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Infant Temperament and Cardiac Physiology as Predictors of Infant Locomotion

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INFANT TEMPERAMENT AND CARDIAC PHYSIOLOGY AS PREDICTORS OF INFANT LOCOMOTION

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ABSTRACT

Infant locomotion is a major milestone that occurs during the first year of an infant's life, and the onset of crawling is associated with various developmental changes. Previous work has focused on changes in infant temperament, specifically anger, during the onset of crawling. Other work has focused on changes in infant cardiac physiology in association with temperament development. Little research has examined both temperament and cardiac physiology (e.g., respiratory sinus arrythmia, RSA) as predictors of infant locomotion. Examining both factors in the same study could further explain variability in infant motor development. The current longitudinal study examined infant temperament (anger, fear, surgency) and cardiac physiology (Baseline RSA, RSA Suppression) at 4 and 6 months as predictors of infant locomotion (pre-crawling, crawling) at 8 months. Findings suggest that infant temperament and cardiac physiology are associated with the age at which an infant began to pre-crawl or crawl. Mother-infant baseline RSA models revealed that anger and surgency are associated with the age of infant crawling. Mother-infant RSA suppression models revealed that infants with high RSA suppression and fear stood while holding on at an earlier age. For father-infant models, high anger with RSA suppression was associated with crawling at an earlier age.

I would like to dedicate my thesis to my parents, Mitchell and Debbie Howard, for their continued support in everything I do. Thank you for always encouraging me to go above and beyond throughout my academic career.

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INTRODUCTION

An infant's development of locomotion is a major milestone that aids infants in experiencing the world in new and exciting ways (Pemberton Roben et al., 2012). Increased locomotion in infants has been associated with various changes in infant temperament and cardiac physiology (Ghassabian et al., 2016; Pemberton Roben et al., 2012). For example, research on predictors of infant crawling has found infant temperament, or individual differences in reactivity and regulation, to play a role. Specifically, previous work has examined infant temperament and crawling as a predictor of infant anger (Pemberton Roben et al., 2012); infants who were crawling showed higher anger than same-age infants who were not crawling. Even though other temperament factors have been associated with crawling (Whiteny & Green, 2011); little work has actually examined multiple aspects of temperament as correlates of infant crawling in one study. The present study aimed to expand the previous work by including multiple temperament factors (anger, fear, surgency) as predictors of infant locomotion.

Cardiac physiology, the parasympathetic branch of the autonomic nervous system, has been associated with better emotion regulation (Stifter, Dollar, & Cipriano, 2010), and much work has focused on associations between cardiac physiology and infant temperament. More specifically, respiratory sinus arrythmia, a measure of parasympathetic function and regulatory capacity, has been shown to interact with temperament to predict child outcomes (Morales, Beckman, Blandon, Stifter, & Buss, 2015; Stifter et al., 2010). Research examining the role of cardiac physiology in locomotion development is lacking and a need for examination has been noted by previous research (Pemberton Roben et al., 2012). Better physiological regulation coupled with specific temperament styles could possibly promote the onset of locomotion. However, research examining these associations are lacking.

Increasing the onset of locomotion during the first year of life is important as hitting milestones early on has been associated with better language development and increased intelligence later in life (Murray, Jones, Kuh, & Richards, 2007). Furthermore, increased maternal activity during pregnancy has been associated with increased infant locomotion (McMillan, May, Gaines, Isler, & Kuehn, 2019). Specifically, infants are more equipped to be mobile thus promoting locomotion when their mothers were active during pregnancy (McMillan et al., 2019). Multiple factors contribute to the promotion of infant mobility further affecting development later in life.

Across research examining infant temperament, cardiac physiology, and locomotion, the majority of work has focused on outcomes with mother-infant dyads; however, few studies have previously examined both mothers and fathers. Specifically, Lamb (1977) found that mothers often hold their infants to provide caretaking whereas fathers hold their infants to play. Furthermore, it has been noted that fathers spend more time engaged in active play with their infants than mothers (Forbes, Cohn, Allen, & Lewinsohn, 2004). Overall, research is lacking on how both parents interact independently with their infant such that father-infant dyad research is limited (Forbes et al., 2004). The current study aimed to close the gap in previous literature by examining how infant temperament and cardiac physiology with both parents is associated with the age at which infants begin to pre-crawl or crawl. Specifically, the present study examines infant temperament (anger/fear/surgency) and RSA (baseline/suppression) at 4 and 6 months as predictors of locomotion (pre-crawling/crawling) at 8 months of age.

Infant Locomotion

Over the course of the first year of life, infants experience many changes as they develop the ability to hold their head at 90 degrees, roll over, sit with and without support, raise to hands and knees, and stand while holding on. Each motor milestone aids the infant's development of self-produced locomotion: crawling or walking (Adolph, 2008). Furthermore, completing each milestone during a respective timeframe has implications for future infant developmental outcomes. Specifically, increased speech production, intelligence, and cognitive development (Flensborg-Madsen & Mortensen, 2018).

The development of self-produced locomotion brings many changes to both infants and parents. Infants begin expressing more independence as they can self-explore their surroundings (Hendrix & Thompson, 2010). In addition, infants begin to show changes in temperament and cognitive function with implications for future motor development (Hendrix & Thompson, 2010). Specifically, Pemberton Roben et al. (2012) found that infants who crawl expressed higher anger during a gentle arm restraint procedure than non-crawling infants. Implications for infant temperament, fear and surgency, have been shown to further promote an infant's self-produced locomotion (Braungart-Rieker, Hill-Soderlund, & Karrass, 2010; Whitney & Green, 2011).

Parents begin observing these developments in infants, which could lead to various changes in parenting. Hendrix and Thompson (2010) found that infant behavior did not change at the onset of crawling; however, parent discipline changed due to infant locomotion. Specifically, mothers were found to use the word no more often as a regulatory control when the infant was crawling (Hendrix & Thompson, 2010). Furthermore, parents may recognize delayed motor development throughout an infant's first year of life, which may also lead them to alter their parenting strategies in an effort to assist their child where they may be lacking. Further, infants that have delayed motor development may also be cognitively delayed (Ghassabian et al., 2016), which is logical as motor development and cognitive development are both the result of brain structure and function. Implications of delayed motor development are serious as there is shown potential for future intellectual disabilities and delayed cognitive and language skills (Ghassabian et al., 2016).

The implications for self-produced locomotion also expand into an infant's ability to learn and adapt in new environments (Adolph & Hoch, 2019). Crawling has been shown to help promote infant exploration physically and mentally as infant's learn new skills through independence. Overall the onset of crawling has been shown to promote many changes in an infant's development such as temperament, locomotion, intellect, and cognition. Further work is needed to expand previous findings and determine future implications of infant locomotion.

Infant Temperament

Temperament is a key aspect of an infant's emotional development and is defined as individual differences in reactivity and self-regulation (Rothbart, 2007). Temperament has been shown to develop over the course of an infant's first year of life but stabilizes throughout the second half of the first year and in early childhood (Rothbart & Bates, 2006). Even though temperament has a strong biological basis, it is acknowledged that both an individual's genetics and environment influence its development (Rothbart & Bates, 2006). Infant temperament has shown influences on later personality development, as well as the development of behavior problems such as internalizing and externalizing behaviors (Rothbart & Bates, 2006).

Temperament can be measured through questionnaires (parent or self-reported amongst older children), laboratory observations, and home observations (Rothbart & Bates, 2006). Parent-report of infant temperament is the most commonly utilized measurement due to the availability and reliability of the measure (Rothbart & Bates, 2006). The present study used the Infant Behavior Questionnaire-Revised (IBQ-R) to measure infant temperament across the varying subscales (Gartstein & Rothbart, 2003). The IBQ-R consists of 191 questions and is a reliable and valid measure of infant temperament because of the internal consistency across the fourteen scales (Gartstein & Rothbart, 2003). Furthermore, the IBQ-R can be utilized to measure various temperament variables as it is a comprehensive measure.

Temperament is often defined as three factors: orienting, negative affectivity, and extraversion/surgency (Rothbart, 2007). Orienting is an infant's ability to direct attention toward or away from distressing objects presented to him/her in the environment (Rothbart, 2007). Negative affectivity relates to an infant's ability to respond to interruptions, distress, and negative emotions including fear and anger (Rothbart & Bates, 2006). Surgency consists of an infant's positive affect and also involves increased activity, smiling, excitement, and high pleasure (Rothbart & Bates, 2006). The current study focused on infant negative affectivity and surgency.

The negative affectivity factor of temperament includes distress to limitations, fear, falling reactivity/rate of recovery from distress, and sadness (Putnam, Rothbart, & Gartstein, 2008). The current study focuses only on the distress to limitations and fear subscales. Distress to limitations (i.e., anger) includes negative affect related to confinement, interruption of ongoing tasks or goal blocking (Putnam et al., 2008), and has been shown to develop around 2-3 months of age and increase across the first year (Braungart-Rieker et al., 2010). Anger development begins as infants learn to control their actions translating into their desire to move and be independent (Braungart-Rieker et al., 2010) through pre-crawling and crawling.

Fear is defined as negative affect related to anticipated pain, distress, and/or threat including reactions to novelty social stimuli (Putnam et al., 2008) and has been shown to develop around 6-8 months of age (Braungart-Rieker et al., 2010). Fear expression is shown later than approach responses due to vast development within the first year. During the first half of the first year of life, infants' express interest to novel items or people. However, during the second half of the first-year infants begin expressing fear towards novel social stimuli through the ability to hypothesize what fits into their typical environment and what does not (Braungart-Rieker et al., 2010). For example, when an infant realizes that a social stimulus is not meant to be in their environment, fear is expressed. Infants who are high in fear (e.g., dysregulated fear) may exhibit bodily freezing their temperament through freezing. Specifically, children with dysregulated fear do not engage with the fearful task because they are unable to engage in their fight-flight system (Buss, Davis, Ram, & Coccia, 2018).

The surgency factor of temperament includes activity level, smiling/laughter, high intensity pleasure, approach, perceptual sensitivity, and vocal reactivity (Putnam et al., 2008), and is similar to extraversion in adults. Activity level is defined as gross motor activity, including rate and extent of movement (Putnam et al., 2008). Smiling/laughter is the positive affect in response to changes in stimulus intensity, rate, complexity, and incongruity (Putnam et al., 2008). High-intensity pleasure is the pleasure or enjoyment related to high stimulus intensity, rate, complexity, novelty, and incongruity (Putnam et al., 2008). Approach is defined as the excitement in the anticipation of pleasurable activities (Putnam et al., 2008). Perceptual sensitivity is the detection of slight, low-intensity stimuli from the external environment (Putnam et al., 2008). Vocal reactivity is defined as the vocalization during daily activities (Putnam et al., 2008). Infant surgency has been shown to develop around 2-3 months of age; however, over the course of the infant's first year of life surgency increases and then stabilizes (Rothbart & Bates, 2006). Due to the overall activity level and approach tendencies that are comprised in the surgency factor, the present study examined the associations between infant surgency and infant motor development (e.g. pre-crawling and crawling).

Infant Temperament and Locomotion

Anger. Previous research has focused on infant locomotion and independence as the motivator of infant anger. Infants that are able to crawl assert more independence; therefore, the infant uses their ability to crawl to further reach their goal through utilization of anger (Pemberton Roben et al., 2012). Previous work has primarily examined associations between infant crawling and anger development (Hendrix & Thompson, 2011; Pemberton Roben et al., 2012), such that infants who were crawling showed higher anger than same-age infants who were not crawling. Pemberton Roben et al. (2012) determined that crawling experience was associated with observed anger when infants were restrained; however, the effect was moderated by infant temperament. The length and frequency of anger expressed were affected by the infant's ability to regulate their emotion. However, it is unclear if anger aids in the development of locomotion, and whether or not an infant's ability to regulate his/her emotions decreases anger expression. The current study aimed to examine how infant anger is associated with infant locomotion in contrast to previous work. Furthermore, an infant's ability to regulate their emotions may affect their expression of anger.

Fear. In addition, fear can also be a motivator of crawling due to withdrawal tendencies. Previous work has primarily focused on infant fear as the outcome of regulatory capacity through the parasympathetic nervous system (Buss et al., 2018), such that infants with dysregulated fear cannot regulate their RSA to engage in fight-flight responses. For example, an infant may be introduced to a new person whom he/she does not know. If the infant is fearful of that person, the infant would be motivated to crawl to get away from the stranger. The infant could also be so fearful that he/she does not utilize crawling as a means of emotion regulation (Braungart-Rieker et al., 2010). In other words, the infant exhibits frozen posture resulting from the fearful event (Buss et al., 2018). Research examining fear as a motivator to crawl is lacking. The current study aimed to bridge the gap in the current literature through examining how infant fear is associated with infant locomotion. Furthermore, an infant's ability to regulate their emotions may affect their expression of fear.

Surgency. Surgency (or exuberance) can also be a motivator of crawling due to approach tendencies. Previous work has focused on the longitudinal role of exuberance, such that infants high in exuberance continue to show high levels of surgency into early childhood (He et al., 2013). Children high in surgency express high activity level, approach to novelty, and impulsivity (Stifter et al., 2010); therefore, it would be expected that infants would crawl to express high activity or reach novel toys. Infants who express high levels of surgency have also been shown to express anger when goals are blocked (He et al., 2013; Stifter, et al., 2010) leading to externalizing problems (Morales, Beekman, Blandon, Stifter, & Buss, 2015). Though it would be expected that infants with high surgency would crawl earlier, previous work has found that infants do not express higher surgency after the onset of crawling (Whitney & Green, 2011). Infants that have increased anger expression along with high surgency may display more anger when asserting their independence through locomotion; therefore, diminishing the expression of surgency. The current study aims to examine how infant surgency is associated with infant locomotion.

Infant Cardiac Physiology

A child's regulatory capacity can be reflected through respiratory sinus arrhythmia (RSA), a measure of parasympathetic function (Beauchaine, 2001; Stifter et al., 2010), and has been shown to interact with temperament to predict child outcomes. RSA measures heart rate variation in regard to the respiratory cycle (Morales et al., 2015). Specifically, RSA is measured using three of the five electrodes placed on the infant/parent.

An infant's regulatory capacity can be measured through baseline RSA and RSA suppression. High baseline RSA has been associated with better emotion regulation (Stifter et al., 2010), thus low baseline RSA is associated with the inability to self-regulate emotions. Specifically, infants displaying lower RSA show higher anger expression due to the inability to regulate their emotion through cardiac physiology (Beauchaine, 2001). Little work has examined the effects of RSA and fear; however, Morales et al. (2015) found that fear was a predictor of internalizing problems but did not significantly interact with RSA. This finding could be due to RSA primarily predicting externalizing behaviors and not internalizing ones (Morales et al., 2015). Furthermore, temperament has been shown to interact with baseline RSA, such that children with low surgency and high baseline RSA have poorer emotion regulation than children with low surgency and baseline RSA (Stifter et al., 2010). Previous work has also examined the effects of RSA suppression in relation to temperament (Moore et al., 2009).

RSA suppression, the change in RSA from a baseline task to a stressor (e.g., still-face episode of the Still-Face Paradigm; Moore et al., 2009) has been shown to interact with temperament to predict externalizing behaviors (Morales et al., 2015). Moore et al. (2009) found that infants expressed greater suppression during SFP after being exposed to anger than infant's who were not exposed. Previous work has mainly found that RSA suppression is not predictive of infant fear due to the high internalizing behavior of fear (Morales et al., 2015). Morales et al. (2015) found high RSA suppression and increased activity, surgency, in girls predicted more externalizing behaviors. Overall, higher RSA has been shown to predict more externalizing behaviors than internalizing behaviors.

Temperament, cardiac physiology, and locomotion: do all three interact?

A large focus of previous work in developmental science has been on the individual aspects of temperament, cardiac physiology, and locomotion. Such that previous work has identified that temperament changes during the onset of crawling (Pemberton Roben et al., 2012). Furthermore, an infant's cardiac physiology aids in an infant's ability to regulate their temperament (Beauchaine, 2001; Stifter et al., 2010). However, current literature is lacking in connecting both temperament and cardiac physiology to infant locomotion. The current study adds to previous literature by expanded the implications of fear as a predictor of crawling (Braungart-Rieker et al., 2010). Furthermore, the current study expands surgency as a predictor of infant locomotion. Little work has examined infant cardiac physiology as correlates of infant temperament, so this study aims to further expand infant cardiac physiology as predictors of pre-crawling/crawling.

Present Study

The current study aimed to examine infant temperament (anger, fear, and surgency), and infant RSA (baseline and suppression) at 4 and 6 months as predictors of infant locomotion (pre-crawling/crawling) at 8 months of age. More specifically, this project aims to answer the following questions: 1) Does infant temperament at 4 and 6 months predict infant locomotion at 8 months? 2) Does infant cardiac physiology (baseline RSA and RSA suppression) at 4 and 6 months predict infant locomotion at 8 months? 3) Does infant temperament and RSA at 4 and 6 months interact to predict infant locomotion at 8 months? To address this goal, three hypotheses were proposed.

Hypothesis 1: Infant Anger and RSA Predicting Infant Pre-Crawling/Crawling. The first aim of the study was to examine infant anger and RSA (baseline and suppression) at 4 and 6 months as predictors of infant pre-crawling/crawling at 8 months. Previous literature has shown infant temperament and crawling are predictors of infant anger, such that infants who were crawling showed higher anger than same age infants who were not crawling (Hendrix & Thompson, 2011; Pemberton Roben et al., 2012). Therefore, it was hypothesized that infant anger and RSA (baseline and suppression) would interact to predict infant age of pre-crawling/crawling decreases. Specifically, it was expected that infants who exhibit higher infant anger and higher baseline RSA were expected to pre-crawl/crawl earlier than infants who exhibit low infant anger and low baseline RSA. Infants exhibiting high baseline RSA have better regulatory capacity; therefore, the infant is able to regulate with their anger through locomotion. For example, if an infant has high anger but is able to regulate their cardiac physiology, he/she can use locomotion as a way to get away from the angering situation. Similarly, it was also expected that infants who are high in anger and high in RSA suppression would also pre-crawl/crawl at a younger age than infants who are low in anger and low in RSA suppression.

Hypothesis 2: Infant Fear and RSA Predicting Infant Pre-Crawling/Crawling. The second aim of the study was to examine infant fear and RSA (baseline and suppression) at 4 and 6 months as predictors of infant pre-crawling/crawling at 8 months. Previous literature has shown that fear develops in the last half of the first year and can also be a motivator of crawling (Braungart-Rieker et al., 2010; Rothbart, 2007). Although fear and anger develop similarly, little previous research on infant fear as a predictor of crawling exist. It is expected that like anger, fear would promote infant crawling as an infant would crawl to move away from the fear; however, it is also expected that due to the fear experienced the infant could freeze and not crawl. The fear may elicit two different flight or fight responses; however, the regulatory capacity through RSA (baseline and suppression) of the infant may further promote one response over the other. Due to little previous research on infant fear as a predictor of infant crawling, it was expected that pre-crawling would differ from crawling. Specifically, it was expected that infants who exhibit higher fear and lower RSA (baseline and suppression) would pre-crawl at a later age than same age infants who exhibit low fear and high RSA (baseline and suppression). Such that an interaction would occur between infant fear and RSA (baseline and suppression). Furthermore, it was expected that infants who exhibit higher fear and higher RSA (baseline and suppression) would crawl at a younger age than infants who exhibit low fear and low RSA (baseline and suppression).

Hypothesis 3: Infant Surgency and RSA Predicting Infant Pre-Crawling/Crawling. The third aim of the study was to examine infant surgency and RSA (baseline and suppression) at 4 and 6 months as predictors of infant pre-crawling/crawling at 8 months. Previous literature has anger as a predictor of surgency such that high anger infants showed increased surgency later in life (He et al., 2013). However, research examining infant surgency as a predictor of infant locomotion is lacking. Due to the lack of research on associations between infant surgency and infant locomotion, the hypothesis is exploratory. Specifically, it was expected that infants who exhibit high surgency and high RSA (baseline and suppression) would pre-crawl/crawl at a younger age than infants who exhibit low surgency and low RSA (baseline and suppression).

METHOD

Participants

Participants included 91 families (mothers, father, and infant) when infants were 4, 6, and 8 months of age (+/- 14 days old; 59% infant males) from a larger longitudinal study. Participants were recruited through distributing/mailing flyers to families with birth announcements in the local newspaper, expectant parent classes and fairs at the local medical center, and local childcare facilities and businesses. Families interested in participating called or emailed the laboratory in order to receive more information. Potential participants were also contacted through email if they provided contact information at the expectant parent fairs. To be included in the study interested families must have met the study inclusion criteria: infant was at least 4 months old (+/- 14 days), parents were both able to read and understand English, mother had a healthy pregnancy and delivery, infant was full-term (birth weight greater than or equal to 5.5 lbs.; gestational age greater than or equal to 37 weeks), both parents are available to come in together and participate in the study, and the family would not be moving out of the Bowling Green area in the next 6 months. Families were compensated $20 after completing each time-point (4, 6, and 8 months).

The study consisted of parents of varying ages with mothers (19-44) average age of 30.4 years old and fathers (19-55) average age of 32.1 years old. The majority of families were predominantly European American (Mothers: 91.2%; Fathers: 89.0%; Infants 87.9%) and middle class (62.7%) with an annual average income of $45,000-$104,999. Education amongst parents also varied: 0% of mothers and 3.3% of fathers attended but did not complete high school, 3.3% of mothers and 8.8% of fathers completed high school, 1.1% of mothers and 1.1% of fathers reported completing some or all of trade school, 51.7% of mothers and 53.9% of fathers reported completing or going to some of college, 44% of mothers and 33% of fathers reported having some or finished postgraduate training. The majority of parents were married (91.2%) or unmarried and living together (7.7%).

Eighty-four families completed the 4-month visit, 79 families completed the 6-month visit, and 70 families completed the 8-month visit. This revealed an attrition rate from 4-months to 8-months of 24.2%. Analyses were run between families who participated in all time-points versus those who did not. No significant differences were revealed.

Procedure

Two weeks prior to their scheduled laboratory visit, parents were mailed a packet of questionnaires to be filled out independently. They were instructed to bring them to the laboratory at the time of their visit. This packet included a questionnaire assessing infant temperament (Infant Behavior Questionnaire-Revised; Gartstein & Rothbart, 2003).

Upon arriving to the laboratory for their first appointment, informed consent was obtained by the lead experimenter. Parents also participated in an interview about demographic information and their infant's motor milestones. The lead experimenter then instructed parents how to place electrodes on themselves as well as their infant (five electrodes on the front torso and two on the back) in order to collect cardiac physiology during the first task, an adapted Still-Face Paradigm (SFP, Tronick, Als, Adamson, Wise, & Brazelton, 1978).

The adapted SFP involved a series of five episodes: baseline, play, still-face, reunion, and recovery. The lead experimenter instructs the first parent to enter the observation room, and a cheat sheet is located on the wall behind the door. Upon entering the room, the first parent is instructed to sit in the chair with the infant in their lap during the baseline task. Baseline begins once the lead experimenter has left the room and closed the observation room door. Baseline lasts for 3-minutes. The lead experimenter re-enters the observation room and instructs the parent to place the infant in the high-chair for play, still-face, and reunion. Play begins after the lead experimenter has left the room and the first doorbell has been sounded. The second doorbell signals the end of play and beginning of still-face. Prior to play the parents were instructed to sit back with a blank face during still-face for 90 seconds. The third doorbell signals the end of still-face and the beginning of reunion. During reunion parents play with their infant once again for 90 seconds. The fourth doorbell signals the end of the SFP task. The lead experimenter reenters the room and instructs the parent to remove the infant from the highchair. The infant sits in the parent's lap for 3-minutes during recovery. The play, still-face, and reunion task each lasted for 90-seconds. The lead experimenter re-enters the room and instructs the parent to sit quietly with the infant in their lap for recovery to measure RSA for the final time with parent one. Once the first parent has completed the adapted SFP and the infant is calm, the second parent will complete a second series of the adapted SFP with the infant (baseline, play, still-face, reunion, and recovery).

Following the SFP, infants participated separately in a free-play task with each parent (Kochanska, Friesenborg, Lange, & Martel, 2004). In addition, they participated in an additional series of observational temperament tasks including being shown a series of

Halloween masks, playing peek-a-boo with each parent, and a modified gentle arm restraint (Stifter & Spinrad, 2002) from the Laboratory Temperament Assessment Battery (Lab-TAB; Goldsmith & Rothbart, 1999). Upon completion of each laboratory visit at each time point, families received compensation of $20. At each time point, the task completed are the same and parent order is counterbalanced.

Measures

Infant Temperament. Parents completed the Infant Behavior Questionnaire-Revised (IBQ-R; Gartstein & Rothbart, 2003) independently of each parent prior to each lab visit at 4, 6, and 8 months of age. The IBQ-R is 191 items that measures parent ratings of infant temperament, that breaks down into 14 subscales of temperament. In the current study, the subscales of infant anger and fear, as well as the surgency factor (approach, vocal reactivity, high intensity pleasure, smiling and laughter, activity level, and perceptual sensitivity) were used (Putnam et al., 2008). A sample item of fear is "How often did the baby seem angry (crying and fussing) when you left her/him in the crib?" A sample item of anger is "When in the presence of several unfamiliar adults, how often did the baby cling to a parent?" A sample item of surgency is "How often during the last week di the baby smile or laugh after accomplishing something (e.g., stacking blocks, etc.)?" Parents rate the infant on a Likert scale of 1 (*never*) to 8 (*does not apply*) for each item. The IBQ-R has been shown to be a reliable and valid resource of caregiver feedback on infant temperament (Gartstein & Rothbart, 2003). Cronbach alpha scores were calculated for infant anger (Mother $\alpha = 0.73$; Father $\alpha = 0.72$), infant fear (Mother $\alpha = 0.84$; Father $\alpha = 0.89$), and infant surgency (Mother $\alpha = 0.73$; Father $\alpha = 0.75$).

Infant temperament was assessed with each parent at 4 and 6 months by averaging the data at the two time points. Data was also averaged across parents (mother and father).

Infant Locomotion. During the demographic interview parents were asked about infant motor milestones at each time point 4, 6, and 8 months of age. Motor milestones include: lifting his/her head 90 degrees while lying on stomach, rolling over, sitting propped up, sitting without support, standing while holding on, raising to hands and knees, and crawling or scooting. Motor milestones were recorded in months and weeks at the time of initial onset, but were converted to weeks for data entry and analysis. For the present study, locomotion was categorized as pre-crawling (standing while holding on and raising to hands and knees) and crawling (crawling or scooting). Pre-crawling and crawling variables were created across all 3 time-points to capture outliers as some infants begin pre-crawling earlier than others. Including all 3 time-points captures parent-infant dyads that only participated during the 6-month and 8-month laboratory visits as some dyads did not complete the 4-month laboratory visit.

Infant Cardiac Physiology. Electrocardiograms (ECG) and impedance cardiograms were recorded from parents and infants during the baseline, SFP, and recovery tasks. Infants have five pediatric electrodes on the front torso and two on the back. A 2-slot Bionex chassis (MindWare Technologies), which records heart period and ZCG (impedance) was used. To quantify the cardiac data, the ECG and impedance signals were passed through an A/D converter sampled at 500ms and band-pass filtered at 40 and 250 Hz. After the visit, inter-beat intervals were screened for artifacts using a validated algorithm (Bernston et al., 1990) by trained, research assistants. The natural log integral of the RSA band 9.24-1.04 Hz for infants was extracted, calculated in 30-s epochs within each task using MindWare HRV version 3.0.25. A team of research assistants trained to inspect cardiac data for artifacts until they achieved an intraclass correlation of 0.80 and did not edit infant data from both parents in one age group (e.g., 4 and 6 months). The 30-s epochs within each task were averaged to create one infant RSA score for baseline and the still-face episode with both parents, mother and father. Coders overlapped by rating 27% of the baseline data and 28% of the still-face data resulting in intraclass correlations of 0.94 – 0.98 for baseline RSA and 0.95 – 0.99 for still-face RSA. Infant baseline RSA data were averaged across epochs to create individual scores with mothers and fathers at 4 and 6 months. Similarly, infant still-face RSA data was averaged across epochs to create individual scores with mothers and fathers at 4 and 6 months. Infant RSA suppression was calculated by creating difference scores between the average infant baseline RSA score and the infant still-face RSA score with mothers, and fathers. Infant baseline RSA was averaged across 4 and 6 months to create average infant baseline RSA in early infancy with each parent. Similarly, infant RSA suppression was averaged across 4 and 6 months to create average infant RSA suppression with each parent. Higher scores indicated higher infant baseline RSA and better regulatory capacity (Beauchaine, 2001). Higher infant RSA suppression change means greater suppression (Morales et al., 2015).

RESULTS

Descriptive Statistics and Correlations

Descriptive statistics were run for all study variables (See Table 1). Each of the variables showed a normal distribution. Correlations were conducted between all of the variables of interest. Table 2 reports the within-parent correlations for mothers. Several significant correlations were revealed between mother-report of infant temperament and infant locomotion. For example, infant anger and infant fear were positively correlated such that as infant anger increases, so does infant fear (r (90) = 0.23, p = 0.03). Furthermore, pre-crawling (raise to hands and knees) was negatively correlated with infant surgency and standing while holding on (r (56) = -0.27, p = 0.05). Specifically, as infant's raised to hands and knees at a younger age surgency increased and infants would stand while holding on at an older ager. In addition, there were significant correlations between infant RSA suppression with mothers and infant anger (r (89) = 0.22, p = 0.04) and infant baseline RSA (r (90) = 0.49, p = 0.00). As infant RSA suppression increases infant anger and infant baseline RSA also increased.

Table 3 reports the within-parent correlations for fathers. Similar to the within-mother correlations, within-father correlations revealed the same significant correlations for infant fear and infant anger, standing with holding on and raising to hands and knees, and infant RSA suppression and infant baseline RSA. In contrast to within-mother correlations, a significant correlation for within-fathers was found for infant fear and infant surgency (r (90) = 0.31, p = 0.003). Specifically, as infant fear increases infant surgency also increased. Furthermore, infant anger and crawling were correlated such that as infant anger increased infant age of crawling decreased (*r* (53) = -0.38, *p* = 0.01). In addition, there were significant correlations between infant RSA suppression with fathers and the age infants stand while holding on (*r* (69) = -0.25, *p* = 0.04). More specifically, as infant suppression increases infants stand while holding on at a younger age.

Table 1.

Descriptive Statistics for Study Variables

Variable	n	M (SD)	Skewness	Kurtosis
Infant Locomotion				
Raising to Hands & Knees	56	24.77 (5.68)	-0.76	-0.38
Standing While Holding On	74	17.92 (8.42)	0.37	-0.87
Crawling	56	25.64 (5.72)	-1.39	3.06
Mothers				
Infant Anger	90	3.44 (0.72)	0.28	0.01
Infant Fear	90	2.19 (0.70)	0.80	0.12
Infant Surgency	90	4.47 (0.52)	-0.18	0.05
Infant Baseline RSA	90	3.15 (0.81)	-0.78	1.53
Infant RSA Suppression	90	-0.13 (0.75)	-0.61	1.78
Fathers				
Infant Anger	90	3.56 (0.74)	0.55	0.28
Infant Fear	90	2.26 (0.71)	1.16	1.70
Infant Surgency	90	4.38 (0.64)	-0.22	0.28
Infant Baseline RSA	88	3.13 (0.82)	-0.22	-0.50
Infant RSA Suppression	87	-0.98 (0.86)	-0.92	6.26

Lastly, between-parent correlations revealed several significant results (See Table 4). Mother reported infant anger and father reported infant anger were positively correlated (*r* (90) = 0.56, *p* = 0.00). Furthermore, infant surgency was also positively correlated as mother-infant surgency increased so did father-infant surgency (*r* (90) = 0.43, *p* = 0.00). Furthermore, as mother-infant fear decreased father-infant baseline RSA increased (*r* (87) = -0.22, *p* = 0.04). In addition, a significant positive correlation was found between mother-infant baseline RSA and father-infant baseline RSA (*r* (88) = 0.59,

$p = 0.00$). No significant between-parent correlations were revealed for infant RSA suppression.

Table 2.

Within-Parent Correlations for Mother-Infant Variables

Variable	1	2	3	4	5	6	7	8
1. Infant Anger	1.00							
2. Infant Fear	0.23*	1.00						
3. Infant Surgency	0.02	0.05	1.00					
4. Raise to Hands & Knees	-0.04	0.08	-0.27*	1.00				
5. Standing While Holding On	-0.11	0.17	0.05	-0.27*	1.00			
6. Crawling	-0.23T	-0.003	-0.37**	0.15	0.02	1.00		
7. Infant Baseline	-0.13	0.001	0.08	0.01	-0.02	0.26 T	1.00	
8. Infant Suppression	0.22*	0.16	-0.13	0.01	0.03	-0.07	0.49**	1.00

Note: *$p < 0.05$, **$p < 0.01$, T $p < 0.10$

Table 3.

Within-Parent Correlations for Father-Infant Variables

Variable	1	2	3	4	5	6	7	8
1. Infant Anger	1.00							
2. Infant Fear	0.35**	1.00						
3. Infant Surgency	0.16	0.31**	1.00					
4. Raise to Hands & Knees	-0.06	-0.13	-0.19	1.00				
5. Standing While Holding On	-0.10	0.03	0.19	-0.27*	1.00			
6. Crawling	-0.38**	-0.09	-0.21	0.15	0.02	1.00		
7. Infant Baseline	-0.13	-0.17	-0.09	0.08	-0.15	0.22	1.00	
8. Infant Suppression	0.11	-0.04	-0.18	0.14	-0.25*	-0.08	0.31**	1.00

Note: *$p < 0.05$, **$p < 0.01$, T $p < 0.10$

Table 4.

Between-Parent Correlations for Mother-Infant versus Father-Infant Variables.

Mother/Father	1	2	3	4	5
1. Infant Anger	0.56**	-0.07	0.08	0.01	0.14
2. Infant Fear	0.15	0.20	0.07	-0.22*	-0.16
3. Infant Surgency	0.07	0.12	0.43**	0.15	-0.06
4. Infant Baseline	-0.07	-0.05	0.03	0.59**	-0.05
5. Infant Suppression	0.09	-0.04	-0.001	0.15	-0.01

Note: Rows are mother data. Columns are Father data.
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{T}p < 0.10$

Multiple Regression Results

Multiple regression models were run to test whether infant temperament (anger, fear, surgency) and infant cardiac physiology (infant baseline RSA, infant RSA suppression with mothers and fathers) predicted infant locomotion (pre-crawling; raising to hands and knees; crawling or scooting). Parent age was included as a covariate in the regression models due to significant correlations found between parent age and a number of the variables of interest. Separate models were run for the infant temperament, cardiac physiology, and infant locomotion variables.

Infant Baseline RSA. For mother-infant models (n = 53), several significant main effects were found to predict infant crawling (See Table 5). A significant main effect of infant anger (B = -2.07, SE = 0.84, p = 0.02) was found to predict infant crawling. More specifically, as infant anger increased, infants achieved crawling at an earlier age. In addition, a significant main effect of baseline with fear (B = 2.34, SE = 1.02, p = 0.03) was found to predict infant crawling. More specifically, as infant baseline RSA increased, infants began crawling at a later age. Furthermore, a significant main effect of infant surgency (B = -2.94, SE = 1.32, p = 0.03) was found to predict infant crawling. Specifically, as infants increased in surgency, infants achieved crawling at an earlier age. There were no significant effects found for father-infant models.

Table 5.

Multiple Regression Results with Infant Crawling and Infant RSA Baseline: Mother-Infant Models (n = 53)

Model	Variables	B (*SE*)	df	F	R^2
Anger			4	4.50^{**}	0.27
	Infant Anger	$-2.07\ (0.84)^{*}$			
	Infant Baseline	$1.87\ (0.96)^{T}$			
	Mother Age	$0.28\ (0.12)^{*}$			
	Anger X Baseline	$2.26\ (1.18)^{T}$			
Fear			4	2.85^{*}	0.19
	Infant Fear	0.01 (0.99)			
	Infant Baseline	$2.34\ (1.02)^{*}$			
	Mother Age	$0.29\ (0.12)^{*}$			
	Fear X Baseline	2.03 (1.35)			
Surgency			4	3.69^{*}	0.24
	Infant Surgency	$-2.94\ (1.32)^{*}$			
	Infant Baseline	$2.25\ (1.16)^{T}$			
	Mother Age	0.16 (0.13)			
	Surgency X Baseline	-0.75 (2.20)			

Note: Mother age was included as a covariate. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{T}p < 0.10$

Infant RSA Suppression. For mother-infant regression models involving infant RSA suppression (n =53), one significant main effect was revealed (See Table 6). For mothers, a significant main effect of surgency (*B* = -3.22, *SE* = 1.38, *p* = 0.03) was found to predict crawling. More specifically, as infant surgency increased, infants achieved crawling at an earlier age.

In addition, a significant infant Fear X RSA suppression interaction predicting standing while holding on was found (n = 69, *B* = -5.36, *SE* = 1.99, *p* = 0.01; See Figure 1). A simple slope analysis probing infant fear one standard deviation above and below the mean (Aiken & West, 1991) revealed that for infants high in infant fear that as infant

RSA suppression increased, age of standing while holding on decreased (*B* = -5.03, *SE* = 2.24, *p* = 0.03). The simple slope for infant low in fear was nonsignificant.

Table 6.

Multiple Regression Results with Infant Crawling and Infant Suppression RSA: Mother-Infant and Father-Infant Models (n = 53)

Model	Variables	B (*SE*)	df	F	R^2
I. Mother					
Anger			4	2.32^{T}	0.16
	Infant Anger	$-1.75\ (0.92)^{T}$			
	Infant Suppression	-0.28 (1.03)			
	Mother Age	$0.31\ (0.12)^{*}$			
	Anger X Suppression	0.44 (1.11)			
Fear			4	1.34	0.10
	Infant Fear	0.30 (1.05)			
	Infant Suppression	-0.97 (1.09)			
	Mother Age	$0.29\ (0.13)^{*}$			
	Fear X Suppression	-0.50 (1.45)			
Surgency			4	3.02^{*}	0.20
	Infant Surgency	$-3.22\ (1.38)^{*}$			
	Infant Suppression	-1.26 (0.93)			
	Mother Age	0.20 (0.13)			
	Surgency X Suppression	1.05 (2.08)			
II. Father					
Anger			4	3.53^{*}	0.23
	Infant Anger	$-2.25\ (0.90)^{*}$			
	Infant Suppression	-0.27 (0.99)			
	Father Age	$0.23\ (0.10)^{*}$			
	Anger X Suppression	0.77 (1.83)			
Fear			4	1.82	0.13
	Infant Fear	-0.31 (1.17)			
	Infant Suppression	-0.84 (0.92)			
	Father Age	$0.26\ (0.10)^{*}$			
	Fear X Suppression	-0.68 (2.27)			
Surgency			4	2.48^{T}	0.17
	Infant Surgency	-1.64 (1.21)			
	Infant Suppression	-1.35 (0.98)			
	Father Age	$0.24\ (0.11)^{*}$			
	Surgency X Suppression	-0.98 (1.23)			

Note: Parent age was included as a covariate. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{T}p < 0.10$

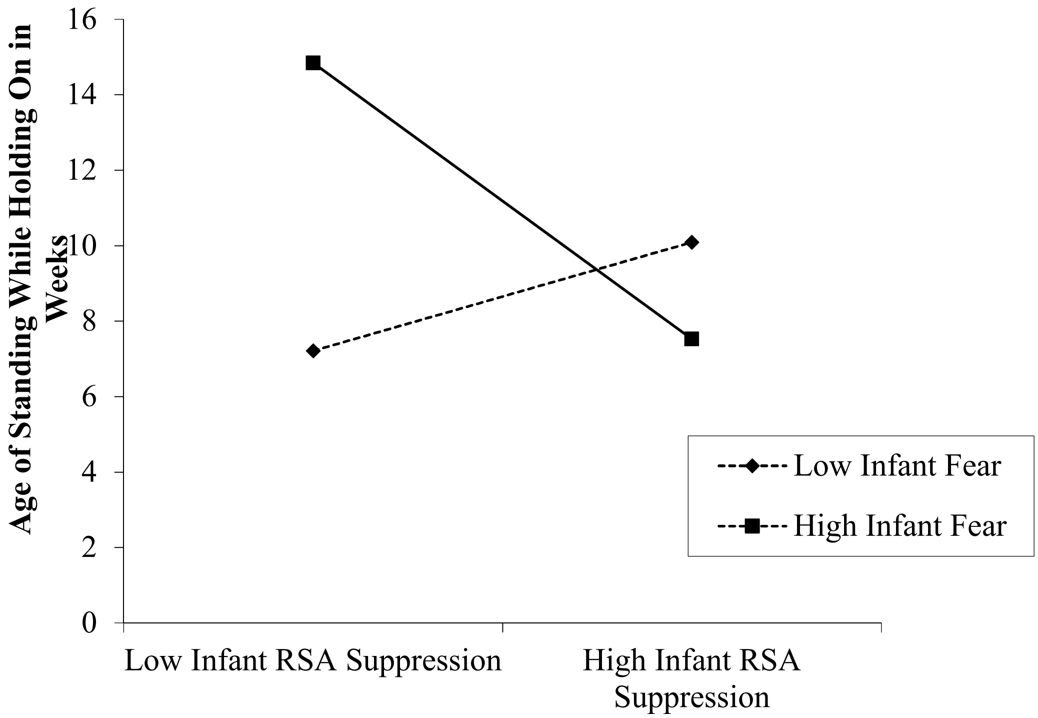

Figure 1. Infant Fear X RSA Suppression Predicting Infant Age of Standing While Holding On in Weeks

For father-infant regression models involving infant RSA suppression (n = 53), a significant main effect of anger (B = -2.25, SE = 0.90, p = 0.02) was found to predict crawling (See Table 6). Such that infants with increased anger achieved crawling at an earlier age. There were no other significant findings for the father-infant models.

DISCUSSION

The current study expanded on previous work by examining the effects of infant temperament and cardiac physiology on infant locomotion. Specifically, how both infant temperament and cardiac physiology are associated with the promotion or delay of the age at which infants begin to pre-crawl or crawl. As hypothesized, there were differences in infant cardiac physiology depending on infant temperament leading to the development of locomotion. Specifically, significant results were revealed for mother-infant models with infant baseline RSA. Furthermore, significant results were revealed for both mother-infant and father-infant models with infant RSA suppression. Overall, there was only one significant finding for pre-crawling as the majority of significant results were with crawling.

The Role of Infant Anger in Locomotion

Findings involving infant anger were consistent with previous work. More specifically, previous research has discovered that infant anger promotes infant crawling (Pemberton Roben et al., 2012; Hendrix & Thompson, 2011; Whitney & Green, 2011). Consistent with Hypothesis 1, the present study found a significant main effect of infant anger predicting crawling, such that as infant anger and baseline RSA increased age of crawling decreased with mothers. Previous work has shown that higher baseline RSA is associated with increased negative reactivity. Specifically, Beauchaine (2001) discussed how high RSA is associated with increased reactivity such as anger. Furthermore, previous work has identified that increased anger expression is observed at the onset of crawling (Pemberton Roben et al., 2012). Considering the connection between increased baseline RSA and anger, it is not surprising that results were found to promote crawling.

Similar to findings involving baseline RSA, the infant RSA suppression models revealed a significant main effect of anger predicting infant crawling. However, this significant effect was only for father-infant models. There were no significant findings for infant RSA suppression or infant anger with mother-infant models, which was surprising. The majority of previous work has examined mother-infant interactions and RSA suppression, finding that infant RSA decreased from SFP to baseline (Moore et al., 2009). Furthermore, infants with higher anger have been shown to have greater RSA withdrawal (Moore, 2009). Little work has looked at father-infant dyads with cardiac physiology. However, based on the current finding's differences between mother-infant and father-infant dyads need to be further explored with RSA suppression.

The Role of Infant Surgency in Locomotion

Similar to findings involving infant anger, infants with high surgency crawled at a younger age (Hypothesis 3). More specifically, significant main effects of surgency were revealed across both sets of mother-infant models: baseline RSA and RSA suppression. Previous work has found that increased surgency is also associated with increased anger (He et al., 2013; Stifter et al., 2010). Children with high surgency have been shown to have increased activity level (Stifter et al., 2010) suggesting that the infant would be more likely to crawl at a younger age. Considering these similarities in the mechanisms through which anger and surgency might be associated with infant locomotion, it is not surprising that similar findings were revealed for both sets of models.

However, it was rather unexpected that father-infant models had no significant findings. Since fathers are typically more active with children in toy and physical play than mothers (George, Fletcher, & Palazzi, 2017). It would be expected that infants with higher surgency would engage in more play with fathers. However, fathers do become more involved as infants age (George et al., 2017), so perhaps this lack of findings could be due to the study focusing on early infancy. In addition, infant surgency in the context of father-infant dyads has rarely been examined in previous research (Stifter, Putnam, & Jahromi, 2008). Future work should explore infant surgency during play interactions with fathers, as well as examine whether fathers promote locomotion.

The Role of Infant Fear in Locomotion

Only a significant main effect of infant baseline RSA was revealed in the infant-mother model including infant fear. More specifically, it was found that as infant baseline RSA increased, infants crawled at an older age. This is counter to what was hypothesized; increased infant baseline RSA coupled with increased fear would result in a younger age for crawling. This was predicted because fear responses can promote locomotion (Braungart-Rieker et al., 2010).

However, a significant infant fear X RSA suppression interaction predicted pre-crawling (e.g., standing while holding on) with mothers. Specifically, as infant fear and RSA suppression increased the infant stood while holding on at an earlier age. The finding is inconsistent with Hypothesis 2, which expected that high infant fear and low RSA suppression would be associated with pre-crawling at a later age. This result is also the opposite of what was seen with infant baseline RSA, further suggesting that there are differences between infant RSA suppression and baseline RSA. It is possible that these findings could be due to the mechanisms through which fear is associated with locomotion. Specifically, that the association between fear and cardiac physiology is affecting the way infant locomotion is expressed. Further, there could be more underlying factors associated with infant locomotion affecting infant temperament and cardiac physiology.

Fear is known to be associated with the fight or flight response, promoting either locomotion towards or away from a fearful stimulus (Adolph, Kretch, & LoBue, 2014). During times of threat, infants might experience dysregulated fear, which might be translated into being unable or unwilling to crawl (Buss et al., 2018) or pre-crawl. In fearful or ambiguous situations, infants might also turn to caregivers for comfort (Braungart-Rieker et al., 2010). Previous work has shown differences in mothers and fathers in regard to their responses to fearful infants. Mothers are more protective and responsive to their infant’s emotion during a fearful situation than fathers (Kochanska et al., 2004). Infants in this study are in the phase of attachment in the making, during which they are developing expectations of how their caregivers will respond to them (Tracy, Lamb, & Ainsworth, 1976). This may result in infants in this age period knowing that mothers will provide security and comfort during a fearful situation. Future studies should further examine the processes through which infants might respond differently to mothers and fathers during a fearful situation and how this relates to infant locomotion.

Study Limitations

Overall, these findings suggest that differences in locomotion are associated with infant temperament and infant RSA (baseline and suppression). Specifically, with crawling the results suggest that infant anger and surgency promote infant independence through full mobility. Furthermore, pre-crawling seems to be affected by different factors than crawling. This suggest that infant locomotion is complex, and more work needs to be done to further expand the underlying predictors of infant locomotion.

The differences in pre-crawling and crawling can also be attributed to mother-infant and father-infant dyads. There was a lack of findings for father-infant baseline RSA models, but increased father-infant RSA suppression findings. The opposite is true for mother-infant dyads. It is clear that differences in parent-dyads affect infant locomotion. Possibly baseline RSA models were significant for mother-infant dyads because it is similar to a natural mother-infant interaction. Fathers are less likely to partake in a caregiving task (Forbes et al., 2004) in which infants sit in their laps which could result in less significant findings during baseline. Further, more results could have been revealed for father-infant dyads during RSA suppression because this simulates a more interactive or play scenario in which fathers are typically more involved (Forbes et al., 2004).

To further explore the differences in parent-infant dyads with infant pre-crawling and crawling, future studies should expand the sample size. Specifically, researchers should include a diverse population to maximize the generalizability of the results. The current sample has variability amongst income, education, and race; however, many families that choose to participate in research studies differ from families that do not participate. The current study did not find significant differences from families that participated at all time points from families that did not; however, there could still be differences between families that participated at any time point from those that did not participate at all. Due to the current study being correlational, causal claims cannot be made. Furthermore, future studies should include infants that did and did not complete each milestone. The current study only included infants that completed the milestone; therefore, differences between infants who did not complete the milestone were not examined. Future studies should not only look at the age of milestone completion but also whether the milestone was achieved.

Another limitation of the current study is the last laboratory visit was at 8-months old. Between the second laboratory visit at 6-months and the last visit at 8-months many infants are just beginning to crawl. However, infants that have slight delayed motor development would not be captured at the 8-month visit. Locomotion development varies among infants as there is not an exact time at which every infant begins crawling, but crawling is typically achieved between 6-months and a year old (Adolph, 2008). Therefore, future studies should expand the longitudinal study such that the last visit is at a year old. This would allow more infants to achieve crawling and could result in more significant results for mother-infant and father-infant dyads. Furthermore, fear has been shown to develop around 8-months but is more likely to develop later. By delaying the last visit fear would be fully established in infants resulting in potentially more significant results.

The last set of limitations involve the parent-report measures (e.g., infant milestones and infant temperament). Although parent report has been shown to be a relatively valid assessment of child functioning, parent report is only modestly correlated with laboratory measures (Gartstein & Rothbart, 2003). Future studies should include more objective laboratory measures of locomotion (Pemberton Roben et al., 2012). One way to assess locomotion within the laboratory is through the inclusion of a pediatric

Physical Therapist who could assess infant motor development. This is important as many parents have varying interpretations of each milestone and the time at which their infant completed the milestone. With parent report there could also be desirability bias as parents might not admit that their infant is not completing a milestone the infant should be. In addition, future studies should also include laboratory assessments of infant temperament. Including infant temperament as a coded assessment by trained research assistants would strengthen the results.

Implications and Conclusions

The current study has implications for future research and intervention planning. Future research needs to further examine the effect of infant temperament on infant locomotion. Specifically, how early can infant temperament predict the age at which an infant can pre-crawl or crawl. Furthermore, more work needs to be done to further determine how cardiac physiology and infant temperament interact to predict locomotion.

The current study found associations between infant anger and surgency with crawling. Future research can further explore how early infant temperament and cardiac physiology are associated with the age of infant locomotion. Intervention planning for children that are potentially at risk for delayed motor development is possible with more research. More specifically, screenings could be developed to help researchers determine if the child is at risk for motor delay based on their temperamental reactivity and cardiac physiology. Furthermore, prevention programs can be developed to help prevent locomotion delay. Addressing the topic of motor delay can be a tough situation as many parents do not want to find out their child is at risk; however, finding the underlying factor prohibiting infant locomotion early on could result in better developmental outcomes for the infant later in life. A potential intervention plan could include taking the infant to a physical therapist or occupational therapist. Parents could also be taught various activities that would help promote locomotion such as holding a toy just outside of the infants reach, therefore requiring the infant to move in order to get the desired toy.

Early intervention planning for children with potential motor delay could drastically change the infant's life as achieving milestones early results in implications for future development. Specifically, infants and children who develop motor skills earlier in life are more likely to continue to be active and move throughout their childhood (McMillan et al., 2019; Telama, 2005). Telama et al. (2005) also found that high activity levels in older children (e.g., age 9 to 18 years of age) predicted high adult physical activity. As previous work has shown, infant locomotion is associated with several developmental outcomes in later childhood and adulthood (McMillan et al., 2019; Telama et al., 2005). Early motor development across infancy and early childhood leads to several implications for future cognitive, language, and motor development.

Overall, the current study examined infant temperament and cardiac physiology as predictors of infant locomotion. Results revealed that infant temperament and cardiac physiology affect the age at which an infant begins pre-crawling or crawling. This study was a step in the right direction, but future works need to further examine the implications of locomotion. In sum, the study indicates the importance of examining underlying factors that affect a major milestone in any individual's life: locomotion.

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