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Attachment, Vagal Tone, and Co-regulation During Infancy

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ABSTRACT

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This study examined the development of attachment as it relates to co-regulation and vagal tone over the second half of the first year of life. Links to infants' attachment and developmental status were also examined. Symmetrical and unilateral co-regulated patterns of interactions at 6 months demonstrated significant linkages with attachment. Developmental status did not show direct linkages with attachment. Direct links between vagal tone and attachment were also not identified. Correlations between co-regulation and vagal tone at the 6 month time point were identified. Findings suggest an important role of co-regulation as it relates to attachment development. Future studies may benefit from evaluating the role of co-regulation as a mediating variable between vagal tone and attachment development.

Keywords: vagal tone, co-regulation, infancy, attachment

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Affectional bonds developed between individuals, is the foundation of attachment theory (Bowlby, 1969; Bretherton, 1993). It is thought that human attachments play an important role by providing individuals feelings of safety and security through supportive relationships. These relationships are then thought to serve as an important context for developing other important interpersonal skills (van IJzendoorn, 1995; Sroufe & Waters, 1977; Ainsworth, 1978). Individuals with a history of secure attachment, or the belief that others will consistently respond to meet their needs, typically perform better emotionally, socially, scholastically, professionally, and tend to thrive in inter-personal relationships (Ainsworth, 1978; Moss & St- Laurent, 2001; Hazen & Shaver, 1990; Lieberman, 1977).

It is thought that a history of interactions that lead to the formation of an attachment may serve an important role in organizing infants' behaviors, particularly with respect to the infant's regulatory abilities. Some have argued (Pipp & Harmon, 1987) that the interactional history that leads to attachment may play an important role in the development of children's biological organization as well (e.g., Meaney, 2010). The current study is designed to address whether the interactional history between a mother and her child influence the organization of the child's physiological regulation and subsequently, the child's attachment organization. Or conversely, does the child's physiological organization influence his ability to engage with his mother that then leads to differing attachment organizations? I will begin a discussion of these issues by first overviewing the basic principles of attachment theory. I will then examine the environmental and physiological variables that contribute to attachment development and provide a literature review of the work previously completed. Finally, I will present a theoretical model to evaluate the interdependent contribution of dyadic interactions and physiology on attachment. The paper will conclude with results and discussion that delineates the neuropsychological foundations of attachment.

Overview of Attachment

Starting in the 1950s, John Bowlby advanced a theoretical framework about the psychological importance of relational connections between individuals, particularly between parent and child (Bowlby, 1951; 1969; 1988). In essence, Bowlby believed that establishing an emotional attachment between infant and caregiver is just as vital for positive developmental outcomes as it was to have access to sufficient food or shelter. Early in his career, Bowlby noticed theoretical inconsistencies with other scholar's conclusions, which suggested that individual wellbeing was more than solely having physical needs met (i.e. food and shelter) (Cassidy & Shaver, 1999). Specifically, he incorporated constructs gleaned from ethological work demonstrating behavioral systems that emerged in animals to seemingly keep offspring in close proximity to mature, and nearby protective adults to help promote their survival (e.g. Lorenz, 1935). He was also influenced by the work of Harlow (1958) who found that infant rhesus monkeys preferred the company of surrogate "mothers", or an object covered in cloth and made to look like a monkey, more than they preferred a wire-mesh "mother" which provided food but no "contact comfort." Harlow's work suggests that immature primates need more than just food to derive security from their immediate context. Based on this work, Bowlby believed that ideal development extended from affectionate, warm bonds found in supportive relationships in addition to a relationship that provided the basic needs of food and shelter (Ainsworth, 1979; Beijersbergen, Juffer, Bakermans-Kraneburg, & van IJzendoorn, 2012).

In this early work, Bowlby began to combine several theoretical strands together including systems theory, evolution, ethology, and psychoanalytic constructs to devise his attachment framework. Central to his thinking was the important role of behavioral control systems that were designed to help infants maintain close proximity to mature, nurturing, and protective adults while also balancing the child's needs for exploration. Bowlby believed that these behavioral control systems emerged in the context of an interactional history between the child and his caregiver. An optimal relational history that was marked by sensitivity, warmth, engagement, and responsiveness on the part of caregivers towards the child, were thought to signal to the child the adult's psychological and physical availability. These parent-child interactive behaviors are often coordinated in the face of what Bowlby called "attachment behaviors" (e.g., signaling behaviors such as crying, reaching or smiling, proximity and contact seeking behaviors, following behaviors, etc.). Attachment behaviors are often exhibited on the part of the child and directed toward an attachment figure whenever the child feels threatened or at risk, such as during brief separations from the caregiver. Such threats are thought to activate the behavioral control system (a series of attachment behaviors) that can then get the child in close proximity to a caregiver who then can help coordinate their behaviors in such a way to help soothe and comfort the child.

Over time, relationship patterns begin to emerge that are centered on these attachment behaviors and the caregiver's response to them. If there is optimal coordination of these behaviors, Bowlby believed that the child would begin to perceive the adult as being "available" to them and learn to trust the relationship and feel secure in the presence of this "attachment figure." If the child did not perceive the adult as being available to them, because of inconsistency, insensitivity, or lack of nurturance or warmth, then the child may begin to feel insecure in the presence of this adult. Bowlby further argued that felt security would then provide a foundation from which the child could engage in exploratory behaviors, potentially leading to greater exploration within a secure relationship or decreasing exploration in an insecure relationship, ultimately influencing the child's opportunities to develop a number of developmental competencies (Bowlby, 1982).

Working with Bowlby, Ainsworth expanded the attachment construct by building on the concept of a "secure base" and creating a classification system for attachment styles (Ainsworth & Bowlby, 1965; Ainsworth, 1967; 1979; Ainsworth, Blehar, Waters, & Wall, 1978). A secure base is described as someone whom the child references for support should he become frightened, but who simultaneously provides confidence for the child to explore his environment—knowing there is someone to retreat to at any time.

Growing out of her longitudinal work that tracked the relational history of mothers and infants, Ainsworth went on to develop a lab analog that allowed her to observe caregivers and infants' in an increasingly "distressing" context (Ainsworth & Wittig, 1969). This paradigm, known as the "strange situation" was designed to activate the behavioral control system and provide a window for observing the child's attachment behaviors in the presence of mothers and strangers. Ainsworth believed that by contrasting the child's attachment behaviors in the presence of mothers and strangers, we could learn something about the child's attachment organization, specifically if they responded to mothers differently than strangers.

Ainsworth's classification system identified three attachment styles: secure, avoidant, and resistant (Ainsworth, et al., 1978). A child who is classified as having a secure attachment will feel safe exploring his environment and interacting with strangers, but will often become visibly upset when the mother leaves the room. Strangers can typically soothe a securely attached child, because he or she feels safe to trust the individual until the primary caregiver returns. However, if the mother is not present in the room, the child will be less likely to interact with strangers given that the mother plays the role of a secure base. Upon the return of the mother, baby will typically express excitement or positive emotion; receiving the mother immediately and may cleave to her person. These behaviors are thought to suggest an acknowledgement of the return of someone whom the child can trust and look to for continuous support.

Children who are classified as having avoidant attachment styles will typically act indifferent to mother whether or not she is present in the room (Ainsworth et al., 1978). These children demonstrate higher levels of independence and often do not orient their security toward any one person. This active avoidance of the attachment figure suggests that the presence of their mother holds little significance, but rather a stranger may be just as likely to meet their needs. This commonly occurs in cases of neglect, or when the adult is viewed as fear arousing or over stimulating when a child has lost the majority of trust for a parent to provide necessary nurture and support. Well-intentioned but overwhelmed or withdrawn parents may also encourage the development of avoidant attachment within their child if the primary caregiver is not able to consistently provide sufficient support to meet the child's needs, and the child is instead left to care for himself (Sroufe, 2005).

Lastly, resistant children often demonstrate conflicting emotions such as the desire to be exploring when the mother is holding him or her, and the desire to be held when the mother is allowing exploration (Ainsworth et al., 1978). Resistant attachment typically develops as a result of a long history of inconsistent support from a primary caregiver (i.e. mothers who are able to support children in some instances, but often fail to show sufficient warmth or responsiveness at other times). It is thought that resistant children desire closeness and support from mother, but have repeatedly not been able to access her affection. In short, it is suggested that resistant attachment occurs when a mother is responsive, but only on her terms and timetable. Thus, the child is not neglected but his requests are not necessarily honored as desired. When examined in the strange situation, caregivers with resistant attached children are typically greeted with frustration or resentment from their child—expressing a hesitancy to trust because of mother's unreliable interactions and the simultaneous need for her love and support.

Interestingly, in addition to the outward differences of behavior among children according to their attachment style, previous work has also demonstrated differential patterns of heart rate activity among children with differing attachment types (Sroufe & Waters, 1977). For instance, securely attached children typically have an increase in heart rate during the absence of their primary caregiver which recovers quickly when mother returns (less than a minute) suggesting the reassurance and comfort found from mother's presence. Avoidant children tend to show high levels of physiological arousal and take longer to calm physiologically following a separation episode than a securely attached child. This may suggest that even though avoidant children look well regulated on the outside, they may actually be internalizing their reactivity because they do not see their caregiver as one they can trust to help calm them down. Resistant children experience more difficulty to return to a homeostatic state when reunited with mother. Children with a resistant attachment experience an increase in heart rate upon the separation from mother, similar to children with different styles of attachment. However, resistant children, when reunited with mother, do not experience a decrease in heart rate for an extended period of time in contrast to securely or avoidant attached infants.

The developmental significance of the attachment relationship has been the focus of a burgeoning research tradition over the past three decades. For example, Schore (2001) and Ainsworth (1979) both found that children with a secure attachment demonstrate better outcomes both socially and cognitively than children with insecure attachments. Developmentally, the early stages of life are critical for establishing the quality of attachment a person will maintain throughout life (Bowlby, 1980). An individual, who as a child experiences warm and responsive relationships, is more likely to develop a positive internal working model, or the set of expectations and beliefs someone maintains about relationships that is thought to carry into the future (Bretherton & Munholland, 1999; van IJzendoorn, 1995; Bretherton, Ridgeway, & Castleton, 1990; Cassidy & Shaver, 1999). It is for this same reason that if an individual receives unreliable or insufficient support as a child, it is likely that he or she may experience poorer developmental outcomes, including poorer relational skills and individual competencies (i.e. regulatory abilities).

From an emotional perspective, children who establish secure attachments during infancy are much more likely to display positive personality traits, be well liked among their peers, and are less likely to report social anxiety (Bohlin, Hagekull, & Rydell, 2000). Furthermore, infants who manifest a secure attachment demonstrate higher levels of emotional intelligence, or the ability to understand and respond to both positive and negative emotions during childhood (Steele, Steele, Croft, & Fonagy, 2001). Easterbrooks, Biesecker, and Lyon-Ruth (2010) also found that children are more likely to be involved with family members and show higher levels of responsiveness when secure attachment is developed during infancy. Additionally, past research has suggested that parent-infant relationships serve as an important context for both the modulation of emotional and physiological arousal and the development of regulation (e.g., Field, 1981; Gable & Isabella, 1992; Izard & Ackerman, 2000; Tronick, 1989). Working from an attachment perspective, Cicchetti, Ganiban, and Barnett, (1991) have argued that differences in the quality and patterning of parent-infant relationships may well “reflect different styles of emotion regulation that have developed out of the children’s history of distress remediation and emotional synchrony with their caregivers” (p. 27). As a result, it is believed that the history of emotion modulation serves to influence the development of either regulation or dysregulation.

Since attachment is believed to influence an individual’s physiological regulation and consequent emotional regulation capabilities, it may be important to consider the way these factors (patterning of parent-infant relationships and infants regulatory abilities) work together to influence each other.

Relational Histories and Attachment

While attachment is thought to be a relational construct, meaning that the behaviors of both members of the partnership contribute to the creation of an attachment, past research has commonly emphasized three main *parenting* constructs when discussing the development of attachment, namely maternal warmth or sensitivity, responsiveness, and engagement. Most times these behaviors are described in the absence of the infant's contribution to the mother's behaviors or by examining the individual contributions of each partner somewhat independently. This focus often highlights the problematic nature of the way past research has conceptualized the interactional history of mothers and infants in relation to the formation of attachments with most of the focus being placed on the role of maternal behavior independent of the infant's contribution.

Still, past research has helped to establish a foundation for understanding factors that contribute to mother-infant relationship history. As such, it is important to overview these constructs to help set up a comparative approach to studying the mother-infant relationship history that also accounts for the infant's contribution.

First, maternal warmth has often been defined as showing love, gentleness, affection, comfort, or interest on behalf of a child's well-being, while attending to a child's needs (Lee, Altschul, & Gershoff, 2013; Rohner, 2004). Put another way, this warmth is the caregiver's personal concern for a child who is in need of support, or the ability to show care in a gentle manner as opposed to being angry, impatient, or upset. Wolff and van IJzendoorn (1997) meta-analysis found direct effects between children's attachment styles and amounts of maternal warmth. Specifically, maternal warmth predicted infants who were more securely attached while lower amounts of warmth typically resulted in insecure outcomes. In addition to warmth, attachment scholars have also examined the construct of maternal responsiveness. Maternal responsiveness refers to the primary caregiver's ability to consistently recognize and act on infant cues for support (Karl, 1995). While warmth indicates the disposition of the parent while caring for a child, responsiveness is the amount of consistency a parent is able to show in meeting the needs of the child (i.e. recognizing and fulfilling the need a child has to eat or be held). A third parenting construct commonly examined in the literature is maternal engagement. Maternal engagement primarily refers to the parent participating in shared activities with the child in a manner that helps promote trust between the two individuals. This may be expressed in the form of facial-visual interactions or play interactions (Beebe & Gerstman, 1980). It is believed that when consistent patterns of warmth, responsiveness, and engagement are present, a mother is most likely to form a secure attachment with her child. Said another way, a healthy attachment is typically developed for children whose mothers are able to demonstrate competent levels of care both physically and emotionally.

Although warmth, responsiveness, and engagement are often referred to as primarily the mother's responsibility, the mother is not the only individual who enables the establishment of a secure attachment from an environmental perspective. The child is a contributor whose behavior also enables or inhibits secure attachment development. From the perspective of warmth and responsiveness, children are responsible for demonstrating trust and reciprocity as a result of mother's care (Darling & Steinberg, 1993; Maccoby & Martin, 1983; Parpal & Maccoby, 1985; Drake, Humenick, Amankwaa, Younger, & Roux, 2007). In this way, warmth and responsiveness are one side of an elaborate equation when it comes to producing the desired outcomes of trust and reciprocity in the parent-child relationship. For example, maternal warmth is associated with fewer defiant behaviors in children (Stormshak, Bierman, McMahon, & Lengua, 2000). Good behavior demonstrated by a child perpetuates trust in the parent-child relationship and consequently strengthens the attachment present. It may be logical to conclude that trust and reciprocity are enablers of secure attachment. Unless a child is able to demonstrate these behaviors in return, a secure attachment will have a difficult time taking root. Children are equally important contributors to the establishment and maintenance of secure attachment.

Maternal engagement, a third component of secure attachment, also requires child reciprocity. The definition of engagement from a relational viewpoint suggests the need for at least two contributing parties, whether relating to a parent-child relationship or a different type of interaction. It is not possible for one individual to be engaged socially with another individual, without the reception of him or her. Maternal engagement is also a mechanism for promoting trust within the parent-child relationship. The presence of trust may promote the maintenance of a secure attachment more than most other factors. An example of maternal engagement involving both individuals may be a mother trying to play a game with her child. Unless the child's attention is captured and he or she is willing to respond in a harmonious, synchronous, and reciprocated fashion, trust between the parent and child cannot be established and the attachment is left undeveloped. Maternal engagement requires willingness from both partners involved in the interaction.

Parenting components of maternal warmth, responsiveness, and engagement were among the first to be considered and continue to receive significant focus with respect to the parent's role in the formation of an attachment (Bowlby, 1969; 1988; George, Solomon, & McIntosh, 2011; Evans & Porter, 2009). The mother-infant relationship has been the primary environmental component linked to attachment outcomes and requires sufficient amounts of warmth, responsiveness, and engagement from both individuals in order to establish and maintain a secure attachment with the child.

Co-regulation. While maternal behaviors are no doubt an important contributor to the organization of a child's attachment, it is only one side of the story. Mothers *and* infants both contribute to the creation of a new relationship as part of dynamic interpersonal processes over time. Fogel (1994) introduced an alternative way to conceptualize the role of both partners when it comes to measuring relational histories. Fogel called this construct co-regulation. Co-regulation can be defined as, “a social process by which individuals dynamically alter their actions with respect to the ongoing and anticipated actions of their partners” (Fogel, 1993, p.34). This process elaborates upon the forms of coordinated action between participants, specifically mothers and their infants and involves a continuous mutual adjustment of actions and intentions (Fogel & Garvey, 2007). In this sense, both partners are influenced by one another as a result of anticipating the cues and body language of one another and consequentially modifying their communication within the framework of the interaction.

Fogel (1994) developed a coding system to capture co-regulated communication patterns. This coding system incorporates five patterns of co-regulation, which include symmetrical, asymmetrical, unilateral, disruptive, and unengaged patterns (Fogel, 1994). Symmetrical co-regulation is described as a fluid, dynamic communication between mothers and infants that captures their ability to engage in a joint activity while nonetheless appropriately anticipating one another’s emotional cues and responses. An example of this may be a mother and baby actively engaged in singing a song together while coupling specific hand gestures or facial expressions with the lyrics (i.e. the familiar nursery rhyme “Patty Cake”). In order for the interaction to demonstrate symmetrical co-regulation, the child does not necessarily have to match the mother, especially in the case of a young infant, but the child would be carefully following mother’s gestures and likely cooing or smiling in return. The child would be participating as much as he is able given their developmental status.

Asymmetrical interactions are classified by both partner’s giving their full attention to the activity being completed, but only one partner is participating while the other is observing (Fogel, 1994). Referring back to the example of playing “Patty Cake” with a child, the mother may be singing the lyrics while the child only observes the mother and acknowledges she is singing a song, but does not reciprocate behaviors or join in the process in any way.

Third, unilateral interactions indicate a situation where one partner is watching or communicating with the other partner, without deference to the activity the other partner is engaged in (Fogel, 1994). As an example of this, a child may acknowledge the mother is present and giving him attention, but completely ignores the gestures or behaviors the mother is demonstrating.

Lastly, disruptive co-regulation occurs when one partner neither gives attention to nor acknowledges, but also interrupts the activity of the engaged partner. An example of this would occur when a child interrupts mother as she is singing to the child or attempting to play "Patty Cake" and sends a cue for her to stop engaging in the behavior entirely. As a final note, unengaged behaviors suggest interactions where little or no co-regulative interaction occurs. Environmental components of the parent-child relationship provide significant insight to the development and maintenance of secure attachment. In addition to environmental factors, physiology is believed to contribute to attachment development and maintenance.

Physiology and Attachment

Earlier research has examined the developmental impact of early social relationships and has demonstrated links between relationship features and biological organization in offspring.

For instance, Hofer's (1994) research with rats has shown that interactions in the mother-pup relationship provide a context for developing biological regulation. Hofer argues that the evolutionary imperative for the development of mother-infant relationships may not necessarily be for protection from predators alone (e.g., Bowlby, 1969/1982), but also for the development of biological regulation. Similarly, Pipp and Harmon (1987) have suggested that early human relationships help promote homeostatic regulation. They go on to suggest that early relationship features, particularly the history of emotional responding and regulation, may influence the biology of the infant that then influences behavior across the life span.

These notions appear supported by prior research examining mother-infant interactions and infant physiological regulation. For instance, Field (1981) has examined the use of infant gaze in mother-infant enface interactions and found increasing patterns of sympathetic arousal (increasing heart rate) with direct face-to-face gazes and decreasing patterns of arousal when gaze was broken. These findings possibly suggest that a sustained history of interactive sensitivity to infants' arousal/regulatory needs may influence the emergence of later emotional and physiological regulatory abilities.

Not surprisingly, other physiological markers are gaining increasing attention in relation to attachment outcomes. For example, physiological indicators such as heart rate have been collected from individuals and compared against attachment outcomes (Zelenko et al., 2005; Willemsen-Swinkels, Bakermans-Kranenburg, Buitelaar, van IJzendoorn, & Engeland, 2000; Sroufe & Waters, 1997). These studies further discuss heart rate patterns upon a baby being separated and reunited with mother and suggest that children with secure attachment recover a homeostatic state in less time than insecurely attached peers. Additional studies have focused on constructs such as temperament (Sroufe, 1985, Belsky & Rovine, 1987) and genetics (Bokhorst, Bakermans-kranenburg, Fonagy, & Schuengel, 2003; O'Connor & Croft, 2001). Studies evaluating temperament suggest a controversial relationship with attachment with some studies showing strong linkages and others finding no relations with attachment (e.g., Sroufe, 1985; Belsky & Rovine, 1987). Geneticists have also evaluated the relationship between monozygotic and dizygotic twins and attachment outcomes—and thus far have found only negligible data to support linkage between the genetic-attachment interaction (Bokhorst, Bakermans-kranenburg, Fonagy, & Schuengel, 2003; O'Connor & Croft, 2001). Thus, physiological indicators are gaining increasing attention despite the varied results.

Polyvagal Theory. Another area that is gaining attention is the neurophysiological perspective which focuses on the relationship the nervous system has with both psychological and physiological functioning (Porges, 2011). Porges' Polyvagal theory discusses the influence of the nervous system on an individual's ability to regulate a broad number of behavioral systems including social, emotional, and behavioral systems (1994; 2011; Porges, Doussard-Roosevelt, & Maiti, 1995). It is likely that the same types of behavioral interactions that help to promote optimal attachment outcomes might also provide an important developmental context for developing biological regulatory abilities as well. These behavioral and physiological systems have the potential to feed off of each other. For example, when an individual has a strong ability to regulate his or her emotions, the individual will more likely be consistent in relationships with others. When faced with higher levels of stress or anxiety, an individual with strong emotional and physiological regulatory abilities will likely be better able to cope with negative emotion and continue to sustain interactions that promote the formation of healthy relationships.

However, research that has examined the links between physiological markers and attachment outcomes have been somewhat mixed. For instance, Izard et al. (1991) found a direct link between heart-rate variability and insecure attachment outcomes. Infants who demonstrated higher levels of heart-rate variability (HRV) typically had more insecure attachment outcomes. HRV is one potential marker of the way the physiological system of the individual is organized. However, HRV can be caused by a number of competing neurophysiological systems, including respiration, movement, psychological states, and baseline levels of heart rate activity. To more carefully pinpoint the role of physiology on individuals' behaviors, Porges has developed a measure of heart rate variability that captures the contribution of the parasympathetic branch of the nervous system, the branch primarily responsible for regulating arousal states and maintaining homeostasis. Porges calls this construct vagal tone. To date, few studies have examined direct links between vagal tone and infants' attachment status. This study was designed, in part to fill this gap in the literature. Porges, Doussard-Roosevelt, and Maiti (1994) described vagal tone as, "a measurable organismic variable that contributes to individual and developmental differences in the expression and regulation of emotion" (pg.2). In other words, vagal tone is a method for evaluating the activity of the vagus nerve—the tenth cranial nerve located in the medulla oblongata of the brainstem and a key component to the parasympathetic nervous system which helps to regulate emotion (Diamond, Fagundes, & Butterworth, 2012). Typically, infants who demonstrate higher levels of baseline vagal tone functioning or who engage in higher levels of vagal tone functioning after particularly stressful experiences, have been shown to demonstrate higher levels of emotional regulation (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996). Thus, by evaluating the functioning of an infant's vagus nerve through the assessment of vagal tone, indication of the infant's ability to regulate emotion can be obtained. These regulatory abilities may assist infants in sustaining or even prolonging interactions with a partner and subsequently contribute to more optimal patterns of co-regulated states with their attachment partner. In this way, Polyvagal Theory may be useful framework for explaining the neurophysiological development of attachment.

As a result of the influence of both environmental and physiological systems researchers are starting to suggest that attachment develops through a complex interaction, rather than a mutually exclusive source of environmental inputs (Bates, Maslin, & Frankel, 1985; Carleton & Padolsky, 2012; Freeman, 2011; Gunnar, 1989; Keller, 2013; Luijk et al., 2010; Porges, 2011). By illuminating the interdependent relationship between nurturing behaviors as part of a complex co-regulation system as well as the child's own behavioral and physiological contributions, researchers can perhaps provide a more comprehensive understanding of the factors that contribution to the organization of attachment in early childhood.

In contrast to previously completed work, the current paper intends to evaluate Polyvagal Theory with an infant sample as opposed to an adolescent age group previously examined (Diamond, Fagundes, & Butterworth, 2009) by assessing the relationship between infant cardiac vagal tone and attachment outcomes. It is thought that baseline vagal indicators will provide insight to the level of parasympathetic activity occurring in infants, thus demonstrating the level of emotional regulative abilities possessed by the infants during the first year of life.

Research Questions and Hypotheses

The current paper examines contributions of co-regulated interactive states in mother-infant dyads and infants' physiological capacity to regulate (vagal tone) in connection to the infants' attachment status.

Past work (Evans & Porter, 2009) has demonstrated direct relationships between co-regulation and attachment. Specifically, Evans and Porter (2009) found that symmetrical co-regulation measured at 6-months was directly related to secure attachment when infants were 12-months of age. In other words the more frequently a mother is able to symmetrically co-regulate with her infant, the greater the likelihood that she and her child will develop a secure attachment.

Currently, research that examines the relationship between vagal tone and attachment outcomes is very limited especially regarding the mother-infant relationship. However, Diamond, Fagundes, and Butterworth (2012) examined the vagal tone and attachment relationship in the mother-adolescent relationship and found that secure attachment was related to higher levels of vagal tone functioning. This study suggests a possible linkage between vagal functioning and attachment outcomes during infancy as well, despite that this specific age group is yet to be examined.

From a neuropsychological viewpoint, Porter (2003) found a direct link between vagal tone and levels of co-regulation. Higher levels of symmetrical co-regulation were linked with higher levels of cardiac vagal tone, while asymmetrical interactions were negatively related to vagal tone outcomes. This indicates that co-regulation may be linked to vagal functioning, which is in turn related to emotional regulation abilities, however; no path model analysis has occurred to demonstrate this possibility. Furthermore, children who engage in more symmetrical patterns of co-regulation may also demonstrate higher levels of sustained attention, which fosters trust and the secure attachment between mother and child. Figure 1 provides a theoretical model based on the previously completed research:

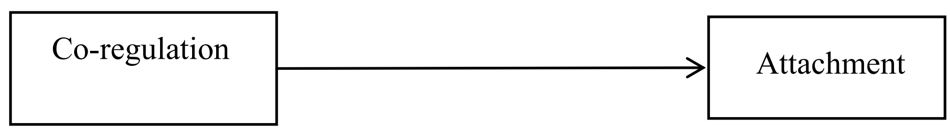

Figure 1

After acknowledging the direct relationship between co-regulation and attachment (Evans & Porter, 2009), as well as the significant correlations between vagal tone and co-regulation (Porter, 2003), the current paper intends to evaluate the mutual interaction between co-regulation and vagal tone, which in turn contributes to attachment outcomes. The purpose for presenting the two indicator variables, co-regulation and vagal tone, as mutual influencers is to support current research which is trending towards the supposition that both environment and physiology are key indicators for developmental outcomes, including attachment. The current paper discusses two main questions: (1) Is there a significant relationship between vagal tone and attachment outcomes during infancy; and (2) Do vagal tone and co-regulation have a meaningful, shared, mutual influence on the development and maintenance of one another as it relates to attachment development. The current paper will also evaluate the model shown in Figure 2 from two time points—6 and 9 months, with attachment measures occurring at the 12 month time-point only. The purpose for evaluating two different time points is to acknowledge the significant development that occurs during the first year of an infant's life and the possible differences that may result during a sensitive 3-month period.

Based on the previous literature, it is hypothesized that a direct, significant relationship will be identified for the infant vagal functioning-attachment relationship. Furthermore, it is logical to conclude that both co-regulation and vagal tone will play a meaningful role on one another, given the literature, which discusses the mutual influence of both environment and physiological variables. If these hypotheses prove accurate, a neuropsychological viewpoint will be supported.

Methods

The data collection process for this project has already been completed and is contained in the Mother-Infant Relationship Research Project (MIRRP) data set at Brigham Young University (BYU) as a part of Dr. Chris Porter's Infant Studies Lab.

Participants

The overall sample consisted of 101 mothers and their first-born infants (53 females). Vagal tone assessments and attachment data was obtained on 101 infants at approximately 12-months of age (M = 372.68 days, SD = 15.78 days). Participants were recruited from a Mountain-West community by local birth announcements, pediatric practices, and by advertising. Infants were healthy and carried to full-term (average birth weight M = 7.26 lbs., *range* = 5.04 – 9.13 lbs.) with no major pregnancy, birth, or perinatal complications. Mothers (mean age in years M = 25.22, SD = 3.80) were predominately white (94% Caucasian, 5% Hispanic, 1% Asian), well educated (M = 14.45 years of education SD = 1.79) and from intact marriages (99.2%) with an average length of marriage at 36.57 months (SD = 21.38). Approximately one-third of the mothers worked outside of the home (30 mothers stated that they worked full or part-time outside of the home, 62 mothers stated that they did not work outside of the home, and 9 mothers did not respond to this question). Modal family income was $29,000 to

$39,000 per year (range less than $5,000 to more than $100,000). The sample included a high percentage of couples (43%) with at least one spouse in college. Family income was consistent with average levels based on county comparisons from public tax records.

Procedures

Co-regulation and heart rate data were originally collected at three different time points, as a part of a longitudinal study. Attachment quality was only measured at the final time point (12-month). At approximately 6 (*M*= 195.53 days, S.D. = 18.28 days, range = 164–251 days), 9 (*M*= 275.41 days, S.D. = 9.13 days, range = 253–300 days) and 12 months of age (*M*= 372.68 days, S.D. = 15.78 days, range = 362–397 days).

Attachment quality. Attachment quality was measured using Ainsworth et al.'s (1978) strange situation procedure. This measure was designed to distress the child by separating him/her from the mother, therefore, eliciting attachment behavior when reunited with her. The strange situation consisted of eight continuous episodes. Researchers who were trained at Alan Sroufe's attachment workshop and achieved reliability using his tape set coded the strange situation episodes. Infants were coded as either having avoidant, resistant, or secure attachments. Approximately 95% interrater agreement was achieved on 30% of all attachment protocols by a second coder. Disagreements were resolved through mutual coding and then consensus with a third coder. Avoidant and resistant attachments were collapsed into an insecurely attached category. For subsequent analyses, secure attachments were then dummy coded as 1 and insecure attachments as.

Mother-infant co-regulation. The 15-min free play episodes were coded using Fogel's (1994) global Relational Coding System. Fogel's coding system is designed to capture qualitative features of the interpersonal communication process that consists of the creation of innovative joint patterns of interaction (Fogel, 1994). The coding system is designed to capture the quality of the relational

communication process over time (Fogel & Lyra, 1997; Hsu & Fogel, 2001). Due to the dynamic nature of communication sequences, the duration of co-regulated sequences can be either brief (seconds) or long (several minutes) in their duration. Fogel's co-regulation examines observed communication dynamics, regardless of emotional valence or intent, between partners.
Here, the focus is more on the quality of the structure and patterning of the communication sequence rather than the content of the communicated message (e.g., angry or pleasant exchanges can be symmetrical as long as both partners are involved in the innovation of the communicative sequence). Mother–infant communication patterns were coded along one of four co-regulated dimensions, symmetrical, asymmetrical, unilateral, and disruptive or a dimension of non-regulation or unengaged behaviors.

Symmetrical co-regulation. Symmetrical co-regulation (or mutual innovation with co-participation) occurs when individuals share a joint focus of attention and mutually create new actions in succession. Each partner interacts anticipating the actions of the other and offers the opportunity to play as a bridge between interactive segments. The opportunity is acknowledged and accepted by the other and interaction is able to continue uninterrupted.

Asymmetrical co-regulation. Asymmetrical co-regulation (or innovation with respect to the other: attention to partner) is observed when coordination of actions is continuous and there is a joint focus of attention between the dyad. However, in contrast to symmetrical interaction, only one partner is elaborating upon the activity while the other watches (e.g., mother demonstrates a toy while the child observes or vice versa).

Unilateral co-regulation. Unilateral co-regulation (or innovation with respect to other, or attention to other vs. innovation with respect to self) occurs when only the first partner acts with respect to the other's activity, but the second partner does not elaborate on, attend to, or seem to acknowledge the activity of the first partner. The first partner may be watching or talking to the second partner, cleaning up the play area near the second partner, or preparing the area for joint engagement with little attention or interest displayed by the second partner.

Disruptive co-regulation. Disruptive co-regulation (or attempt at mutual innovation is disruptive of the other/withdrawal or rejection) patterns are observed when one partner's attempt at mutual innovation is disruptive of the activity of the other. This behavior is coded when one partner interrupts the other in an inappropriate manner. The first partner's actions are done in a way which indicates misinterpretation of the other's intent for interaction, or disregard for it. For example, the mother takes a toy away from the infant while the infant is still playing with the object.

Unengaged co-regulation. Unengaged co-regulation (or innovation for self) patterns emerge when each individual is engaging in a different activity and there is no joint focus of attention. Partners are neither trying to engage with each other nor trying to disrupt the activity of the other. They are both engaged in and elaborating upon separate tasks or they may be trying to innovate different activities with the same task or object. Behaviors lasting two seconds or longer were coded. Duration of time in each category was calculated by summing the total amount of time spent in each category. Proportion scores were then determined by dividing the sum of each category by the total duration of the play episode. These proportions were then used in subsequent analyses. Inter-laboratory training occurred with the authors by Fogel and members of his research staff at the University of Utah. Intra-laboratory training then occurred with several research assistants until 90% inter-observer agreement was reached. During training and subsequent reliability checks, disagreements between observers were resolved through discussion until consensus was obtained. Differences between raters were corrected by additional training to within 90% inter-observer agreement. Interrater reliability was assessed by random assignment of approximately20%of the play episodes based upon the total duration of the play episodes. Average interrater agreement for duration and sequencing of co-regulated patterns was 89.24% with an average interrater kappa of .85 across co-regulation categories.

Cardiac vagal tone data. At the beginning of the scheduled laboratory visit a 3-min, baseline heart-rate recording was gathered from the participating infant. Three adhesive electrode patches (Protrace/Silver Chloride) were applied to the infant's chest in a triangular fashion and a remote electrocardiogram (EKG) monitor (Transhetic, Inc.) was connected to the patches. Mothers were asked to hold their infants quietly on their laps during the baseline period. Infants were given approximately 30 sec. to adjust to placement of electrodes prior to the baseline data collection. Baseline heart-rate data were collected using a Transkinetic Real TeIemetry monitoring system (TXM-206, TXR-205). The signal from the remote monitoring system was transmitted simultaneously to an oscilloscope (HitachiV212) for a visual display as well as digitized on-line via a Delta-Biometries Vagal Tone Monitor (Model VTM-1) to detect the peak of the R-wave of the EKG and time sequential heart periods, i.e., R-R intervals, to the nearest millisecond. The data were stored for editing and generation of heart-period files off-line on a laptop computer. MXedit software (Delta-Biornetrics, Inc.) was used for visual display of heart-period data, to edit outliers due to movement and recording artifacts, and for calculating the amplitude of respiratory sinus arrhythmia using Porges's (1985) vagal tone index. MXedit is a software package that employs the time series analyses developed by Porges (1985) with which to estimate respiratory sinus arrhythmia per epoch. MXedit incorporates a detrending algorithm (a moving polynomial filter and band-pass) to remove aperiodc trends and periodic heart patterns outside of the respiratory frequency band (Fracasso, Porges, Lamb, & Rosenberg, 1994). The heart period data were first transformed into time-based data by estimating heart periods for successive 200-msec. intervals. A 21-point moving cubic polynomial is then applied to the heart-period data to remove complex trends due to movement. The residual data are subjected to a 25-point symmetrical band-pass filter to extract the variance in heart period between a .24- and 1.04-Hz range. Scores on the vagal tone index reflect the natural logarithm of the variance within the .24- to 1.04-Hz frequency band and is expressed in log $msec^2$ units. The vagal tone index was calculated on sequential 30- sec. epochs from the 3-min. baseline, and the mean of these epochs were used in subsequent data analyses. Mean heart period (the average interbeat period per 30-sec. epoch), heart-period range (maximum heart period minus minimum heart period during each 30-sec. epoch), biased variance (the natural logarithm of the variance of all heart periods), and the mean standard deviation (the mean standard deviation of heart period per 30-sec. epoch) were also employed in subsequent analyses. Past research (e.g., Fracasso, *et al.,* 1994; Porges, *et al.,* 1994; Porter, *et al.,* 1995; Bornstein & Suess, 2000) has demonstrated both the short- and long-term stability of the cardiac vagal tone index in varying samples of infants and preschoolers.

Results

Preliminary analyses were computed to include mean, standard deviation, ranges, and mean differences across time for attachment, vagal tone, and all four types of co-regulation (see Table 1). The purpose for doing this was to check for distribution abnormalities. Results indicated satisfactory distribution within the data and that results would not be skewed.

Other variables, including personal characteristics and demographic information such as infant gender, amount of hours a mother works outside of the home, mother ethnicity, and mother's age, were also evaluated during preliminary analyses in relation to variables of interest (e.g. vagal tone, co-regulation). None of these demographic variables were related to the variables of interest.

Preliminary correlational analyses were also computed for each of the variables of interest. Results indicated that several variables were significantly related. Specifically, symmetrical co-regulation at six months was related to vagal functioning at six months, asymmetrical co-regulative behaviors at nine months, and attachment outcomes at twelve months. Unilateral co-regulation at six months was also related to vagal tone at six months, asymmetrical co-regulation at nine months, and attachment outcomes at twelve months. Additional findings also demonstrated significant relations between the variables of interest concurrently and across time including vagal functioning at nine months, unilateral co-regulation at nine months, disruptive co-regulation at nine months, and vagal functioning at six months. I also evaluated the means across times for the variables of interest. Two variables, asymmetrical co-regulation and vagal tone, posted significant changes with asymmetrical being positive and vagal tone being negative (See Table 2).

Since bivariate correlations do not allow for examination of simultaneous linkages between variables and their relative contribution to specific outcomes of interest, the next step of analyses includes the use of SEM to evaluate the direction and relative contribution of the variables of interest. M*plus 7.1* was used to create cross-lagged structural equation models (Muthen & Muthen, 2011). Bayesian estimation was also used to more accurately account for the smaller sample size (n=101). The use of Bayesian estimation allows researchers to use a sample size which is only two or three times the amount of degrees of freedom, whereas maximum likelihood requires a much larger ratio (van de Schoot, 2013). The use of cross-lagged models allows researchers to examine the relationship between variables longitudinally, as opposed to only viewing items at individual time points or cross-sectionally. Lastly, because Bayesian estimation was applied, assumptions of normality were theoretically based using the least-informed priors in MPLUS (Muthen & Asparouhov, 2012; Muthen & Muthen, 2011). See Figures 2-5 to view the final evaluated models.

To account for the possibility that mental and physical development factors influence vagal functioning, co-regulative behaviors, or attachment, I ran preliminary models using the Physical Development Index (PDI) and Mental Development Index (MDI) from the Bayley Scales of Infant and

Toddler Development for each subject (Bayley, 2006). These measures evaluate specific physical and psychological functioning and significant results would provide logical reason to control for either or both of these constructs. Results indicated no significant linkages with the PDI on attachment outcomes, but did find a significant relationship with the MDI variable for each model. As a result, each model was evaluated while controlling for the influence of the MDI for each case. Figures 2-5 show the models for each type of co-regulation.

Originally, the four different models were evaluated to test the data based on the Posterior Predictive P-Values (van de Schoot et al., 2013). When using Bayesian estimation, posterior predictive checking is intended to ensure that the model being used to evaluate the data is accurate. In other words, it is a confidence rating in the amount of deviation between the actual data, and the data produced by the model. Bayesian estimation examines a series of hypotheses simultaneously to produce an overall prediction for the question at hand, whereas maximum likelihood estimation uses one test of the hypothesis to prove or disprove a specific question. However, after further research it was indicated that when seeking to evaluate model adequacy, it can be more profitable to utilize different model fit information which in this case was to focus on the confidence interval affiliated with the model, rather than the posterior predictive p-value (Meng, 1994). Therefore, although the posterior predictive p-values for these models each indicated poor model fit, the confidence interval suggested the model's validity and ability to adequately evaluate the research questions (J. Olson, personal communication, November 14, 2014). Tweaking the model to create a satisfactory posterior predictive p-value would have decreased the models ability to accurately describe the questions being evaluated. Thus, the model fit was evaluated and decisions were made to proceed with each model based on satisfactory confidence intervals, rather than a posterior predictive p-value.

Overall, there were very few significant findings in each of the models' results (see Figures 2-

5). Although many of the results were not significant, symmetrical co-regulation did reveal two noteworthy linkages. The first was a positive, significant relationship between co-regulation at six months and attachment at twelve months of age ($r = .11$, $p < .05$). The second link was the significant, positive relationship shared between co-regulation at six months of age and vagal tone at the nine month time point ($r = .13$, $p < .05$). It is meaningful to note that both occurrences took place at the six month time point, which suggests the importance of understanding why this time period may be more influential than other times during the first year of life. There were no other significant links or correlations identified in this model (see Figure 2).

Unilateral co-regulation also revealed two significant findings. The first involves a negative relationship between unilateral co-regulative behaviors at the six month time point and the control variable of MDI at nine months ($r=-.24$, $p< .05$), suggesting that more unilateral engagement may lead to poorer developmental status at nine months. The second link is a negative concurrent correlation between unilateral co-regulation and vagal tone at six months ($r=-.23$, $p< .05$). A correlation that remains significant when incorporated into a path model may suggest the strength of the correlation is stronger and potentially more meaningful than some of the other correlations noted during the preliminary analysis. No other significant linkages were found (see Figure 4).

Aside from these four reported linkages no other significant findings were found for each of the successive models (i.e. asymmetrical and disruptive co-regulation models). Despite having many significant preliminary correlations, a lack of significant paths in each of the models suggests that variance may be limited when evaluating the contribution of multiple variables of interest simultaneously.

Discussion

The current paper examines contributions of co-regulated interactive states in mother-infant dyads and infants' physiological capacity to regulate (vagal tone) in connection to the infants' attachment status. Two main questions have been addressed: (1) Is there a significant relationship between vagal tone and attachment outcomes during infancy; and (2) Do vagal tone and co-regulation have a meaningful, shared, mutual influence on the development and maintenance of one another as it relates to attachment development. The current paper has also evaluated attachment development from a longitudinal perspective, to identify whether specific components provide greater influence at a specific time during the first year of an infant's life, acknowledge the significant development which occurs during the first year of an infant's life and the possible differences which may result during a sensitive three month period.

Based on the results, it appears that the first question of whether or not there is a direct relationship between vagal tone and attachment does not seem to be supported. The only direct link found with vagal tone was between symmetrical co-regulation at six months and vagal functioning at nine months of age. When reconsidering the necessary components to produce a secure attachment, mainly warmth, responsiveness, and engagement between child and caregiver, these results seem logical because vagal tone is strictly a physiological component. Regardless of how ideal vagal functioning is occurring within an infant, physiological functioning can only influence environmental interactions, not take the place of relational interactions. Thus, the direct relationship between vagal tone and attachment outcomes is, as expected, non-significant.

However, recognizing this direct link between vagal tone and co-regulation, as well as other direct linkages between co-regulation and attachment, it becomes logical to wonder whether vagal tone could influence attachment outcomes if co-regulation were to act as a mediator in the relationship. The current study found that both symmetrical and unilateral co-regulation at the six month time point directly links to attachment outcomes at twelve months of age. Porter (2003) previously noted this linkage when examining significant correlations between the two variables. Perhaps if co-regulation provides the necessary environmental components to form a secure attachment, and vagal tone indicators speak to the physiological functioning enabling a child to mutually participate in relational interactions, then future studies could examine the relationship between vagal tone and attachment when mediated by co-regulation.

Another consistent finding to note throughout this study is the significant role which co-regulation seems to play specifically at the six-month time point. It is interesting to note that linkages between the nine-month time point and attachment were not found for any of the types of co-regulation. This finding supports previous research completed by Evans and Porter (2009) that likewise found linkages between co-regulation behaviors at six months and attachment outcomes at twelve months, but did not find connections between nine-month co-regulation and attachment outcomes. My initial assumption was to expect that co-regulation would build upon itself over time, and that if a significant link was found at six-months that when examined in light of a path model, something the Evans and Porter (2009) study did not do, that significant pathways might emerge between six and nine months in relation to attachment outcomes. However, after further consideration it may be that at an earlier age, caregiver involvement is more necessary because of the limited abilities an infant might have to engage in and maintain complex interactive behaviors that might support the formation of an attachment (Kochanska & Aksan, 2004). Thus, at six months maternal involvement may play a bigger role in helping to form an attachment, whereas by nine months of age a child is able to engage in increasingly complex dynamic exchanges with the mother that may support the interaction but perhaps are now indicators of the past relationship histories rather than on-going attachment organization. Support for this argument may be found in the changing patterns of co-regulation from 6 to 9-months. Specifically, it is interesting to note that on average symmetrical interactions increased while unilateral interactions significantly decreased from 6 to 9-months. Perhaps with a larger sample it might be possible to look at variations between cases of mother-infants where these general patterns of change in co-regulation did not hold up to see if the changing patterns might be a better indicator of later attachment organization. In essence, attachment may be primarily developed during the first year of life when a child is more dependent on a parent—suggesting the specific importance of a parents' ability to respond and promote engagement during the first six months of the child's life. Thus, our findings that co-regulation at six months of age consistently influences attachment outcome at twelve months appears consistent with previous literature (e.g., Ainsworth, 1979; Evans & Porter, 2009).

Another finding to note is the negative link established between unilateral co-regulation at six months of age and MDI levels at nine months of age. This finding mirrors previous results published by Evans and Porter (2009) who found positive links between symmetrical co-regulation at six months of age and MDI levels at nine months of age. Given that an infant is still primarily reliant on their caregiver to explore their environment and consequentially mature mentally, a unilateral interaction is likely not supportive of higher cognitive functioning, because unilateral interactions may require less effort from the part of the child to maintain a dynamic interactions and may be less cognitively demanding than more consistent symmetrical engagement (Fogel, 1993). Thus, the findings which suggest unilateral co-regulation negatively influences MDI levels at nine months appears to support this general pattern of previous results demonstrating that co-regulation may be an important contributor to infants' early developmental status.

An additional future consideration may be to further evaluate the co-regulation-attachment relationship when the attachment variable is broken down into more than a bivariate outcome. In other words, breaking down the attachment variable into secure, insecure-avoidant, and insecure-resistant styles may show direct linkages to different types of co-regulation not previously established.

Unfortunately, given the limited number of insecure attachments observed in this study (n=27) there does not appear to be sufficient power to further delineate this relationship. It seems likely though, that future studies that can examine these more fine grained variations in attachment outcomes may help us better understand linkages between insecure types of attachment and specific types of co-regulation. Examining multiple types of attachment might also provide further insight to vagal functioning and the polyvagal theory. When specific levels of vagal functioning are measured against specific types of attachment, direct linkages may be established which are currently unknown, thus furthering the current understanding of polyvagal theory. Examining different types of attachment styles may provide additional insight into the use and application of co-regulation, and vagal tone.

As mentioned previously, future studies may benefit by examining the role of vagal tone specifically when being mediated by co-regulative behaviors at both the six and nine month time points. The current study has reinforced the important influence of the environmental interactions to help form a secure attachment. Additionally, different components of heart rate, such as the heart period may be beneficial to include when examining physiological elements. The heart period averages the intervals of heart rate, rather than vagal tone directly, and may provide another indicator to the comprehensive relationship between physiology and emotional development (Porges, 1985).

Limitations to this study include the use of a fairly low-risk, homogenous middle-class Caucasian sample, which limits generalizability across populations. Perhaps a more diversified sample, particularly a sample that includes infants across a continuum of risk factors (e.g., lower SES, non-intact marriages, and lower educational attainment) may produce findings that demonstrate the risks of poor co-regulation on infants' emerging physiological regulation and attachment outcomes. For example, examining participants based on their history of traumatic experiences may be one way of examining the sample based on groups. A recent study found distinct differences in cardiac functioning when examining individuals with post-traumatic stress disorder as compared to those without some sort of traumatic history (Sack et al., 2008). Measuring vagal tone on the basis of traumatic history among participants would provide greater perspective on the vagal tone-attachment relationship.

A second limitation to this study arises because the co-regulation data was based on proportionate scores of a 15-minute observation, and as a result very few cases were rated as having high amounts of disruptive co-regulative behaviors. Much of the data for disruptive co-regulation read as "zero" because study participants generally demonstrated other types of co-regulation. This may be a contributing factor as to why there were no significant results affiliated with this construct. Future studies may benefit by grouping cases into a four types based on the type of co-regulative behavior which was most often present during a timed interaction, and then conducting their statistical analysis. The effects of attachment development are far reaching for each individual (van IJzendoorn, 1995; Sroufe & Waters, 1977; Ainsworth, 1978). The current paper has examined methods for developing a secure attachment, and specifically the influence of the relational and physiological components, which contribute towards the development of a secure attachment. Continued study on the topic of attachment development enables individuals to intentionally create circumstances which will be ideal for successful development.

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Table 1: Descriptive Statistics

	N	Min	Max	Mean	SD	t
Symmetrical Co-regulation 6 Mo. 9 Mo.	 101 101	 .00 .00	 .97 .90	 .38 .44	 .29 .19	 -1.92
Asymmetrical Co-regulation 6 Mo. 9 Mo.	 101 101	 .00 .00	 .41 .16	 .08 .03	 .09 .04	 5.63**
Unilateral Co-regulation 6 Mo. 9 Mo.	 101 101	 .02 .00	 .96 .80	 .53 .46	 .28 .19	 1.89
Disruptive Co-regulation 6 Mo. 9 Mo.	 101 101	 .00 .00	 .039 .059	 .00 .00	 .01 .01	 -.561
Vagal Tone 6 Mo. 9 Mo.	 85 88	 1.05 1.74	 5.48 6.69	 2.68 3.89	 1.10 .93	 -7.29**
Bayley Scale (MDI) 6 Mo. 9 Mo.	 101 95	 71.00 70.00	 116 116	 93.81 95.80	 9.56 10.01	 -1.41
Attachment Quality (0=insecure, 1=secure)	 84	 .00	 1.00	 0=27 1=57 (frequencies)	 n/a	 n/a

Table 2: Pearson Two-tailed Correlations

	6 Month Symmetrical Co-regulation	6 Month Asymmetrical Co-regulation	6 Month Unilateral Co-regulation	6 Month Disruptive Co-regulation	6 Month Vagal Tone	6 Month MDI	9 Month Symmetrical Co-regulation	9 Month Asymmetrical Co-regulation	9 Month Unilateral Co-regulation	9 Month Disruptive Co-regulation	9 Month Vagal Tone	9 Month MDI	Attachment Quality (0=insecure 1=secure)
6 Month Symmetrical Co-regulation	1.00												
6 Month Asymmetrical Co-regulation	-.29**	1.00											
6 Month Unilateral Co-regulation	-.94**	-.037	1.00										
6 Month Disruptive Co-regulation	-.11	.13	.048	1.00									
6 Month Vagal Tone	.30**	.06	-.35**	.28*	1.00								
6 Month MDI	.072	-.067	-.052	-.035	.123	1.00							
9 Month Symmetrical Co-regulation	.19	-.04	-.19	.04	.22	.04	1.00						
9 Month Asymmetrical Co-regulation	.20*	.05	-.23*	.14	.29**	.09	-.03	1.00					
9 Month Unilateral Co-regulation	-.05	-.03	.07	.01	-.12	.17	-.37**	.00	1.00				
9 Month Disruptive Co-regulation	.09	-.13	-.05	-.06	.08	.12	.037	.097	-.027	1.00			
9 Month Vagal Tone	.02	-.01	-.02	.04	.02	-.15	.20	-.08	-.16	-.01	1.00		
9 Month MDI	.42*	-.26**	-.37**	.06	.18	.31**	-.01	.25**	-.04	.07	-.00	1.00	
Attachment Quality (0=insecure 1=secure)	.29*	-.08	-.29*	-.10	-.10	.087	.02	-.06	-.04	.11	-.26	.22	1.00

Figure 2: Symmetrical Co-regulation Model

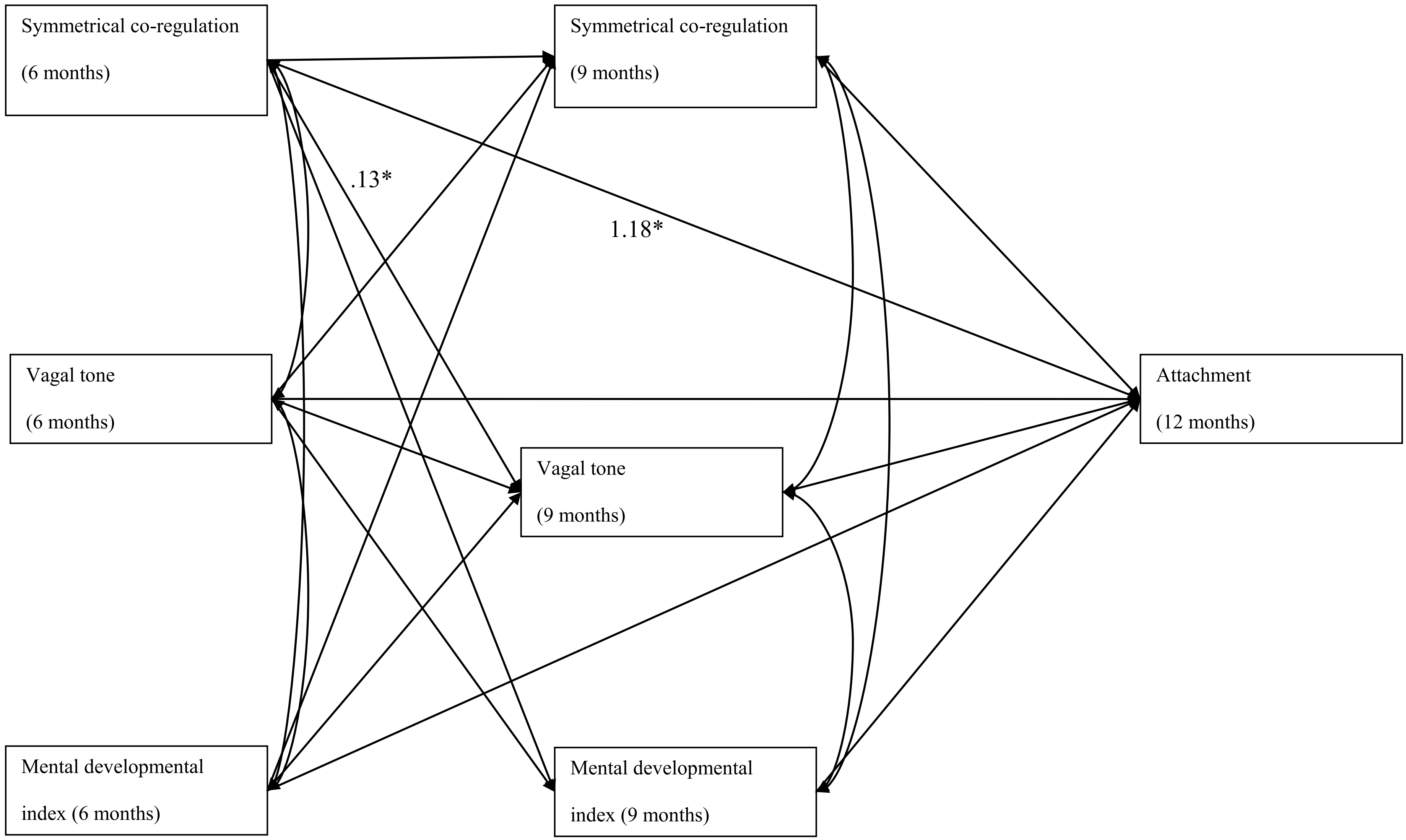

Figure 3: Asymmetrical Co-regulation Model

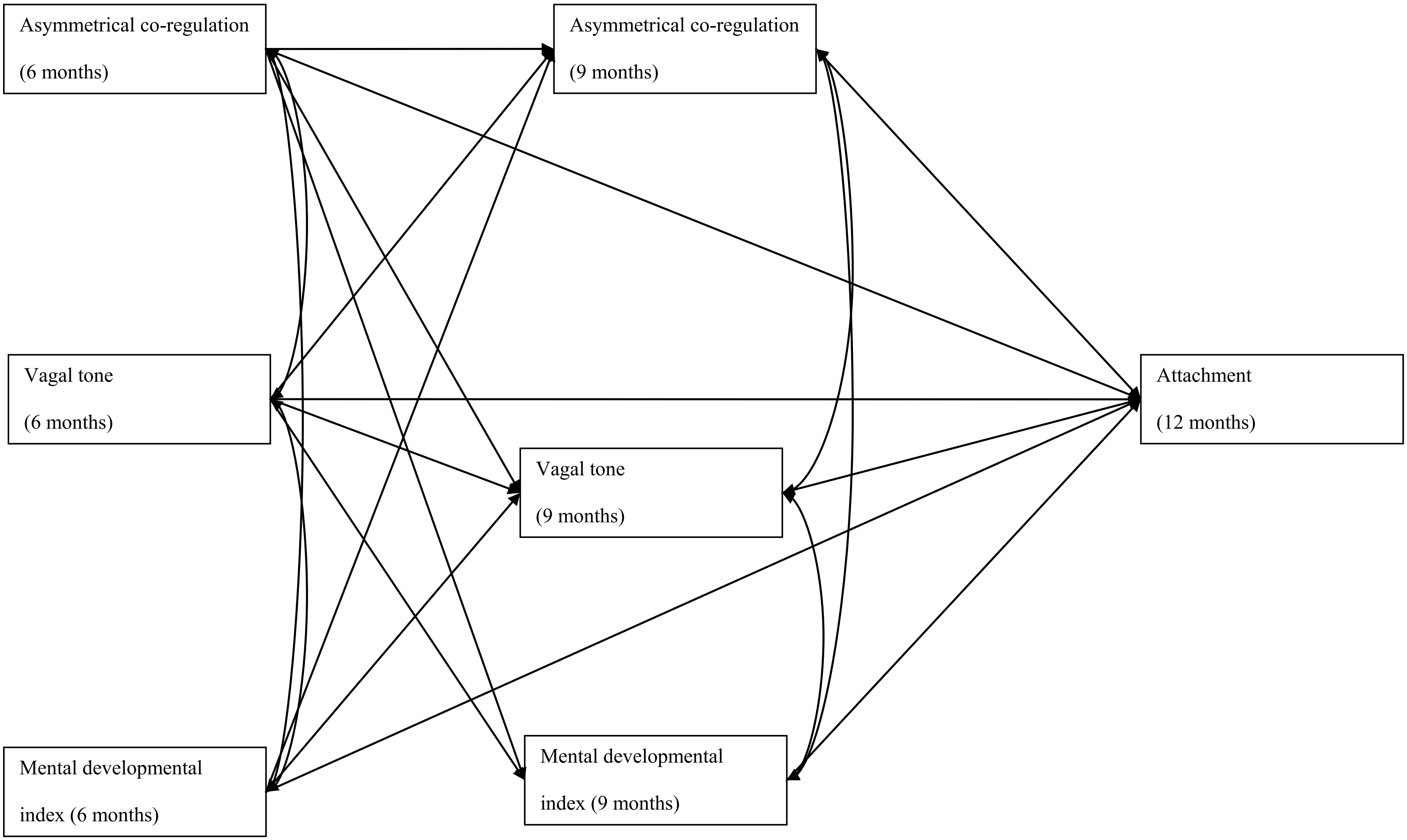

Figure 4: Unilateral Co-regulation Model

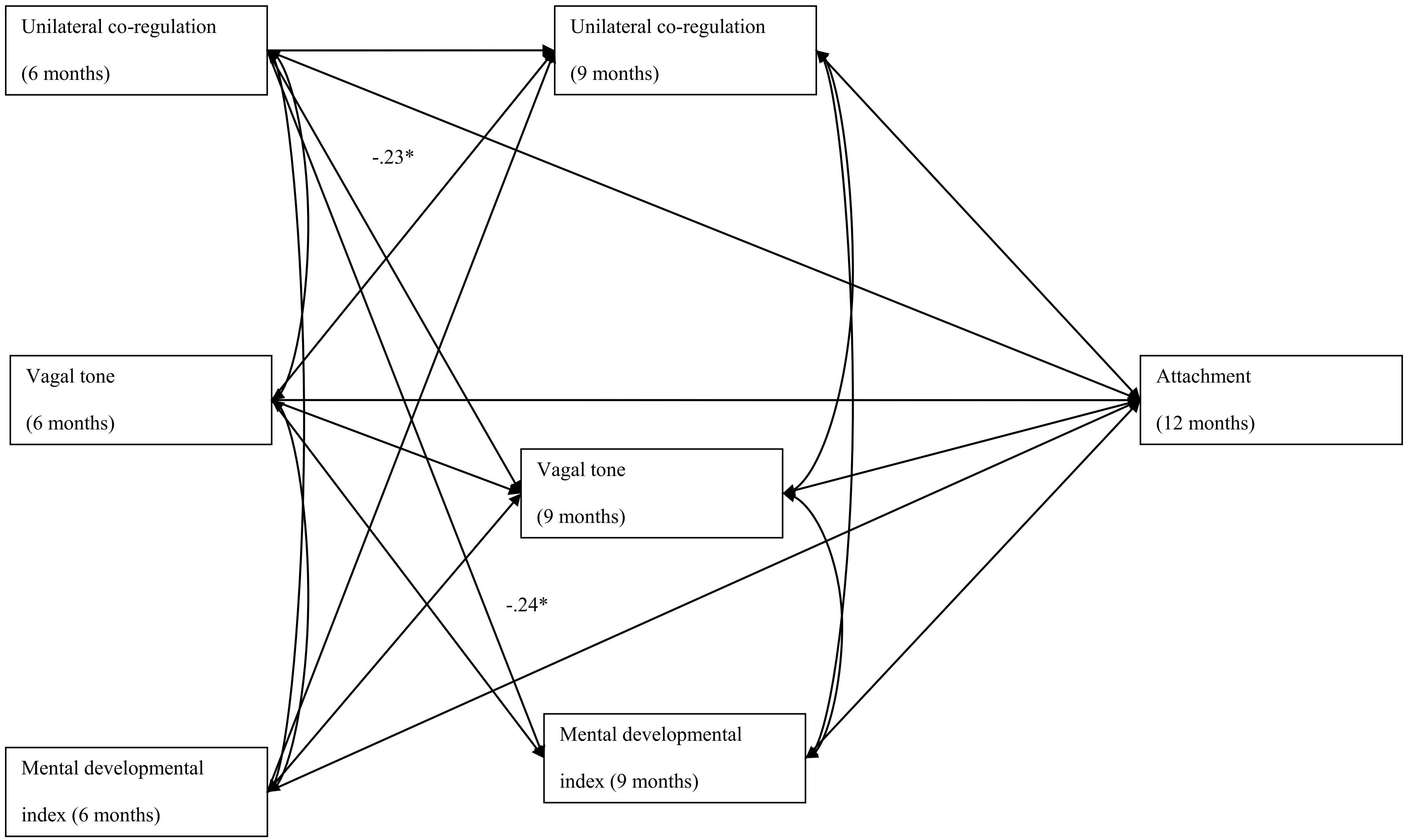

Figure 5: Disruptive Co-regulation Model