each assessment are averaged within each group reported in months with standard deviation in parentheses

Table 2

Participant assessment and trial information

Total n	# dropped	# rescheduled prior	# rescheduled during	# missed assessments	# missed trials	Prep time/infant (hours)	Appointment time/infant (hours)
27	7	10	8	3	3	1	2.5

Note: # dropped = number of participants who dropped out of the study; # rescheduled prior = number of participants who rescheduled prior to completing the visit; # rescheduled during = number of participants who rescheduled during the visit due to e.g., fussy infant; # missed trials = number of participants who did not complete one part of a trial (e.g., reaching phase 4); appointment time/infant includes transportation time

Figure 1. Map of the Greater Toronto Area, with shaded regions indicating the geographical spread of participants. Image retrieved from https://en.wikipedia.org/wiki/List_of_municipalities_in_the_Greater_Toronto_Area

Materials and Stimuli

Session materials. At each assessment session, the researchers used two digital video cameras (Canon *Vixia HFM41*) with two tripods. The digital timer in the researcher's cell phone was used to time the reaching assessment as well as the parent-infant interaction.

Sticky mittens. Infant-sized mittens with Velcro attached to the palms (designed to match those used in previous studies) were worn by infants during the training sessions in both the active and passive training groups (see Figure 2 for reference). When conducting the reaching assessments, sticky mittens were not worn and infants interacted with a different type of toy than they encountered during training.

Training toys. Training toys were provided to parents and consisted of three Duplo blocks that were presented to the infants during training sessions. The blocks were 4.5 cm on each side, and had a rounded dome on the top. The blocks used in the active training group had (~4 cm) strips of Velcro on each side that were complementary to the Velcro that was attached to the mittens. In the passive training group, the blocks had masking tape on all sides in order to appear visually similar to the blocks presented in the active training group (see Figure 2 for reference; Libertus & Needham, 2010).

Figure 2. Example of the sticky mitten that were used during motor training. The blocks contain the corresponding pieces of Velcro and thus would be used for infants in the active training group. Identical blocks were used to train infants in the passive training group; however, masking tape was placed on all sides as opposed to Velcro.

Test stimuli. Motor behaviours and attention were evaluated during the reaching assessment by use of a standardized (across participants and studies e.g., Libertus & Needham, 2010) rattle that was easily graspable, as well as a tabletop (16.5 in x 16 in, see Figure 3 for reference). To complete the reaching assessments, infants sat in their parents' laps and their parents facilitated steady sitting. The tabletop was placed in front of infants, upon which the rattle was placed during the four-step reaching assessment (see Figure 3 for reference). The tray and rattle were brought to the infants' homes to allow for consistency across testing sessions, and were identical at baseline and follow-up assessments. The parent-infant interaction incorporated the use of toys that parents selected from their collection.

Figure 3. Tabletop and Sassy Flip n Grip rattle that were used to completed the reaching assessment.

Procedure

Home visits. The first of three experimental home visits consisted of parent training, supplying parents with training materials, and conducting the first video-recorded reaching assessment with the infants as well as the parent-infant interaction (see Figure 4 for reference). Parents were provided with a printout of the specific instructions for their training sessions with their infants, and were encouraged to ask any questions as they arose both during the first assessment session as well as throughout the two weeks of training. The primary researcher also explained and demonstrated the training paradigm to the parent, and ensured that the parent understood the instruction. Parents were provided with monitoring sheets in order to track when they were training their infant each day as well as if any notable or unusual events occurred during training. In order to encourage consistent training, parents were also contacted once a week by telephone or email in order to check in, review activities, and answer any questions that may have arisen thus far.

During the second home visit, the researcher collected the training toys from the families' homes and instructed the parent to no longer provide training to their infants in the manner that they had for the two weeks prior. A video-recorded reaching assessment was conducted once again during this session, as well as the parent-infant interaction. The third home visit simply consisted of video-recorded reaching assessments and parent-infant interaction. The setup of the home visits and the components involved in participation from the beginning to the end of the study are displayed in Figure 4.

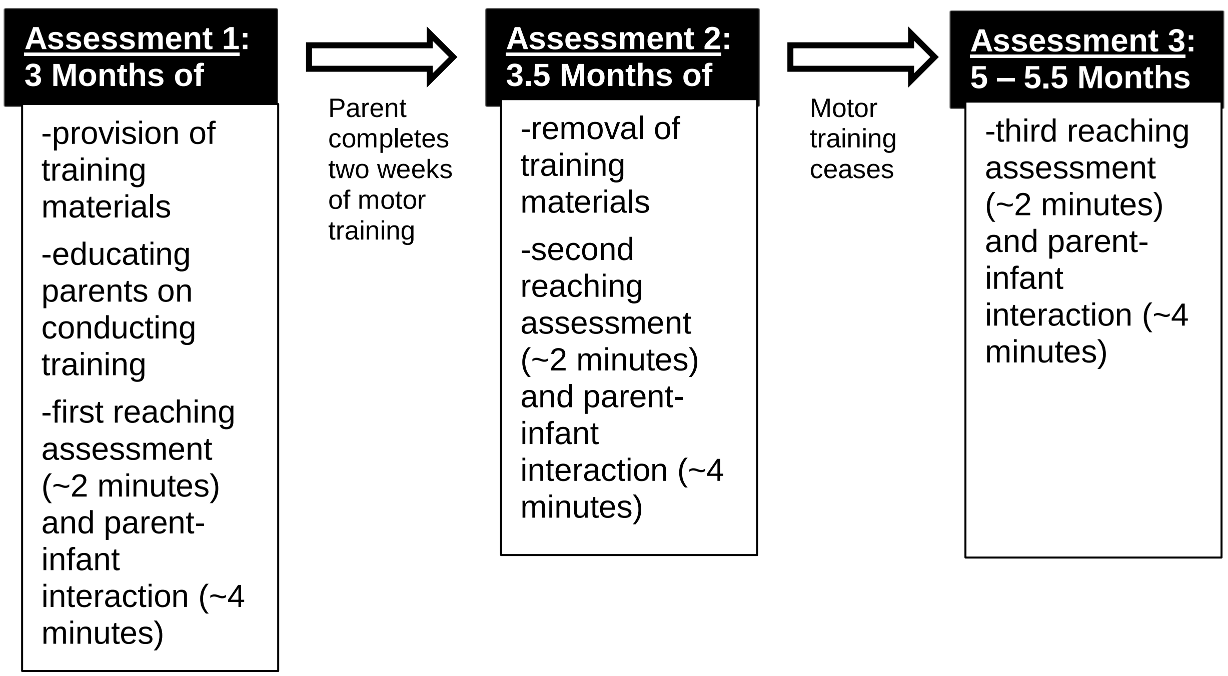

Figure 4. Flowchart describing the timing of, and activities involved during each assessment

Training. Infants received two weeks of motor training that was administered daily by one of their parents, with the same parent conducting each session. All training sessions consisted of a parent interacting with their infant for ten minutes. During these sessions, the parent introduced the blocks and, in some capacity, encouraged their infants to interact with the blocks. The nature of the interaction varied based on whether the infant was randomly assigned to the active or passive training group (see Figure 5 for reference; Libertus & Needham, 2010). In an effort to establish consistency across participants, all parents were encouraged to draw their infant's attention toward the blocks by looking at and speaking about the block (e.g., "*What is this?!*"). Parents were also ensured that, if their infant experienced discomfort during training, the sessions could be broken up into shorter chunks throughout the day (e.g., two 5-minute sessions, five 2-minute sessions, etc.).

The active and passive sticky mitten training sessions followed from the Libertus and Needham (2010) design. Infants in the active training group were supplied with sticky mittens, which contained the soft (loop) side of the Velcro, to be worn by the infants. A set of blocks containing the complementary (hook)Velcro pieces were also used. In these training sessions, the parent demonstrated to the infant that the blocks would stick to their mittens upon contact. After attaching a toy to the mittens worn by the infant, the parent placed the block back on the table, and then drew the infant's attention toward the blocks through pointing, speaking about, or touching the blocks. If the infant successfully reached and contacted a block, they were allowed to "hold onto" and manipulate it for around ten seconds. After the ten seconds had elapsed, the process began again with the parent demonstrating the ability of the blocks to stick to their infant's mittens (Libertus & Needham, 2010). Parents were instructed to demonstrate the function of the sticky mittens following each successful contact made by the infant throughout the 10-minute training sessions.

Infants in the passive training group were trained with the blocks by their parents by use of a procedure called the "object dance" (Libertus & Needham, 2010). In this procedure, the infants wore the sticky mittens with the soft side of the Velcro attached, and the parent drew attention to the blocks. The blocks, however, did not have Velcro attached to them, and thus a successful “grasp” could not be achieved. Upon placing the mittens on their infants, the parents then proceeded to complete the object dance, wherein they lifted a block, tapped it on a table or rough surface, moved the block to the infant’s left hand, tapped the block on the table once again, lifted the block to the infant’s eye level, briefly touched the block to each palm of the infant’s hands, and returned the block to the table. This sequence was repeated at a pace that the parent was comfortable with until ten minutes has elapsed. While the passive training group received a similar amount of exposure to the blocks, they did not have any opportunity to experience self-produced “grasping”. Because they wore mittens, they were unable to use their fingers to assist in picking up the blocks, as outlined by Libertus & Needham (2010).

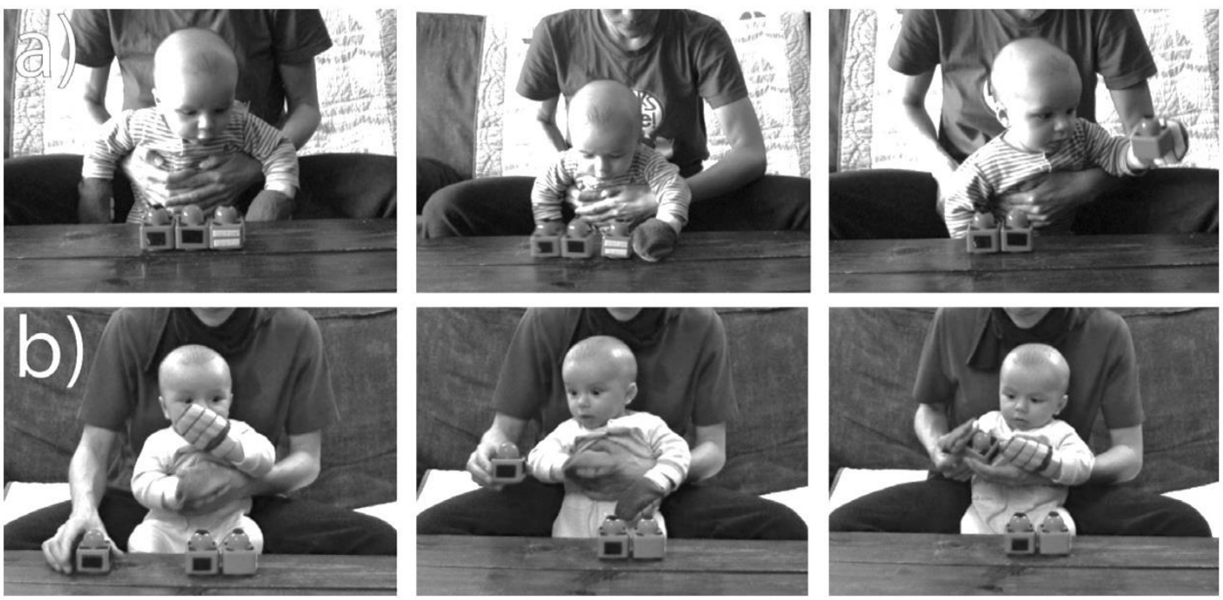

Figure 5. Example of sticky mitten training procedures. a) demonstrates active training wherein infants have the opportunity to ‘grasp’ the block; b) demonstrates passive training wherein the parent completes the ‘object dance.’ Adapted from “Teach to Reach – The Effects of Active vs. Passive Reaching Experiences on Action and Perception,” by K. Libertus, and A. Needham, 2010, *Vision Research, 50*, p. 2751. Copyright 2010 by Elsevier Ltd.

Assessments. All assessments took place in participants’ homes in order to increase ease of participation and to collect parent-infant interaction data in their natural home-environment. Assessment sessions started with a reaching assessment wherein infants were presented with a toy at four different distances (with each distance being maintained for roughly 30 seconds): beyond their reach, far away but within a reachable distance, close and within reach, and placed within their hand (see Figure 6 for reference). At each distance, the researcher drew the infants' attention toward the rattle by pointing and looking at the rattle, as well as using standardized expressions (e.g., *What is this? Do you want it? Can you get it?*; Libertus & Needham, 2010). During all reaching assessments, infants were seated on their parent's lap, facing toward the researcher and away from their parent. The researcher conducted the reaching assessment, and a research assistant was present at all visits to facilitate setup of the video cameras and assist when difficulties arose.

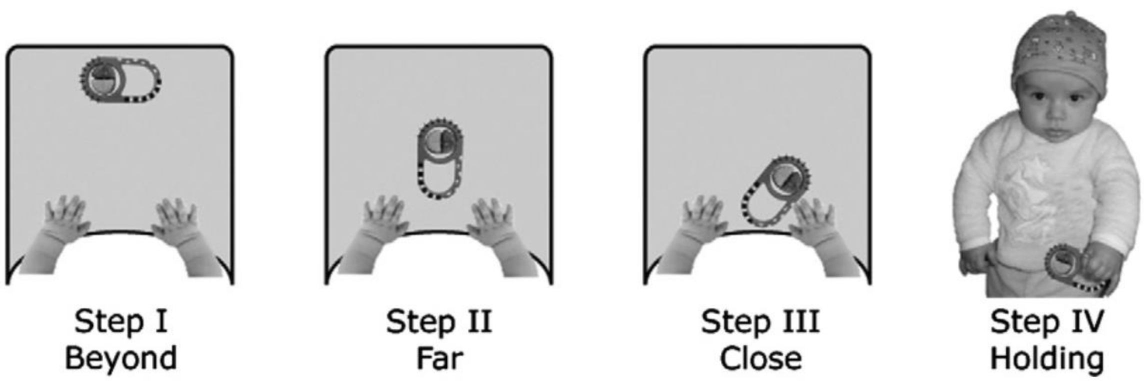

Figure 6. Demonstration of the various distance at which the rattle was placed when conducting the reaching assessment. Adapted from "Teach to Reach – The Effects of Active vs. Passive Reaching Experiences on Action and Perception," by K. Libertus, and A. Needham, 2010, *Vision Research*, *50*, p. 2752. Copyright 2010 by Elsevier Ltd.

In addition to the reaching assessment, a four-minute interaction took place during which the parent interacted with their infant and included a toy. The researchers set up the cameras in such a way that they would be able to capture a wide variety of angles in the event that parents moved around with their infant. Parents were instructed to interact with their infant in a manner that was typical for them, and they were asked to incorporate a toy of their selection. Restrictions were not placed upon words spoken or how parents should approach the interaction with their infant. They were allowed to move around as they desired, but they were asked to remain in such a manner that the infant was able to view both the parent as well as the toy. Upon setting up the cameras and providing the instruction, the researchers left the room in order to eliminate additional distraction. After four minutes transpired, the researchers returned and the interaction concluded.

Measures and Coding

The measures used during the assessments varied according to the task at hand. The reaching assessment comprised of four phases (wherein the rattle was placed i) out of reach; ii) far away but within reach; iii) close and within reach; iv) in the infants' hands; see Figure 6 for reference). Each reaching phase evaluated different variables (Wiesen et al., 2016). The first reaching phase addressed exploratory analyses, evaluating the manner in which infants allocated their attention (defined as the duration of the trial spent looking at the researcher, the rattle, or something else), as well as the number of reaches made toward the rattle. The second and third reaching phases were combined (when the rattle was within reach but not placed in the infants' hands) to address the first and second hypotheses. Reaching frequency (number of reaches made) and duration (amount of time spent reaching), toy contact frequency and duration, and grasping frequency and duration were measured. The fourth reaching phase evaluated the third hypothesis, measuring the duration of bimanual exploration (defined as times when both of the infants' hands were contacting the rattle). Reaching, toy contact and grasping behaviours were not coded according to the right and left hand separately, but were coded together (Libertus & Needham, 2010; Wiesen et al., 2016). A given behaviour was converted into the percentage of time engaged in that behaviour for all variables where duration was measured. Slight variations in trial duration could then be accounted for.

The parent-infant interaction evaluated where infants allocated their attention during the first (addressing the fourth hypothesis), second and third assessments, as well as shifts in attention, and when instances of shared attention took place (exploratory analyses). Measures of attention, in keeping with the coding system noted above, included the duration of time spent looking at the parent, looking at the toy, or looking elsewhere. Looking behaviours during the parent-infant interaction had to occur for at least three seconds in order to be considered as an intentional action (Perra & Gattis, 2012). Looking episodes were also evaluated, such that the number of attentional shifts (e.g., shifts in visual attention toward the parent or the toy) was compared across assessments as well as between groups (Libertus & Needham, 2010).

After each assessment took place, the two videos were merged into one file using Adobe Premiere Pro (see Figure 7 for reference). Infants' motor behaviour and attention engagement were measured frame-by-frame by use of a real-time coding program, *The Observer XTi* (refer to Figure 8 to view a sample of a participant's codes). 25% of trials (5 trials from each assessment point) were then coded by two raters to evaluate interrater reliability, and agreement was high when considering the presence or absence of behaviours (agreement = 91.71%, $\kappa = 0.911$, 95% CI = 0.85 – 0.97, $p < .0005$) as well as the duration of the coded behaviours (agreement = 93.81%, $\kappa = 0.931$, 95% CI = 0.92 – 0.94, $p < .0005$).

Figure 7. Example of a video that has been synced to facilitate coding.

Figure 8. Sample of participant codes using The Observer XTi.

Statistical Analyses

Due to the small sample size and abnormal distribution of the data within and between groups, nonparametric statistics were used to evaluate the above noted hypotheses (Howell, 2013). The sticky mitten studies cited earlier have typically used ANOVAs in order to evaluate the data (e.g., Libertus et al., 2010; Wiesen et al., 2016); however, following considerable review of the sample size and requisite assumptions for use of the ANOVA, nonparametric analyses were considered to be the most appropriate method to analyze the data. In place of the repeated-measures ANOVA, the Related-Samples Friedman's Analysis of Variance (Friedman's ANOVA) was used to evaluate within-group differences across the three assessments. When Friedman's ANOVAs yielded significant results, post-hoc Wilcoxon Signed Rank Tests were used to determine the source of the significant difference. The Mann-Whitney U test was used to evaluate differences between the active and passive training groups, acting as a nonparametric independent-samples *t*-test. Group differences were evaluated both at the assessment of interest (e.g., active versus passive performance at the third assessment) as well as between assessments by calculating difference scores within groups from one assessment to the next, and then comparing each group's difference scores.

The above noted statistical tests convert the data into ranks, and analyses are run based on the ranked data (Howell, 2013). Median values are provided when interpreting results as opposed to means. Because the data are not normally distributed, there are outliers present throughout and this would skew the means upon analyzing the data with parametric statistics. Thus, the results are described according to median values. In keeping with the non-parametric analyses, the mode of visual presentation of the data will also display the median values as opposed to the means. As such, boxplots were selected to visually present the data, as they provide valuable information regarding median values, quartiles and outliers.

Results

The current study sought to investigate the long-term impacts of sticky mitten training on motor development and attentional tendencies in infants between the ages of 3- and 5.5-months-old. A primary focus was placed upon shared attention as well as the generalizability of this training to a home-based setting, which has not been evaluated to date. The implementation of the sticky mitten paradigm reportedly went well for parents, as expected. Many parents indicated that the training was enjoyable and introduced a novel manner in which they could interact with their infants. Some parents noted that their infants did not enjoy wearing the mittens, and as such the motor training was difficult, at times resulting in shorter but more frequent training sessions each day (e.g., two 5-minute intervals as opposed to 10 consecutive minutes). All parents were able to complete at least 8 days of motor training, with most completing ten or more days. During home visits, 96.5% of infants completed the full reaching assessment (i.e., all four reaching phases) as well as the parent-infant interaction. At times that infants became fussy, the parent and researchers worked together to calm the infant, and the sessions subsequently continued as scheduled. Infant engagement was high and parents were also active and enthused throughout the assessment sessions. To track the total number of assessments completed and further details regarding the visits, please reference Tables 1 and 2.

While the implementation of the sticky mitten paradigm and the assessment sessions went as expected, a number of challenges arose during data collection given the nature of the study (home visits), and these difficulties are outlined further within the *Discussion* section. Furthermore, a number of results revealed encouraging trends and confirmed the hypotheses; however, some results (while promising) did not reach the level of significance (as outlined below). The results that follow are organized based on the assessment task (i.e., reaching assessment results presented first, followed by parent-infant interaction), and then subdivided within each section such that results of the associated hypotheses are outlined first, followed by related exploratory analyses.

Reaching Assessment

Hypothesis one. The first hypothesis stated that all infants would demonstrate increased reaching behaviour at the third assessment (at 5-months of age) relative to the first two assessments (at 3-months of age). This hypothesis was evaluated by measuring the number of reaches made across both active and passive training groups during the second and third reaching phases (of the reaching assessment) combined. A Friedman's ANOVA revealed that over the first, second and third assessments, the number of reaches made toward the rattle was significantly different (Mdn_{A1} = .00, range: 0 – 10; Mdn_{A2} = .00, range: 0 – 9; Mdn_{A3} = 1.00, range: 0 – 17; $\chi^2(2) = 7.88$, $p = .019$). A post-hoc Wilcoxon Signed Rank Test indicated that infants reached significantly more at the third assessment relative to the second assessment (Z = 2.287; $p = .022$), thus partially confirming this hypothesis. Reaching frequency also appeared to increase between the first and third assessments; however, this result did not reach the level of statistical significance ($Z = 1.77$; $p = .077$). No significant changes were noted between the first and second assessments regarding reaching frequency ($Z = .180$, $p = .857$).

When changes in reaching frequency were subsequently compared within each group separately, results indicated that there were no significant differences in either the active or passive training group ($\chi^2(2) = 1.04$, $p = .595$; $\chi^2(2) = .839$, $p = .657$, respectively). While the result did not reach significance, a trend toward increasing median values appeared at assessment three in both active (Mdn_{A1} = 1.0, range: 0 – 6; Mdn_{A2} = .00, range: 0 – 9; Mdn_{A3} = 2.5, range: 1 – 8) and passive (Mdn_{A1} = 1.5, range: 0 – 10; Mdn_{A2} = .00, range: 0 – 4; Mdn_{A3} = 2.0, range: 0 – 17) training groups.

Hypothesis two. The second hypothesis stated that during the reaching assessment, when the rattle was placed within reach of the infants (reaching phases two and three combined), i) all infants would contact the rattle more frequently during the third assessment than they did at the first and second; ii) infants in the active training group would contact the rattle for a longer duration than those in the passive training group at the third assessment; and iii) infants in the active training group would grasp the toy more often, and for a longer duration of time, than infants in the passive training group. To address the first component of this hypothesis, the frequency of toy contact was compared over all assessments as a within-subjects factor that included the data from both the active and passive training groups. A Friedman's ANOVA indicated that there was a significant increase in the frequency of toy contact across assessments ($\chi^2(2) = 19.79$, $p = .005$). A post-hoc Wilcoxon Signed Rank Test indicated that infants contacted the toy at a greater frequency during the third assessment (*Mdn* = 3.00, range: 0 – 9) relative to both the first (*Mdn* = .00, range: 0 – 3, $Z = 3.254$, $p = .001$) and second (*Mdn* = .00, range: 0 – 5, $Z = 2.773$, $p = .006$) assessments. Thus, this component of the hypothesis was confirmed. No significant difference in toy contact frequency was noted between the first and second assessments ($Z = .962$, $p = .336$).

Changes in the frequency of toy contact over assessments one, two and three were also compared within each group using a Friedman's ANOVA. For a visual display of the median values in each group across assessments, please reference Figure 9. Among infants in the active training group, toy contact frequency significantly changed across assessments ($\chi^2(2) =8.222$, $p = .016$), such that the median number of toy contacts was greater at assessment three (Mdn_{A3} = 4.5, range: 1 – 9) than assessment one (Mdn_{A1} = .00, range: 0 – 3; $Z = 2.243$, $p = .025$). Changes in the frequency of toy contact did not reach significance between assessments one and two (Mdn_{A2} = .00, range: 0 – 5; $Z = 1.518$, $p = .129$) or assessments two and three ($Z = 1.778$, $p = .075$). Among infants in the passive training group, there was also a significant change in the frequency of toy contact across assessments ($\chi^2(2) = 12.519$, $p = .002$), such that the median number of toy contacts was significantly greater at assessment three ($Mdn_{A3} = 3.0$, range: 0 – 8) than assessments one ($Mdn_{A1} = .00$, range: 0 – 1; $Z = 2.379$, $p = .017$) and two ($Mdn_{A2} = .00$, range: 0 – 1; $Z = 2.539$, $p = .011$). There was no significant difference in the median frequency of toy contact between assessments one and two ($Z = .00$, $p = 1.0$).

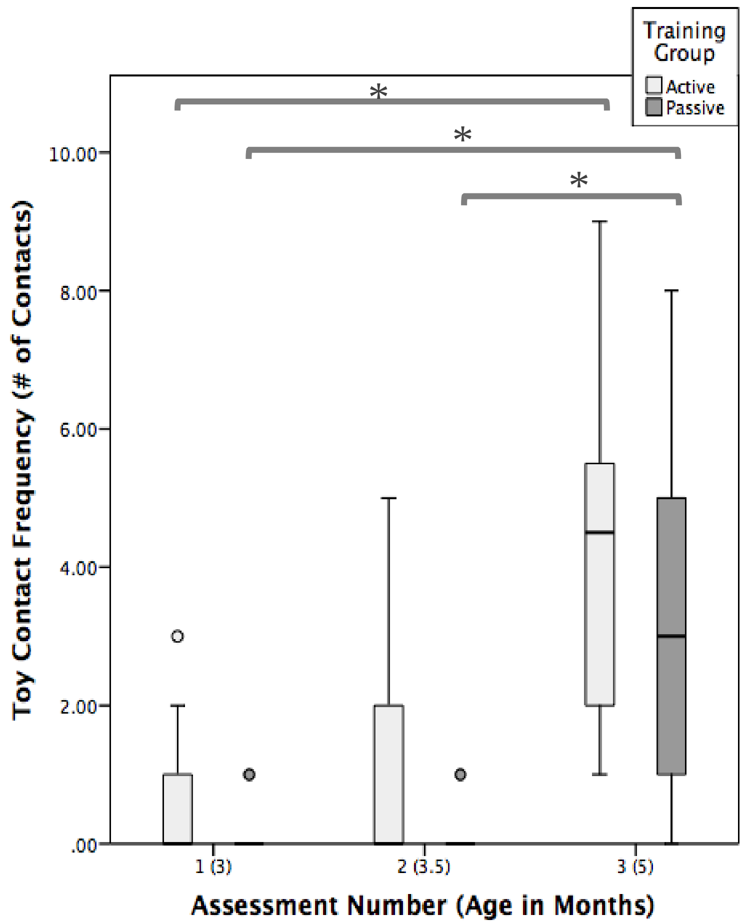

Figure 9. Boxplot displaying the frequency of toy contact achieved by infants in the active and passive training groups during the second and third reaching phases, at assessments one, two and three. The bottom edge of the rectangular box represents the first quartile (25th percentile) at which median scores fell. The upper edge of the rectangular box represents the third quartile (75th percentile) at which median scores fell. The bar located within the rectangular box indicates the median score. The upper whisker indicates the maximum value excluding outliers, and the lower whisker indicates the minimum value excluding outliers. The circles represent outliers.

To determine whether infants in the active training group contacted the rattle for a longer duration than those in the passive training group at the third assessment, a Mann-Whitney U test was selected, using training group as the between-subjects factor. The amount of time spent contacting the toy (during reaching phases two and three combined) was compared. Results indicated that there were no significant differences in the amount of time spent contacting the toy at the third assessment between the active and passive training groups ($U = 44$, $z = .596$, $p = .684$), although the median values suggest that infants in the active training group spent greater time contacting the toy than infants in the passive training group (Mdn_{AT} = 29.67%, range: 12.17 – 44.23; Mdn_{PT} 12.73%, range: 0 – 54.69). This component of the second hypothesis was ultimately not supported.

In addition to evaluating the duration of toy contact at the third assessment, group differences regarding time spent contacting the toy between the first and second, first and third, and second and third assessments were also compared. There were no significant between-group changes in the duration of toy contact between assessments one and two ($Mdn_{A2\text{-}A1}$ = 9.58% increase in active training, range: -5.94 – 27.04; $Mdn_{A2\text{-}A1}$ =12.27% increase in passive training, range: -8.56 – 36.39; $U = 39$, $z = .910$, $p = .363$), assessments one and three ($Mdn_{A3\text{-}A1}$ = 25.69% increase in active training, range: 12.17 – 44.23; $Mdn_{A3\text{-}A1}$ = 12.79% increase in passive training, range: -1.61 – 54.69; $U = 29$, $z = .674$, $p = .501$), or assessments two and three ($Mdn_{A3\text{-}A2}$ = 21.53% increase in active training, range: -11.29 – 44.23; $Mdn_{A3\text{-}A2}$ = 11.18% increase in passive training, range: 0 – 54.69; $U = 30$, $z = .577$, $p = .606$). Between-group comparisons of the difference scores did not reach significance; however, those in the active training group appear to have experienced a greater magnitude of change than those in the passive training group.

Upon evaluating the third component of the second hypothesis, a Mann-Whitney U test indicated that there was no significant difference between the median grasping frequency (active and passive training (*Mdn* = 1.0 in both groups; U = 47.5, $z = .209$, $p = .835$) or duration (Mdn_{AT} = 21.03, range: 0 – 53.52; Mdn_{PT} = 21.95, range: 0 – 50.49; $U = 41$, $z = .683$, $p = .495$) between groups at the third assessment. When difference scores between assessments were compared between groups, a significant difference in grasping behaviour was not found regarding duration or frequency between assessments one and two ($Mdn_{difference} = .00$ for both groups for duration and frequency; $U_{duration} = 40$, $z = 1.451$, $p = .147$; $U_{frequency} = 45$, $z = 1.0$, $p = .317$), one and three ($Mdn_{difference} = .00$ for both groups; $U_{duration} = 26$, $z = 1.299$, $p = .194$; $U_{frequency} = 27$, $z = 1.164$, $p = .245$), or assessments two and three ($Mdn_{difference} = .00$ for both groups; $U_{duration} = 26$, $z = 1.299$, $p = .194$; $U_{frequency} = 27$, $z = 1.164$, $p = .245$). The third component of the second hypothesis was not confirmed.

Hypothesis three. The third hypothesis stated that when the rattle was placed in the infants' hands during the reaching assessment (in the fourth reaching phase), i) infants in both the active and passive training groups would have longer durations of bimanual exploration at the third assessment, and ii) infants in the active training group would surpass those in the passive training group. A Friedman's ANOVA evaluated changes in the duration of bimanual exploration and results indicated that there were marginally significant differences between assessments one, two and three among infants in both the active and passive groups ($\chi^2(2) = 5.626$, $p = .060$; $\chi^2(2) = 5.765$, $p = .056$, respectively). Interestingly, median scores among infants in the active training group remained at 0% at the first (range: 0 – 19.46), second (range: 0 – 3.33) and third (range: 0 – 86.23) assessments. For infants in the passive training group, median scores increased from 0% at assessments one (range: 0 – 23.45) and two (range: 0 – 58.21) to 3.39% (range: 0 – 55.94) at assessment three.

After finding a nonsignificant result within the active and passive training groups individually, bimanual exploration was evaluated using durations from both the active and passive training groups combined. Results of this test were significant ($\chi^2(2) = 10.57$, $p = .005$), indicating that infants' bimanual exploration of the rattle increased somewhere between assessments one, two and three (Mdn_{A1} = .00%, range: 0 – 23.45; Mdn_{A2} = .00%, range: 0 – 58.21; Mdn_{A3} = .595%, range: 0 – 86.23). A post-hoc Wilcoxon Signed Rank Test revealed that there was a significant increase in bimanual exploration duration between assessments one and three ($Z = 2.521$, $p = .012$), and assessments two and three ($Z = 2.10$, $p = .036$). There was no significant increase between assessments one and two ($Z = .405$, $p = .686$). The first component of the third hypothesis was partially confirmed, as infants demonstrated an increased duration of bimanual exploration once the data from both groups were combined. For a visual display of the duration of bimanual toy contact in each group across assessments, please reference Figure 10.

Mann-Whitney U tests evaluated whether infants in the active training group engaged in greater amounts of bimanual exploration than infants in the passive training group by a) comparing bimanual exploration at the third assessment, and b) comparing the difference scores between assessments one and three, and assessments two and three. Results indicated that, at the third assessment, infants in the active training group did not engage in a significantly different amount of bimanual exploration than infants in the passive training group (Mdn_{AT} = .00%, range: 0 – 86.23; Mdn_{PT} = *3.39%,* range: 0 – 55.94*;* $U = 51$, $z = .108$, $p = .914$). Difference scores between assessments revealed that infants in the active training group also did not engage in significantly different amounts of bimanual exploration than those in the passive training group between assessments one and three ($Mdn_{A3\text{-}A1}$ = .00% change in active training, range: 0 – 82.40; $Mdn_{A3\text{-}A1}$ = 8.03% increase in passive training, range: 0 – 73.07; $U = 36$, $z = .509$, $p = .611$) or assessments two and three ($Mdn_{A3\text{-}A2}$ = .00% change in active training, range: 0 – 86.23; $Mdn_{A3\text{-}A2}$

= 12.83% increase in passive training, range: -26.73 – 82.30; $U = 29$, $z = .122$, $p = .902$). The second component of the third hypothesis was not confirmed. Interestingly, infants in the passive training groups appeared to exhibit greater increases in bimanual exploration across assessments relative to those in the active training group. Exploratory analyses evaluating difference scores between active and passive groups from the first to second assessment also did not yield a significant result ($Mdn_{A2\text{-}A1}$ = .00% increase in active training, range: -19.45 – 3.33; $Mdn_{A2\text{-}A1}$ = .00% increase in passive training, range: -9.23 – 34.77; $U = 55$, $z = .497$, $p = .619$).

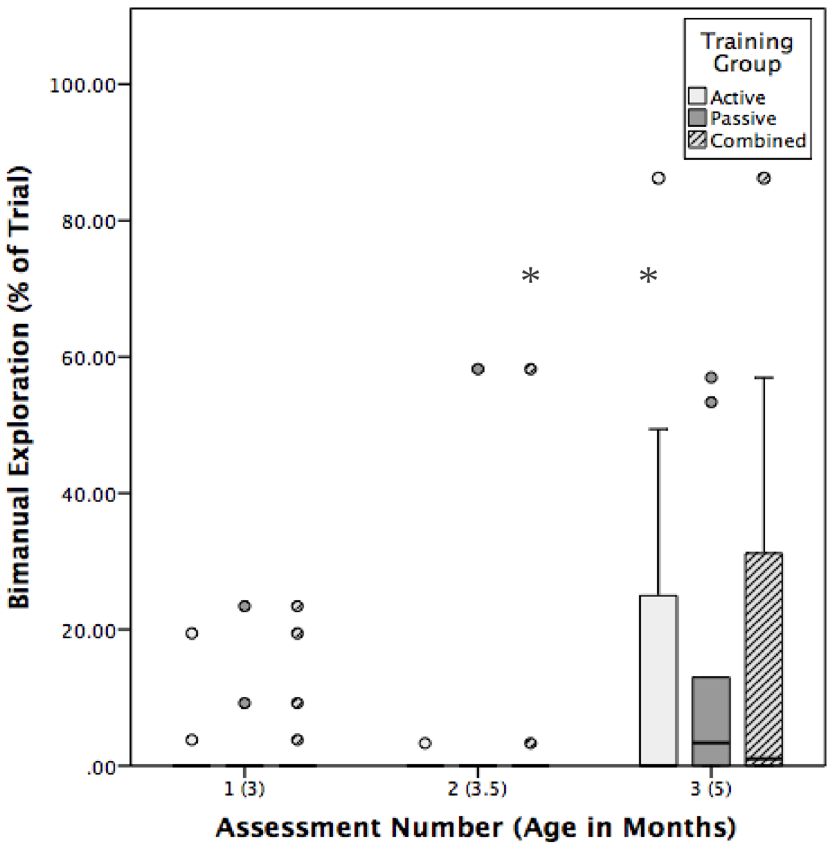

Figure 10. Boxplot displaying the duration of the trial spent bimanually exploring the rattle during the fourth reaching phase, by infants in the active and passive training groups as well as group medians combined, at assessments one, two and three. * indicates a significant result at the 0.05 level. The bottom edge of the rectangular box represents the first quartile (25th percentile) at which median scores fell. The upper edge of the rectangular box represents the third quartile (75th percentile) at which median scores fell. The bar located within the rectangular box indicates the median score. The upper whisker indicates the maximum value excluding outliers, and the lower whisker indicates the minimum value excluding outliers. The circles represent outliers.

Exploratory analyses. During the first reaching phase, exploratory analyses evaluated differences in attention allocation (toward the researcher or the rattle), as well as the number of reaches made toward the rattle. Because the rattle was placed out of reach, infants could not engage in toy contact or grasping and thus these variables were not evaluated (Wiesen et al., 2016).

Within-subjects results. Friedman's ANOVAs evaluated differences between the duration of the trial spent looking at the researcher and the toy as well as reaching frequency across assessments within the active and passive training groups. For a visual display of the medians for the looking data, please reference Figure 11.

Active training group. Results indicated that infants in the active training group looked at the researcher for a significantly different duration across the first, second and third assessments (Mdn_{A1} = 21.59%, range: 0 – 53.68; Mdn_{A2} = 3.78%, range: 0 – 67.73; Mdn_{A3} = 50.77%, range: 0 – 84.11; $\chi^2(2) = 6.2$, $p = .045$). Specifically, infants looked at the researcher for a significantly greater duration at the third assessment compared to the first assessment ($Z = 2.250$, $p = .024$). Infants also looked at the researcher for a greater duration at the third assessment relative to the second; however, this result was only marginally significant ($Z = 1.875$, $p = .061$).

Among infants in the active training group, the duration of time spent looking at the toy increased from the first assessment (*Mdn* = 37.06%, range: 0 – 93.96) to the second assessment (*Mdn* = 78.25%, range: 30.03 – 94.12), and decreased at the third assessment (*Mdn* = 46.36%, range: 6.44 – 76.44). However, these results did not reach the level of significance ($\chi^2(2) = 3.25$, $p = .197$). Lastly, there was no significant difference in reaching frequency between assessment one (*Mdn* = .00, range: 0 – 5) assessment two (*Mdn* = .50, range: 0 – 8) and assessment three (*Mdn* = .50, range: 0 – 6; $\chi^2(2) = 4.522$, $p = .104$).

Passive training group. Among infants in the passive training group, there were no significant differences in the time spent looking at the researcher from the first to third assessments (Mdn_{A1} = 49.38%, range: 0 – 99.87; Mdn_{A2} =14.9%, range: 0 – 86.67; Mdn_{A3} = 28.20%, range: 8.01 – 77.30; $\chi^2(2) = 2.457$, $p = .293$). The median percentage of time spent looking at the toy increased from the first assessment (*Mdn* = 34.19%, range: 0 – 100) to the second assessment (*Mdn* = 78.53; range: 0 – 99.67) and decreased at the third assessment (*Mdn* = 58.74%, range: 23.69 – 91.87); however, this result did not reach the level of significance ($\chi^2(2)$ = .889, $p = .641$). Interestingly, infants in the passive training group demonstrated a significant increase in reaching frequency between assessments one (*Mdn* = .00, range: 0 – 1), two (*Mdn* = .00, range: 0 – 3) and three (*Mdn* = 1.00, range: 0 – 10; $\chi^2(2) = 7.583$, $p = .023$). A post-hoc Wilcoxon Signed Rank Test revealed a significant increase in reaching behaviour from the second to the third assessment ($Z = 2.23$; $p = .026$).

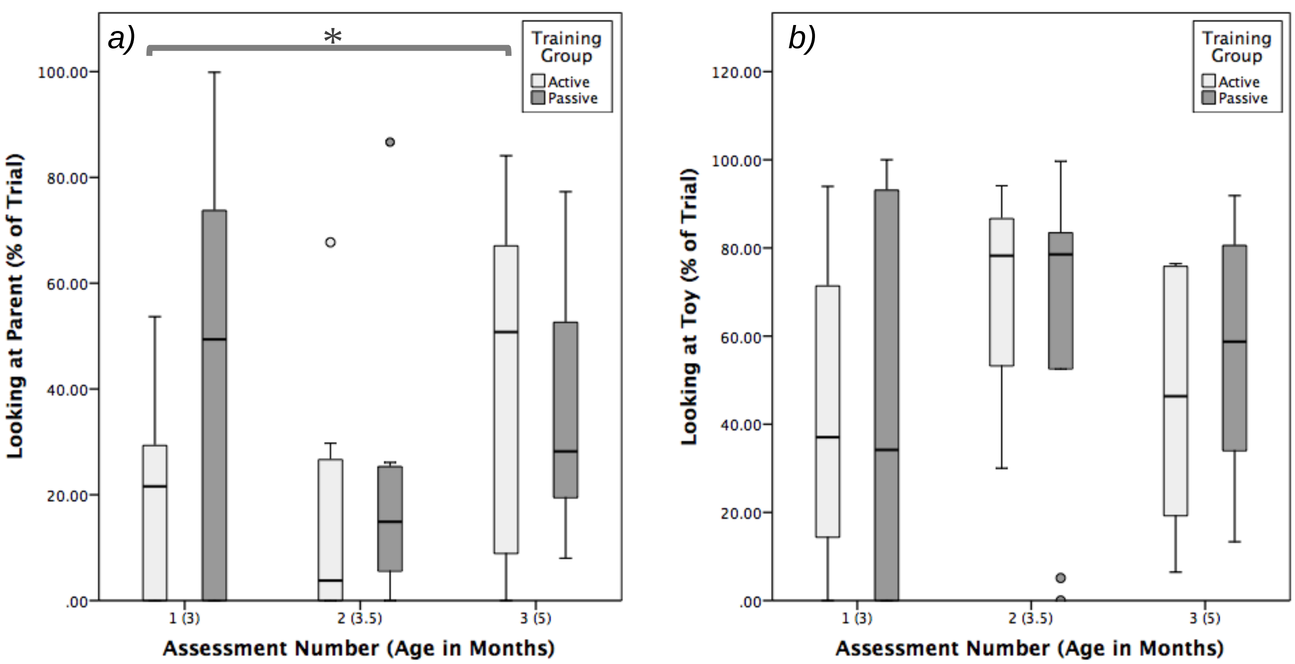

Figure 11. Boxplot displaying the duration of time spent looking at *a*) the researcher and *b*) the toy by infants in the active and passive training groups during the first reaching phase, at assessments one, two and three. * indicates a significant within-group result at the 0.05 level. The bottom edge of the rectangular box represents the first quartile (25th percentile) at which

median scores fell. The upper edge of the rectangular box represents the third quartile (75^{th} percentile) at which median scores fell. The bar located within the rectangular box indicates the median score. The upper whisker indicates the maximum value excluding outliers, and the lower whisker indicates the minimum value excluding outliers. The circles represent outliers.

Between-subjects results. Mann-Whitney U tests evaluated between-groups differences upon evaluation of the percentage of the trial spent looking toward the researcher and the toy, as well as the number of reaches made during the second and third assessments. Results indicated that there were no significant differences between groups at assessments two or three regarding the duration of the trial spent looking at the researcher ($U_{A2} = 61$, $z = .943$, $p = .399$; $U_{A3} = 34$, $z = .192$, $p = .847$), or looking at the toy ($U_{A2} = 42$, $z = .605$, $p = .545$; $U_{A3} = 47$, $z = 1.058$, $p = .290$). Lastly, the number of reaches made toward the toy did not differ significantly between groups at the second or third assessment ($U_{A2} = 38$, $z = 1.118$, $p = .263$; $U_{A3} = 39.50$, $z = .347$, $p = .743$).

In addition to evaluating group differences at the second and third assessments, the change between assessments regarding attention allocation and reaching were also compared between the active and passive training groups. No significant differences were observed between groups when determining changes in looking behaviour toward the researcher ($U_{A2\text{-}A1} = 20$, $z = .567$, $p = .571$; $U_{A3\text{-}A1} = 18$, $z = 1.732$, $p = .083$; $U_{A3\text{-}A2} = 35$, $z = .095$, $p = .923$), or the toy ($U_{A2\text{-}A1} = 20$, $z = .605$, $p = .545$; $U_{A3\text{-}A1} = 38$, $z = .192$, $p = .847$; $U_{A3\text{-}A2} = 45$, $z = .866$, $p = .386$). The change in the number of reaches made toward the toy also did not significantly differ between groups across assessments ($U_{A2\text{-}A1} = 20$, $z = 1.539$, $p = .124$; $U_{A3\text{-}A1} = 41$, $z = .499$, $p = .618$; $U_{A3\text{-}A2} = 49.5$, $z = 2.347$, $p = .178$).

Parent-Infant Interaction and Attention Engagement

Hypothesis four. The final hypothesis stated that at baseline testing, infants in both the active and passive training groups would spend most of their time in an unengaged (not looking at anything in particular) attentional state or looking at a parent relative to looking at the toy. A Wilcoxon Signed Rank Test compared the summed duration of time spent unengaged and looking at the parent versus time spent attending toward the toy at the first assessment. Results revealed that at the first assessment, infants attended to the toy for a significantly shorter duration of the trial ($Mdn_{combined}$ = 6.13%, range: 0 – 97.64) than they did to either their parent or nothing in particular ($Mdn_{combined}$ = 92.93%, range: 0 – 99.98), thus confirming this hypothesis.

Exploratory analyses. Exploratory analyses sought to evaluate changes in infants' attention allocation (between attending to their parent or the toy) across assessments, and whether a distinct change in attention allocation occurred between the active and passive training groups over time. A Friedman's ANOVA evaluated the duration of the trial spent looking at the parent and looking at the toy, as well the number of looking episodes (incidences of attention shifting) made toward each. A visual display of the changes in duration of attention allocation can be seen in Figure 12, and changes in looking episodes can be seen in Figure 13. Exploratory analyses also evaluated the duration of the trial that infants and parents shared attention, either toward one another or toward a toy (see Figure 14 for a visual display of the data). All results are outlined below.

Attention allocation. Upon evaluation of attention allocation in the active training group, results indicated that, although there was a decrease in the median time spent looking at the parent from the first assessment (*Mdn* = 28.59%, range: 0 – 86.85) to the second (*Mdn* = 11.18%, range: 0 – 59.71) and third (*Mdn* = 11.98%, range: 0 – 32.62), the result did not reach the level of significance between any assessments ($\chi^2(2) = 2.6$, $p = .273$). Additionally, there was no significant difference in the percentage of the trial spent looking at the toy ($\chi^2(2) = 1.87$, $p = .393$), although the median values did appear to increase across assessments (Mdn_{A1} = .00%, range: 0 – 97.64; Mdn_{A2} = 19.13%, range: 0 – 61.25, Mdn_{A3} = 47.38%, range: 0 – 98.04).

Similar to actively trained infants, infants in the passive training group appeared to look at their parents for shorter durations of time from the first (*Mdn* = 13.84%, range = 0 – 79.55) to the second (*Mdn* = 2.96%, range: 0 – 68.39) and third (*Mdn* = 2.38%, range: 0 – 37.41) assessment; however, there were no significant differences noted ($\chi^2(2) = 2$, $p = .368$). The percentage of time spent looking at the toy appeared to increase form the first (*Mdn* = 7.05%, range: 0 – 92.40) to the second (*Mdn* = 31.84%, range: 0 – 81.39) assessment, and decrease at the third assessment (*Mdn* = 14.88, range: 0 – 89.39); however, the result did not reach significance ($\chi^2(2) = 2.4$, $p = .301$).

Between-group differences. Mann-Whitney U tests evaluated between group differences in the duration of the trial spent looking at the parent and the toy at the second and third assessments. Results did not reach significance regarding the time spent looking at the parent or the toy at assessment two ($U = 33$, $z = .989$, $p = .323$; $U = 54.5$, $z = .788$, $p = .431$, respectively) or at assessment three ($U = 34.5$, $z = .145$, $p = .885$; $U = 28$, $z = .772$, $p = .440$, respectively). Thus, infants in the passive training group did not allocate their attention in a significantly different manner toward their parent or the toy than infants in the passive training group at the second or third assessments. Infants in both groups also did not differ significantly upon evaluation of changes in the amount of time spent looking at their parent from assessments one to two ($U = 32.5$, $z = 1.021$, $p = .307$), one to three ($U = 34.5$, $z = .144$, $p = .885$), or from two to three ($U = 39$, $z = .735$, $p = .462$). Additionally, there were no significant between-group differences regarding changes in attention allocation toward the toy between assessments one and two ($U = 50$, $z = .410$, $p = .682$), one and three ($U = 30$, $z = .577$, $p = .564$), or two and three ($U = 28$, $z = .420$, $p = .674$).

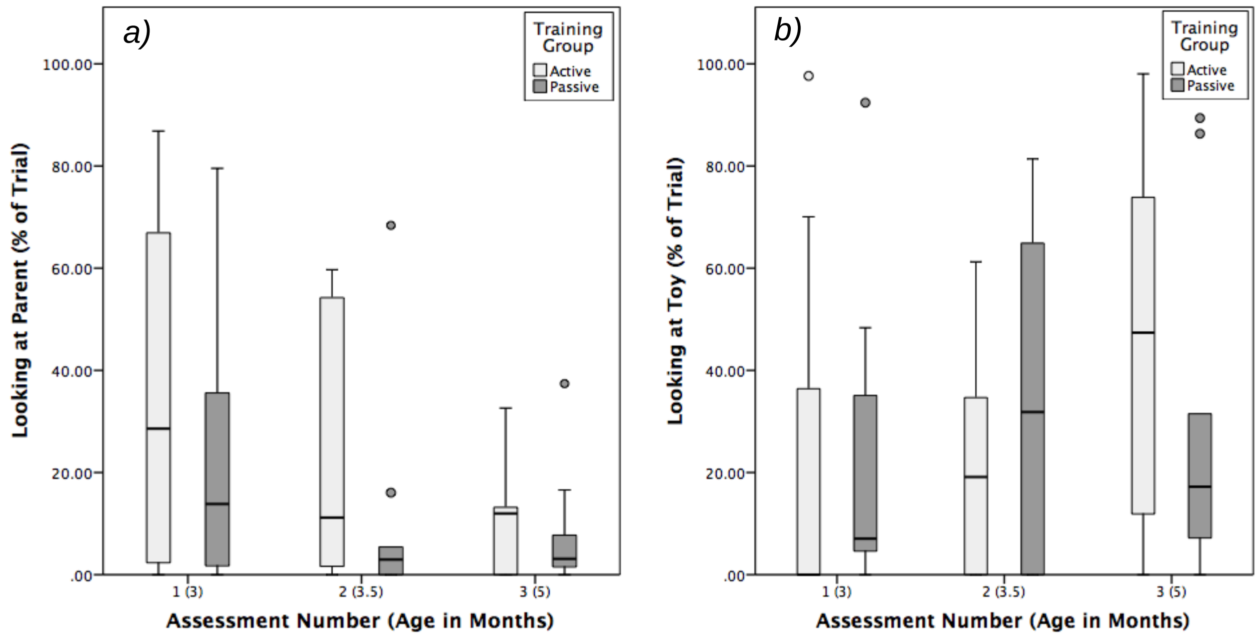

Figure 12. Boxplot displaying the duration of time spent looking at *a*) the parent and *b*) the toy by infants in the active and passive training groups during the parent-infant interaction, at assessments one, two and three. The bottom edge of the rectangular box represents the first quartile (25th percentile) at which median scores fell. The upper edge of the rectangular box represents the third quartile (75th percentile) at which median scores fell. The bar located within the rectangular box indicates the median score. The upper whisker indicates the maximum value excluding outliers, and the lower whisker indicates the minimum value excluding outliers. The circles represent outliers.

Looking episodes. In addition to the duration of the trial spent looking at the parent or toy, the frequency of looking episodes toward each were evaluated across assessments. Among infants in the active training group, there was a significant result ($\chi^2(2) = 6.643$, $p = .036$), indicating that the frequency of looking episodes toward the parent significantly increased between assessment one ($Mdn_{A1} = 2.5$, range: 0 – 5) and assessment two ($Mdn_{A2} = 3$, range: 0 – 10; $Z = 2.25$, $p = .024$). There was also a marginally significant decrease between assessment two and assessment three ($Mdn_{A3} = 2$, range: 0 - 10; $Z = 1.875$, $p = .061$). Thus, infants in the active training group looked at their parent more frequently at the second assessment than the first, and less frequently at the third assessment relative to the second. The median frequency of looking episodes toward the toy appeared to increase from the first assessment ($Mdn = .00$, range: 0 – 7) to the second assessment (*Mdn* = 3.5, range: 0 – 11) and decrease slightly at the third assessment (*Mdn* = 3.0, range: 0 – 6); however, this result did not reach significance ($\chi^2(2) = 2$, $p = .202$).

Infants in the passive training group did not differ significantly across assessments in regards to looking episodes toward their parents ($\chi^2(2) = 1.727$, $p = .422$), indicating that infants looked at their parent a similar number of times at each assessment ($Mdn_{A1} = 2$, range: 0 – 6; $Mdn_{A2} = 2$, range: 0 – 3; $Mdn_{A3} = 1$, range: 0 – 5). The number of looking episodes toward the toy appeared to increase from the first (*Mdn* = 1.5, range: 0 – 5) to second and third assessments ($Mdn_{A2} = 4$, range: 0 – 5; $Mdn_{A3} = 4$, range: 0 – 6); however, this result was not significant ($\chi^2(2) = 3.13$, $p = .200$).

Between-group differences. The number of looking episodes toward the parent and toy were compared between groups at the second and third assessments, as were changes in looking episodes between the first and second, first and third, and second and third. At both the second and third assessments, infants in the active and passive training groups did not shift their attention differentially toward their parent ($U_{AT} = 26.5$, $z = 1.549$, $p = .121$; $U_{PT} = 34.5$, $z = .147$, $p = .883$, respectively) or the toy ($U_{AT} = 42.5$, $z = .209$, $p = .835$; $U_{PT} = 36$, $z = .000$, $p = 1.00$, respectively). Similarly, the change in looking episodes toward the parent did not significantly differ between the active and passive training groups between assessments one and three ($U = 31.5$, $z = .442$, $p = .659$). From the first to the second assessment, however, infants in the active training group looked toward their parent more frequently ($Mdn_{difference} = 1.5$, range: -2 – 7), and infants in the passive training group looked toward their parent a fewer number of times ($Mdn_{difference} = -1.4$, range: -4 – 0). This between groups difference reached the level of significance ($U = 17.5$, $z = 2.261$, $p = .022$). Additionally, at the third assessment relative to the second assessment, infants in the active training group looked at their parent fewer times ($Mdn_{difference}$ = -1.63, range: -8 – 6), and infants in the passive training group looked at their parent a greater number of times ($Mdn_{difference}$ = .75, range: -1 – 5). This result also reached the level of significance (U = 50.50, z = 1.974, p = .048). The change in looking episodes toward the toy did not significantly differ between the active and passive training groups between assessments one and two (U = 30.5, z = 1.233, p = .243), one and three (U = 32, z = .389, p = .697), or two and three (U = 41, z = .954, p = .340).

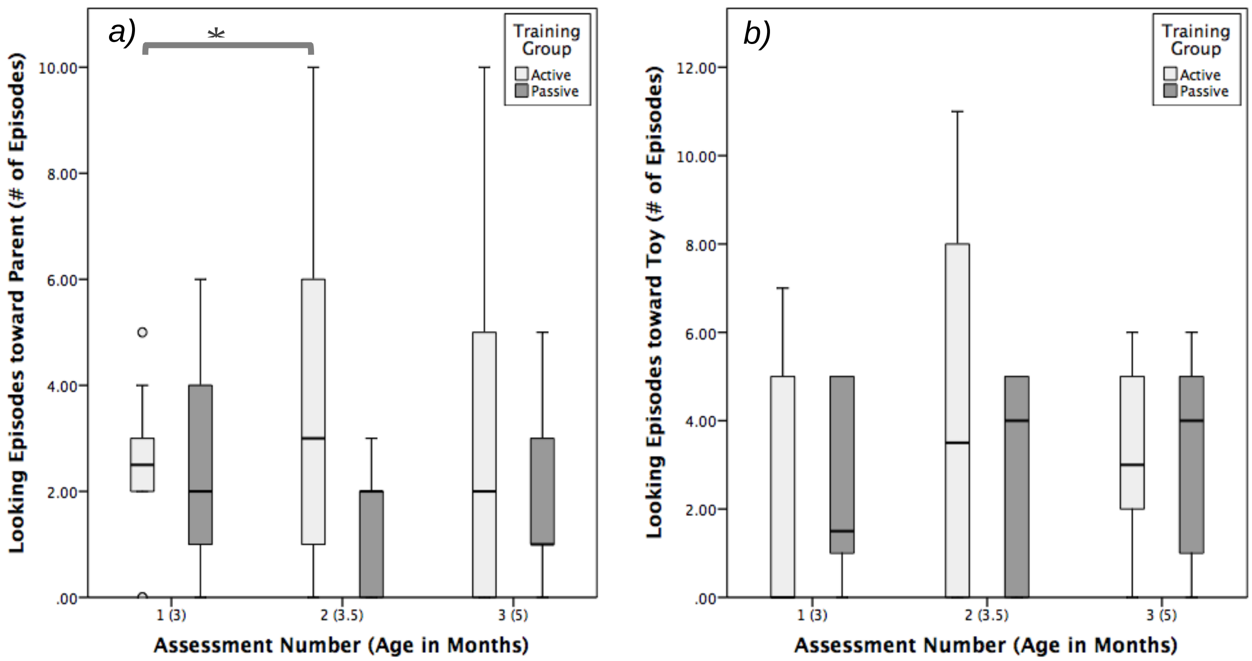

Figure 13. Boxplot displaying the number of looking episodes toward *a*) the parent and *b*) the toy by infants in the active and passive training groups during the parent-infant interaction, at assessments one, two and three. * indicates a significant within-group result at the 0.05 level. The bottom edge of the rectangular box represents the first quartile (25^{th} percentile) at which median scores fell. The upper edge of the rectangular box represents the third quartile (75^{th} percentile) at which median scores fell. The bar located within the rectangular box indicates the median score. The upper whisker indicates the maximum value excluding outliers, and the lower whisker indicates the minimum value excluding outliers. The circles represent outliers.

Shared attention. In addition to evaluating changes in attention throughout the assessments, the occurrence of shared attention between the infant and parent was also assessed.

More specifically, the durations of the trial in which the parent and infant simultaneously looked at the toy and at one another were evaluated. Differences in attention allocation were measured within participants as well as between groups to evaluate potential differences attributable to the motor training received. To view the median values of shared attention across assessments in both groups, please reference Figure 14.

Active and passive training groups. Friedman's ANOVAs evaluated the amount of time in which infants and parents shared attention with one another across assessments (within-groups). Results indicated that the amount of shared attention between infants and parents did not significantly change in either the active (Mdn_{A1} = 14.81%, range: 0 – 86.85; Mdn_{A2} = 11.18%, range: 0 – 57.86; Mdn_{A3} = 10.37%, range: 0 – 32.62; $\chi^2(2) = 4.21$, $p = .122$), or passive (Mdn_{A1} = 13.83%, range: 0 – 79.55; Mdn_{A2} = 2.34%, range: 0 – 68.39; Mdn_{A3} = 3.02%, range: 0 – 37.25; $\chi^2(2) = 2.25$, $p = .325$) training groups. Additionally, there were no significant differences regarding shared attention toward the toy across assessments in the active (Mdn_{A1} = .62%, range: 0 – 12.20; Mdn_{A2} = .00%, range: 0 – 33.21; Mdn_{A3} = 4.36%, range: 0 – 43.21; $\chi^2(2) = 3$, $p = .223$) or passive (Mdn_{A1} = .00%, range: 0 – 20.96; Mdn_{A2} = 1.18%, range: 0 – 41.36; Mdn_{A3} = 4.36%, range: 0 – 57.67; $\chi^2(2) = 2.16$, $p = .340$) training groups.

Between-group differences. Mann-Whitney U tests evaluated the differences between the active and passive training groups regarding the amount of time that infants and parents shared attention, either toward one another or toward the toy. Results indicated that, at the second and third assessments, there were no significant differences between groups in the duration of shared attention between infants and parents toward each other ($U_{A2} = 35$, z = 1.149, $p = .251$; U_{A3} = 34.5, $z = .145$, $p = .888$) or toward the toy ($U_{A2} = 66$, $z = 1.419$, $p = .156$; $U_{A3} = 33$, $z = .299$, $p = .815$).

Additional analyses evaluated whether there were group differences in the change scores between assessments one and two, one and three, and two and three. Infants in the active and passive training groups did not significantly differ from one another regarding changes in shared attention between the infant and parent at assessments one versus two (*U* = 25.5, *z* = 1.593 *p* = .111), assessments one versus three (*U* = 30, *z* = .579, *p* =.563), or assessments two versus three (*U* = 38, *z* = .630, *p* = .529). They also did not differ significantly upon evaluation of changes in the amount of shared attention toward a toy between the first and second assessments (*U* = 54, *z* = .777, *p* = .437), the first and third assessments (*U* = 36, *z* = .00, *p* = 1.00), or the second and third assessments (*U* = 26, *z* = .632, *p* = .527).

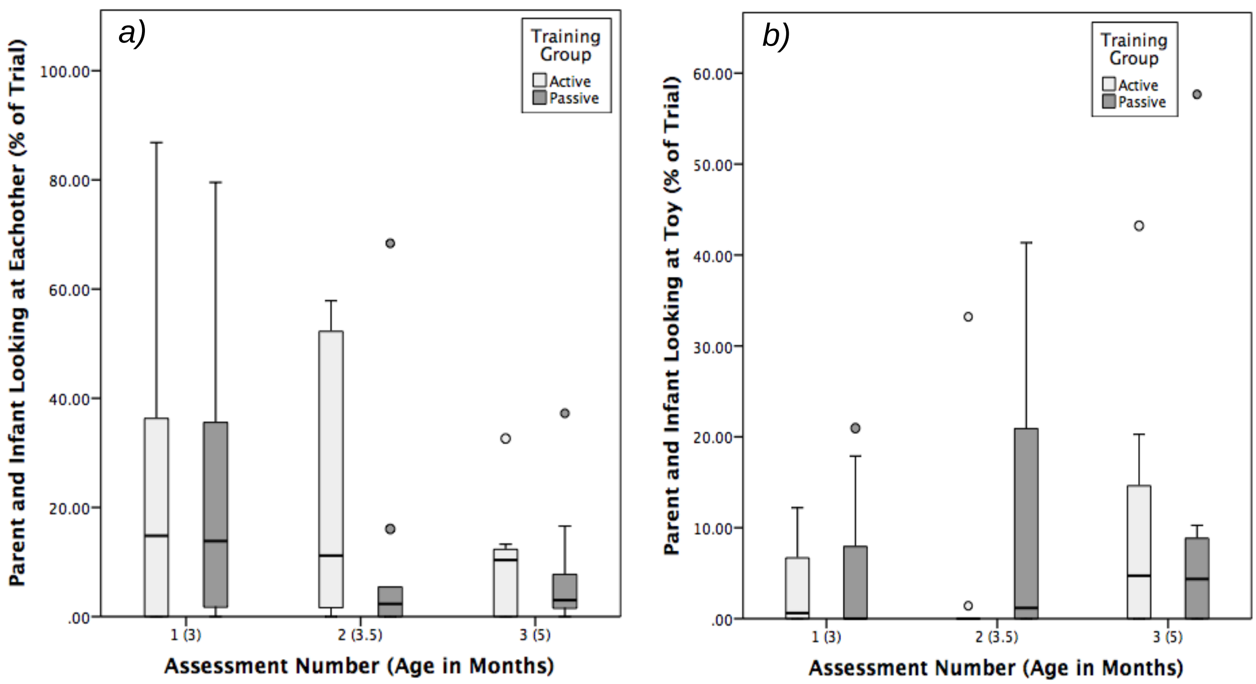

Figure 14. Boxplot displaying the duration of shared attention between the infant and parent toward *a*) each other and *b*) the toy, in both the active and passive training groups during the parent-infant interaction, at assessments one, two and three. The bottom edge of the rectangular box represents the first quartile (25th percentile) at which median scores fell. The upper edge of the rectangular box represents the third quartile (75th percentile) at which median scores fell. The bar located within the rectangular box indicates the median score. The upper whisker indicates the maximum value excluding outliers, and the lower whisker indicates the minimum value excluding outliers. The circles represent outliers.

Discussion

The current study aimed to determine the immediate and relatively long-term effects of sticky mitten training on motor and attentional development. Of particular interest was the generalizability of this training′s effects when in a natural, home-based environment, as well as on shared attention when interacting with a parent. This particular experimental setup and related research questions had not, to date, received attention in the developmental literature.

The implementation of the sticky mitten training and assessments progressed as expected (to review experimental setup, see Figure 4), with both parents and infants actively engaged in the study. The results supported a number of the proposed hypotheses while disconfirming others. This study was met with a number of largely unforeseen challenges related to completing the assessments (e.g., extensive travel times, cancellations and rescheduling, etc.) as well as capturing all the necessary data (e.g., limitations regarding the clarity with which the cameras were able to record the data). The findings from the present study and their implications are discussed below, organized in a similar manner as the Results section (i.e., discussion of the reaching assessment followed by the parent-infant interaction, with interim summaries and formulations throughout). Due to the sample size included within this study, the explanations provided and discussion of the results were relatively tentative.

Reaching Assessment

The four-phase reaching assessment evaluated motor behaviours (reaching, toy contact, grasping, bimanual exploration), with exploratory analyses evaluating looking and reaching behaviours during the first reaching phase. Of the analyses conducted, many of the within-subjects hypotheses were confirmed. Results regarding group differences (active versus passive) at each assessment demonstrated tendencies towards the proposed hypotheses, however they often did not reach the level of significance.

Hypothesis one. The first hypothesis was supported, as all infants (regardless of training group) demonstrated increased reaching behaviour at the third assessment (when they were 5 – 5.5 months of age) relative to when they were 3 months of age. This result was also found in the previous sticky mitten study that followed infants at 5.5-months-old (Wiesen et al., 2016), and can be expected due the natural course of infant development (von Hofsten, 1989; CDCP, 2016). When the training groups were considered separately, there were no significant differences in the number of reaches made at the third assessment relative to the first or second assessments. Given that there was a significant increase in reaching frequency when both groups were combined, the non-significant result within-groups suggests that, had the samples been larger, the result may have reached significance. This possibility is supported by the observed increase in the median number of reaches made within each group at the third assessment (albeit nonsignificant), as well as results of Wiesen and colleagues′ study (2016).

Hypothesis two. The first component of the second hypothesis was supported, as a significant increase in toy contact frequency was observed at the third assessment relative to the first and second, both when medians were combined among the training groups and when they were considered individually (within each group). This result replicates the findings of Wiesen and colleagues (2016), thus providing further support for their results. Similar to increased reaching frequency, increased toy contact over time is likely attributable to natural development (Van Hofsten, 1989; CDCP, 2016), as this result is not based on differences between the active and passive training groups. However, the magnitude of the increase may be larger than what would typically be seen in a population without having received any form of sticky mitten training, simply due to having received a motor intervention. Because the present study did not include a no-training control group (due to feasibility limitations, and following from a number of other studies, e.g., Libertus & Landa, 2014; Needham, Barrett, & Peterman, 2002; Wiesen et al., 2016), it remains unclear whether this result is due to natural development or having received motor training (regardless of whether it was active or passive).

The second component of this hypothesis sought to determine whether there were differences between the active and passive training groups regarding the time spent contacting the toy at the third assessment. The results indicated that there were no significant differences between groups; however, infants in both groups demonstrated a trend toward increased toy contact, and the magnitude of change appeared to be greater in the active training group relative to the passive training group (see Figure 9 for reference). This trend is directionally similar to the results found in Wiesen and colleagues' study (2016), and thus this result may have reached significance with a larger sample size.

The third component of the second hypothesis evaluated grasping behaviours in the active and passive training groups. Results revealed that there were no significant group differences in either the grasping duration or frequency at assessment three, or when difference scores were evaluated between assessments. This finding is not supported by previous research, which has found that, at 5.5 months of age, infants in the active training group grasped the rattle for longer durations than infants in the passive training group (Wiesen et al., 2016). Slight variations in methodology of the current study, such as the incorporation of more refined measures to facilitate the capture of precise movements (e.g., those of individual fingers) may lead to different findings.

Hypothesis three. The first component of the third hypothesis, which stated that infants in both the active and passive training groups would demonstrate increased bimanual exploration at the third assessment, was not supported when the groups were considered separately. Once the training groups were combined, the time spent bimanually contacting the rattle increased significantly at the third assessment when compared with the first and second. This result supports findings from Wiesen and colleagues' study (2016), and it appears as though, once again, with a greater number of participants in each group, this result would have reached significance prior to being combined.

The second component of the third hypothesis evaluated between-group differences in bimanual toy exploration. This part of hypothesis was not supported, as infants in the active training group did not engage in significantly longer periods of bimanual exploration than those in the passive training group. Furthermore, the difference scores in bimanual toy contact between assessments did not significantly change between groups. This result (no between-group differences) has also been observed in previous research (Wiesen et al., 2016). Thus, it appears as though the increase in bimanual toy contact may be related either to natural development, or to having received motor training more generally, be it active or passive.

Exploratory analyses. Exploratory analyses investigated how infants allocated their attention during the first phase of the reaching assessment (i.e., when the rattle was placed out of reach). Reaching behaviours were also evaluated, as infants could still view (and thus reach toward) the rattle, despite being placed out of reach.

Attention allocation toward the researcher and the toy. Results regarding attention allocation indicated that infants in the active training group attended to the researcher for a significantly greater duration at the third assessment relative to the first, and a marginally significant increase was seen from the second to third assessment. This result was not observed among infants in the passive training group. While significant changes were noted in the active but not the passive training group, between-groups analyses did not yield significant results. An interesting trend that emerged was that infants in both training groups tended to look at researcher less at the second assessment relative to the first. Wiesen and colleagues (2016) did not present results related to attention allocation towards the researcher, thus it is unclear what this result would look like when replicated with a larger sample. A study that followed infants 12 months after having received sticky mitten training noted that there was no significant difference between the active or passive training groups regarding time spent looking at the researcher. Further, they reported that among all infants, the majority of the trial was spent looking at the toy one year after having received motor training (Libertus et al., 2015). This finding is sensible given the natural development of the infants just over one year old, but the lack of difference between active and passive training groups (across the present and cited study) suggests that sticky mitten training may not play a long-term role (2.5 months after having received the training) in attention allocation toward other people. That said, the author of this thesis believes it remains an important direction to embark upon as there is not sufficient literature to draw definitive conclusions.

Upon analysis of attention allocation toward the rattle, results revealed that neither infants in the active nor passive training groups differed across assessments. Between-groups analyses also did not indicate significant differences in attention allocation toward the toy at assessments two or three, or in the difference scores between assessments. Infants in both groups, however, did exhibit trends in which they looked at the rattle for a longer duration at the second assessment relative to the first. The present results are at odds with previous research findings indicating that infants in the active training group spent greater portions of the first reaching phase attending to the rattle than did those in the passive training group (Wiesen et al., 2016). However, this result only reached the level of significance after combining data from assessments two and three. Because there is a two-month age gap between the second and third assessments, the present study did not combine these data points as it appears that the data would be inherently different, given that substantial developmental change typically occurs between 3.5- and 5.5-months of age.

Overall, a trend emerged in both groups such that attention toward the researcher decreased at the second assessment relative to the first assessment, and increased at the third assessment relative to the second. At the same time, infants in both groups looked at the rattle for a greater period of time at the second assessment relative to the first and third. Thus, it appears as though immediately after having received training, infants generally displayed an increased interest in the rattle. The magnitude of change was similar in both groups, and this result is inconsistent with a number of other studies that have found between-groups differences both two weeks and two months after having received sticky mitten training (e.g., Libertus & Needham, 2010, 2014; Wiesen et al., 2016). It is possible that with a larger sample size, the magnitude of difference between groups regarding attention allocation would differ from one another at the follow-up assessment. The results of the current study, while at odds with the previous literature, suggest that having received motor training (regardless of type) increased infants' immediate interest in toys that was not sustained two months after training.

Reaching frequency during reaching phase one. Exploratory analyses evaluated the number of reaches made during the first reaching phase, as other studies employing the sticky-mitten paradigm have not typically done so (e.g., Libertus & Needham, 2010). Because the rattle is placed out of reach at this point in the trial, an evaluation of reaching frequency appeared to be well-suited (Wiesen et al., 2016). Results indicated that infants in the passive training group demonstrated a significant increase in reaching frequency at the third assessment relative to the second assessment, whereas infants in the active training group did not. No significant between-groups differences were observed. Interestingly, the study conducted by Wiesen and colleagues (2016) did not find a significant difference in reaching frequency when active and passive training groups were considered separately. The current finding may have arisen as a result of unequal variances in the training groups; however, it may be that passively trained infants engaged in greater reaching behaviour as a result of not having been afforded the opportunity to “grasp” objects during motor training (and thus experienced increased motivation). Alternatively, this result may reflect less-sophisticated reaching behaviours among passively trained infants, as they reached toward the rattle when it was placed outside of their reach. Actively trained infants did not demonstrate significant differences in reaching behaviour during the first reaching phase, which may indicate that infants in this group demonstrated greater intentionality, as they only reached more during the second and third reaching phases, when the rattle was obtainable.

Reaching assessment: Summary and formulation. Findings from the reaching assessment revealed that the within-subjects hypotheses were often supported, and promising trends emerged in the between-subjects results. Infants in the active and passive training groups demonstrated increased reaching behaviour (when the toy was placed within reach), increased toy contact, and increased bimanual exploration at the third assessment. These findings are consistent with previous research (Wiesen et al., 2016); however, because the present study lacks a control group, conclusions cannot be drawn regarding whether these changes are a result of receiving motor training, or simply due to natural infant development.

A curious trend emerged in the results of the reaching assessment such that there were no significant differences noted immediately after having received two weeks of sticky mitten training (i.e. no significant differences noted between assessments one and two). Significant differences only arose when the first and third, or second and third assessments were compared. This result is at odds with the findings of a number of previous studies that have demonstrated the immediate benefits of sticky mitten training (e.g., Libertus & Landa, 2014; Libertus & Needham, 2010; Needham et al., 2002). This trend within the present results, however, provides support for Wiesen et al.'s study (2016), such that the vast majority of significant differences were found at the third assessment as opposed to when the first and second assessments were compared. Because the current study emphasized the long-term effects of motor training, the hypotheses were primarily based on Wiesen et al.'s study. Though speculative at this point, the present pattern of findings lend support to the notion that with an extension of this thesis study (e.g., a larger-scale study that follows infants further longitudinally than 5.5 months of age), results may indicate that sticky mitten training has even greater long-term impacts than immediate benefits.

The trends noted between groups, while not reaching the level of statistical significance, provide credence to the theory of developmental cascades, wherein early experiences have a cumulative effect on later development, either in the same domain as the initial experience, or in an alternate developmental domain (Maten & Cicchetti, 2010). Results indicated that infants who received active training tended to exhibit greater increases in toy contact as well as grasping duration relative to the passive training infants at 5 to 5.5 months of age. Further, at 5- to 5.5-month-old, infants who received passive training tended to spend more time engaging in bimanual exploration than those in the active training group. It is possible that infants who were not afforded the opportunity to explore toys during the motor training demonstrated increased interest in bimanual exploration when they were able contact the rattle during the reaching assessment. This trend suggests that receiving two weeks of active or passive motor training at 3 months of age leads to behavioural differences at 5 months of age. Building a case of support for the developmental cascade theory, Libertus, Joh and Needham (2015) also found that significant behavioural differences between infants who received active and passive training at 3-months-old persisted when they were 15 months of age regarding both motor development and attention. The findings of the present study (alongside others, e.g., Libertus et al., 2015) provide support for the theory of developmental cascades, such that receiving active sticky mitten training at 3 months of age may have been implicated in greater toy contact and grasping at 5 months of age, whereas passive sticky mitten training may have been instrumental in increasing bimanual exploration.

Inclusion of the reaching assessment within this study allowed for the evaluation of the long-term effects of motor training on motor attentional development. While this portion of the study could not evaluate shared attention or behaviour in a natural setting while interacting with a parent, it was important in providing support for the previous study that evaluated sticky mitten training at 5.5 months of age (Wiesen et al., 2016). It also provided the foundation from which the second part of the study could be implemented. Notwithstanding the limitations of this study, the findings are promising and provide compelling support for further exploring the role of sticky mitten training on behaviour in a home-based environment.

Parent-Infant Interaction and Attention Engagement

The parent-infant interaction component of this study sought to extend the findings of the sticky mitten literature to determine whether this training influences how infants interact with their parents in a natural setting, or whether there are any effects regarding shared attention. With elements of the current paradigm drawn from the Perra and Gattis study conducted in 2012, this study initiated the first step in mapping attentional tendencies as measured in the sticky mitten study into the context of natural parent-infant interaction. As such, the attentional variables assessed during the parent-infant interaction were kept consistent with the sticky mitten paradigm (i.e., looking at the parent, toy, or at something else). Retrospectively, a different measurement of attention may have been called for, such as the more refined levels of attention engagement outlined by Perra and Gattis (2012).

Collecting the parent-infant interaction data in participants' homes was met with a number of challenges. Parents were allowed to interact with their infants in the way that best suited them (in order to allow for the observation of a naturalistic interaction), while using a toy and ensuring that their infant had the opportunity to look at the toy as well as the parent. While the researchers set up the cameras such that they could capture a broad area of the room, they then left the room while the interaction took place in order to eliminate distraction in part of the infant. At times during the interaction, parents shifted locations with their infants in such a way that the cameras could not fully capture the interaction, an issue that escaped the view of the research team in the adjacent room. In spite of this, the majority (at least 70%) of each parent-infant interaction was deemed viewable and subject to coding. An additional difficulty arose such that, because the cameras were set to be zoomed out (in order to capture a greater area of the room), it was difficult to discern, at times, where the infants and parents were looking.

In addition to difficulties regarding data collection and capture, the coding parameters used for the parent-infant interaction may have caused interesting and important attentional tendencies to remain unnoticed. Following from a previous study (Perra & Gattis, 2012), attentional behaviours were coded when they lasted for 3 seconds. However, this amount of time may have been too long to pick up on both attention and shifts in attention in the 5.5-month-old infants. As such, utilizing a different duration requirement (e.g., 1 or 2 seconds) likely would have allowed for richer trends to emerge within the data when infants were 5.5 months of age.

Hypothesis four. The fourth hypothesis was confirmed, as infants spent a significantly greater amount of time unengaged and looking at their parent than they did looking at the toy. Because this study did not evaluate all the attentional states outlined by Perra and Gattis (2012), the current result does provide direct support for previous findings, which indicated that infants spent the majority of a parent-infant interaction in the predefined attentional states of unengagement and onlooking (passively attending to a parent's activity). While Perra and Gattis' attentional states were carefully defined and nuanced, their result does appear to be mirrored in this study. More specifically, infants in both studies spent the majority of the interaction attending to their parent or their parent's activity, or in an unengaged attentional state. It appears as though this tendency (to attend to the parent or to nothing in particular during social interactions) arose due to natural infant development at this age (Perra & Gattis, 2012, CDCP, 2016), as there were no experimental manipulations introduced in the Perra and Gattis (2012) study, or at this point in time during the present study (see Figure 4 to review the experimental setup).

Exploratory analyses.

Attention allocation. Exploratory analyses evaluated the changes in attention allocation in both the active and passive training groups from assessments one to three. In both training groups, there was a tendency toward decreased time spent looking at the parent across assessments, but these results did not reach the level of significance. Accordingly, infants in the active training group tended to spend a greater amount of time looking at the toy across assessments. Those in the passive training group tended to look at the toy more at the second assessment relative to the first; however, they demonstrated decreased time spent looking at the toy at the third assessment relative to the second. One explanation for these results may be that, immediately after having received motor training, infants in the active and passive training groups experienced an increased interest in toys that extended to naturalistic interactions with their parents (and thus led to decreased attention toward the parent at the second assessment). However, as time elapsed since receiving training, infants who did not receive active training may have lost interest in looking at toys relative to their parents.

Although interesting trends emerged regarding attention allocation the in active and passive training groups, the between-group differences did not reach the level of significance. Thus, the effects of sticky mitten training on parent-infant interactions remains unknown. Given that a number of previous studies evaluating sticky mitten training have found differential patterns of attention allocation toward the researcher based on the training group (using the same methodology as that of the present study; e.g., Libertus & Needham, 2010, 2014; Wiesen et al., 2016), it is important to further examine whether these results generalize to real-word settings.

Looking episodes. Exploratory analyses compared the number of looking episodes (shifts in attention) made toward the parent and the toy both within and between groups. This analysis was selected as it could provide interesting insights into infant attention when coupled with the data regarding duration of attention allocation to various stimuli. Results indicated that infants in the active training group looked at their parent significantly more frequently at the second assessment relative to the first. Furthermore, there was a marginally significant finding that actively trained infants looked at their parent less often at the third assessment than they did at the second. Infants in the passive training group tended to look at their parent less during the third assessment than the first and second, but this result did not reach significance.

It is worth noting in context that there was a significant result in the difference scores between groups from the first to second assessment. Infants in the active training group looked at their parents more often at the second assessment relative to the first, and infants in the passive training group did so less often. Here again the reverse effect was seen when comparing the second and third assessments, such that, at the third assessment active training infants looked at their parents significantly fewer times, and passive training infants did so more times. Speculation regarding this result suggests that that having received active sticky mitten training may have led to an increased interest in looking at the parent at the second assessment, as this result is similar to that found in a study by Libertus and Needham (2014). In their study, infants who received active sticky mitten training engaged in increased spontaneous orienting towards faces immediately after training, whereas those who received passive training did not (Libertus & Needham, 2014). Given that both groups in the present study showed significant differences in looking episodes at the second assessment that did not persist at the third, it may be the case that the differential impacts of motor training were not maintained two months after implementation. Alternatively, infants may have maintained their attention either on their parent or the toy for longer durations of time at the third assessment, and thus engaged in fewer looking episodes.

Regarding looking episodes towards the toy, infants in both the active and passive training groups looked at the toy more frequently at the second assessment, and less frequently at the third assessment. However, this trend also did not reach significance. Upon careful reflection of this result, it is conceivable that immediately after having received training, infants in both groups demonstrated increased interest in the toy and thus looked toward it more frequently. On the contrary, as noted above, if infants fixated on either their parent or the toy for longer durations, they may have accordingly engaged in fewer looking episodes.

Shared attention. As noted above, this study evaluated differences in shared attention (wherein the infant and parent both attended to one another or toward the toy) across assessments as well as between the active and passive training groups. Within-groups analyses revealed no significant differences in either the active or passive training groups regarding the amount of shared attention between infant and parent, or attention mutually directed toward the toy. An intriguing trend emerged in both groups such that shared attention directly with the parent decreased, and shared attention toward a toy increased between the first and third assessments. This result may have arisen due to the natural shift in curiosity towards environmental stimuli throughout the first year of development. The observed change in shared attention allocation may also provide support for the theory that parent-infant interactions are carefully adjusted over time to accommodate developmental changes in early infancy (Fogel 1990, 1992).

Evaluation of between-group differences yielded no significant results in regards to the time spent sharing attention between the infant and parent directly, or sharing attention toward the toy. Similarly, there were no significant between-groups differences upon evaluation of the changes in shared attention between assessments. Thus, it is unclear as to whether sticky mitten training impacts upon shared attention.

Parent-infant interaction: Summary and formulation. The parent-infant interaction component of this study sought to elucidate the impact of sticky mitten training on shared attention as well as the generalizability of the sticky mitten paradigm. Unfortunately, the overall parent-infant interaction result was not able to definitively answer the initial research question outlining the generalizability of motor training and its impacts on shared attention. All said, reported key findings and trends regarding group differences indicate that sticky mitten training may influence looking episodes during natural interactions with parents. Future studies would be well positioned to extend this research by incorporating a larger sample, additional cameras in order to better capture the interaction, and evaluating the occurrence of the various states of attention engagement outlined by Perra and Gattis (2012). Because a number of studies have noted the role of sticky mitten training on attention (e.g., Libertus & Needham, 2010, 2011), evaluating this training in regards to home-based parent-infant interaction is crucial to further understand the effects of sticky mitten interventions.

Additional Considerations

In addition to the variables analyzed, the researcher sought to evaluate two other variables, but they were ultimately not included within the analyses. The first variable was an elaboration of infant attention toward the researcher and caregiver, and was intended to determine whether the infant was looking at the eyes or elsewhere on individual's face with whom they were interacting. This variable was selected because of the information it could provide regarding whether infants maintained eye contact with their social partner, or whether they shifted their attention between looking at eyes and other facial features (and of course, whether sticky mitten training impacted upon these tendencies). Research has demonstrated that at 3 months of age, infants tend to look at the eyes and mouth equally (Wilcox, Stubbs, Wheeler, Alexander, 2013), whereas around 6 months of age, they tend to shift the focus of their attention primarily to the mouth of their interactive partner (Wagner et al., 2013). However, it was not consistently clear as to where on another's face the infant was looking, and thus this variable could not be evaluated.

The second variable that was considered for coding and analysis was the evaluation of where parents, in addition to infants, were looking during the parent infant interaction. Parent looking behaviours were coded in order to determine at what times the infant and parent were sharing attention; however, due to the scope of the current project, the parent looking data were not analyzed in isolation. Analysis of this data would be beneficial as it would allow for the evaluation of how parents allocate *their* attention when they interact with their infants, and whether conducting the motor training (active or passive) shapes these attentional patterns. This variable should be included in later studies, as the results may provide novel insights regarding parents' attention allocation while interacting with their children.

Motor Training and Attention Allocation: Observations and Conclusions

The current study aimed to extend the sticky mitten literature by following infants longitudinally and evaluating shared attention as well as the generalizability of this training to a natural, home-based setting. When considering together the results of the reaching assessment and the parent-infant interaction, similarities and differences emerged across contexts. Infants in the active training group looked at the researcher for longer durations throughout the reaching assessment across assessments; however, the opposite trend was observed during the parent-infant interaction, at which time they looked at their parent for shorter amounts of time. This pattern could possibly reflect an increased interest in infants to look at a new face as opposed to a toy during the reaching assessment, and perhaps a preference to look at a familiar/favourite toy more than a familiar face (of a parent) during the parent-infant interaction. While this result seems plausible and may be expected, it brings to awareness the challenges of determining the generalizability of sticky mitten training on attention allocation. It may be the case that other factors are driving the differences observed in attention allocation across assessments as opposed to the sticky mitten training itself. This speculation requires further empirical study.

Additionally, infants in the active training group looked at the toy for a longer period of time at the second assessment than the first during both the reaching assessment as well as the parent-infant interaction. At the third assessment, however, infants looked at the toy for a shorter period of time (relative to the second) during the reaching assessment, but for a longer period of time during the parent-interaction. Thus, among infants in the active training group, the trends observed during the reaching assessment do not consistently reflect those seen during the parent-infant interaction. Once again, it may be the case that actively trained infants were increasingly interested in the toy immediately after having received training, but at the third assessment demonstrated a preference to look at a novel face as opposed to the toy. During the parent-infant interaction, there may have been increased interest in the toy relative to a familiar face at the second and third assessments. An alternate explanation is that the parents may have selected a toy that was one of their infant's favourites, whereas the toy used for the reaching assessment may have been less stimulating or exciting for the infant. That said, it is also possible that the actions of the parents were encouraging increased attention toward the toys. For example, parents could have been pointing to and looking at the toy they incorporated into the interaction. However, the researcher also attempted to draw the infants' interest toward the toy, and thus if this was the case, the results should be reflective of one another in each context.

Similar to infants in the active training group, infants in the passive training group demonstrated inconsistency regarding attentional tendencies during the reaching assessment and the parent-infant interaction. Infants looked at both the researcher and parent for shorter durations at the second assessment relative to the first; however, at the third assessment, infants looked at the researcher for a longer duration than at the second assessment, and at the parent for a shorter duration. This result may reflect the tendencies noted in the above discussion of actively trained infants (i.e., preference to look at a novel face as opposed to a toy). The consistency of this result across training groups provides support for the idea that there may be increased interest in a novel or unfamiliar face that causes increased attention to be allocated toward the researcher.

Interestingly, in both the reaching assessment and the parent-infant interaction, infants in the passive training group looked at the toy for an increased duration at the second assessment relative to the first, and a decreased duration at the third assessment relative to the second. Thus, passively trained infants appeared to look at the toy more consistently across contexts than they looked at the person with whom they were interacting. During the parent-infant interaction at the third assessment, passively trained infants demonstrated decreased attention toward both their parent and the toy relative to the second assessment. One explanation for this result could be related to the small sample size and variability within the groups. Alternatively, it is possible that infants simply attended to other environmental stimuli as opposed to their parent or the toy. The next step would be to achieve increased clarity during coding (e.g., by use of an eye-tracker or a *Go-Pro* camera) alongside a larger sample to help determine the generalizability of sticky mitten training in a home setting when infants interact with a parent.

Upon evaluation of shared attention, differential tendencies between groups were not noted across assessments: infants in both the active and passive training groups appeared to engage in less shared attention with their parents during which they looked at one another, and engaged in increased shared attention toward a toy across assessments. Thus, based on these results, it appears as though sticky mitten training may not impact upon shared attention, and accordingly, on the development of joint attention. However, this finding may be the result, in part, of the difficulties that arose when attempting to code the data regarding where both the parent and the infant were looking. It is possible that if future studies shift the approach to capturing the parent-infant interaction at participants' homes (e.g., as noted earlier by use of more advanced technology in order to detect more subtle behaviours), different results may emerge regarding between-group differences. Finally, the incorporation of a no-training control group would be beneficial in determining whether motor training more generally leads to differential tendencies of shared attention.

Overall, this research began to answer a number of the questions it posed, and provided a stepping stone from which future studies can build upon in order to further evaluate the impact of developmental aids (sticky mittens) on shared attention in a natural home environment. The current study is perhaps best viewed as a pilot study; while it was met with both strengths and limitations, it was an adventurous first step in advancing the sticky mitten literature. The strengths and limitations as well as future directions are delineated below.

In addition to the immediate and tangible discussion points that arose from the results of the present study, the methods of this research brought forth questions regarding the general idea of implementing training paradigms (be it sticky mittens or other interventions) in typically developing populations. Evolution throughout time has led to a highly sophisticated, finely tuned developmental system that allows infants to grow and to successfully navigate their world. Typically developing infants do reach the developmental milestones (regardless of *when* they reach them), and as such, it appears at first glance as though the utility of the sticky mitten training may not have tremendous value. The present research was not intended to question the sophisticated developmental course of motor learning and attention, but was intended to a) evaluate the impressive flexibility of the developing motor and attentional systems, b) to gain insight into the link between motor and attentional development more generally, and c) to determine whether there are noticeable differences as a result of training in order to shed light on the potential utility of sticky mitten training in infants at a high risk of developing neurodevelopmental disorders (e.g., ASD). Conducting motor training with typically developing infants can thus provide insight into the developing motor and attentional systems, and there may be even more impactful practical implications and benefits of this training when applied to atypically developing populations (see *Implications and Future Directions*).

Strengths and Limitations

This study design has replicated the only other study to date that evaluates the lasting effects of sticky mitten training two months after having been completed (Wiesen et al., 2016). While the sample size was small, the methodology closely followed that of Wiesen and colleagues (2016) and the results either confirmed those found in their study, or demonstrated trends toward their findings. The present study provides support for the importance of conducting sticky mitten training and further understanding of the scope of its effects.

In addition to replicating a previous study, the present research paradigm has extended the trajectory of sticky mitten research to evaluate whether its achieved effects regarding attention allocation are generalizable to a natural setting wherein the parent interacts with their infant, or whether there is an impact on shared attention. While there is value in knowing the impacts of sticky mitten training in the context of lab assessments, it is crucial that these impacts are understood outside of the lab within infants' daily lives. Thus, this project linked elements from two different research studies to develop a novel method that has moved the sticky mitten literature in a new, innovative direction.

The study, as presented and conducted, has a number of strengths with potential to add to the developmental literature. Of course, and as intimated at several points above, the study also sheds light on a key limitation: the sample size was not large enough to determine the effects of active versus passive sticky mitten training. Thus, a number of between-groups results did not reach the level of significance, and there was substantial variation within and between groups. In the pilot study spirit suggested, it did nonetheless provide future directions from which to build additional studies.

An additional limitation to this study is that it did not measure motor and attentional behaviours in a no-training control group. Thus, when changes were observed across the active and passive training groups, inferences could not be made as to whether they related to having received motor training, or simply due to natural infant development. Due to the ambitious method of this research project, the inclusion of a no-training control group while collecting data for active and passive training groups was not feasible. However, it is hoped that this additional data will be collected as a follow-up to the present study, in order to strengthen the findings and create a more robust framework to submit for future publication consideration.

While the present study followed infants two months after having received motor training, the infants could have been followed further longitudinally (e.g., when they were 7-, 9- and 12-months-old). In the current study (which simply followed infants at one additional time point after training), a great deal of time was spent "waiting" for infants to achieve the next age milestone and as such it was not feasible to follow them further. Future studies within the lab do plan to evaluate the effects of sticky mitten training when infants are 7, 9 and 12 months of age.

Finally, a number of difficulties arose regarding data collection and coding. As noted above, the data collection was extensive and required significant time to travel to participants' homes (in most cases up to two hours of travel time) as well as to accommodate last-minute cancellations. At times, the researchers commuted to a participant's house only to find out that the infant was not in the best state to conduct the observations. Furthermore, it was difficult to control the scene being captured by the camera during the parent-infant interactions, and at times, data were lost due to an inability to capture all angles within a room. Thus, coding this data proved to be quite cumbersome. Lastly occasional difficulties arose upon coding the infants' focus of attention during the reaching assessment, as eye tracking equipment was not.

Implications and Future Directions

This study has provided a foundation from which future research can evolve. Because there have been trends observed between the active and passive training groups in both the reaching assessment and the parent-infant interaction, future studies should use a similar paradigm as that used presently, but increase the sample size as suggested. Additionally, given the difficulties experienced in this study regarding capturing the full duration of the parent-infant interaction, future studies should alter the experimental setup such that the data can still be collected in the infants' natural home environment without loss of data. For example, the use of a third camera or a wearable camera could provide additional coverage when recording the interaction while still allowing for the parent to engage with the infant as they typically would.

A promising area in which this research could expand would be the addition of neurological measures to evaluate whether sticky mitten training leads to differential patterns of brain activity. A number of different imaging techniques could evaluate functional changes that may arise due to having received sticky mitten training. For example, fMRI techniques could investigate differential patterns of activation among infants who received active or passive sticky mitten training. A non-invasive option that could realistically be implemented with infants would be the use of an EEG to evaluate whether there are differences in patterns of brain activation while completing the reaching assessments or the parent-infant interaction after having completed motor training. To this author's knowledge, there is very little research that examines the underlying mechanisms associated with developmental aids, be it sticky mittens or equivalent.

In addition to evaluating changes within infants' neurobiology, future research could evaluate the development of motor behaviours and attention cross culturally. As opposed to implementing a highly focused training paradigm such as sticky mitten training, research could simply chart the development of the motor and attentional systems in different culture. This research could take into account individual differences in development (for example, in regards to each participant as well as child-rearing practices) as opposed to using experimental manipulation as this study did. While there is value in implementing the sticky mitten paradigm, there is substantial variance in infant development both from infant to infant, as established in historical studies that have followed infants longitudinally (e.g., Gesell 1928; Gesell & Thompson, 1929; McGraw, 1932, 1939; Zelazo & Weiss, 2006) as well as cross-culturally (e.g., Blake & de Boysson-Bardies, 1992; Fogel, Toda, & Kawai, 1988; Gesell, Ilg, Learned, & Ames, 1943). As such, a study that simply evaluates natural development of motor and attentional behaviours that captures individual variation would provide valuable information.

As a student of clinical science training, this author would be remiss without closing on a discussion of the clinical implications of sticky mitten training. Learning more about the long-term effects of motor training could impact upon the how parents approach interactions with their infants at a young age (both in clinical and nonclinical settings). If long-term effects are found regarding attention engagement, particularly shared attention with others, this training could be implemented with infants who are at a high risk of developing autism spectrum disorder (i.e., infants who have a sibling with autism) to determine its effects.

Individuals with autism spectrum disorder exhibit different patterns of motor development (e.g., decreased grasping of objects) in infancy relative to typically developing infants (Bryson et al., 2007; Kaur, Srinivasan, & Bhat, 2015; Landa & Garrett-Mayer, 2006; Libertus, Sheperd, Ross, & Landa, 2014), and they lack social attention skills (e.g., making eye contact, initiating and maintaining conversations) beginning in infancy and persisting throughout their lifetime, as indicated in the DSM-5 (American Psychiatric Association, 2013). One study thus far has evaluated sticky mitten training among high-risk infants, and has found this training to be beneficial, as these infants demonstrated increased reaching behaviour immediately after training was complete (Libertus & Landa, 2014). Thus, determining the long-term effects of motor training within this population could inform active and earlier interventions. The current study has paved the way for both clinically- and non-clinically-based longitudinal sticky mitten studies to be conducted, whose results could have far-reaching implications regarding infant development and parent-infant engagement.

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