2011-12-12

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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December 2011

ABSTRACT

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This study examined the relationship between 6-month old infants' orienting response to maternal arm-restraint (as measured by bradycardia), the quality of mother-infant communication at 6 and 9 months (as measured by the Relational Coding System) and attachment at 12 months (as measured by the Strange Situation Procedure). As positive mother-infant communication increases, the chances the infant will experience bradycardia increases. As negative mother-infant communication increases, the chances that the infant will experience bradycardia decreases. For mothers and infants who have more positive communication patterns, orienting response to the maternal arm-restraint suggests that maternal disruption of infant activity was a novel experience for them. This study suggests that mother infant interactions create an expected pattern of behavior for infants. When these expectations are violated, the infant has a physiological reaction that suggests increased attention to the disrupted interaction. Bradycardia at 6 months was not related to attachment at 12 months; however, considering both the physiology and environment of the infant, dyadic positive and negative interactions affect the quality of the mother-infant relationship several months later.

Keywords: attachment, co-regulation, communication, mother-infant, orienting

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Introduction

In humans, involuntary reactions of the heart, glands and muscles are controlled by the autonomic nervous system. This system has evolved over time to respond appropriately to challenges in the environment. For instance, the autonomic nervous system activates to determine the significance of something unfamiliar and novel through an orienting response or to engage the "fight or flight" response to a threat (e.g., Bohlin & Graham, 1977; Lang, Bradley, & Cuthbert, 1990; Ohman, 1977). The infant orienting response is marked by a physiological phenomenon called bradycardia (heart rate deceleration). Bradycardia can be successfully elicited through a maternal arm restraint coupled with a still-face procedure (MAR-SFP). This procedure requires that the mother hold the infant's arms at their sides while maintaining a neutral facial expression.

Many theorists have described how the mother-infant relationship is sensitive to differences in the caregiver's behaviors and interactions (Ainsworth, Bell, & Stayton, 1974; Bowlby, 1969; Grossmann, Grossmann, Spangler, Suess, & Unzner, 1985; Isabella, 1993; Porter, Jones, Evans, & Robinson, 2009). Given the disrupted nature of the MAR-SFP procedure to on-going mother-infant interaction, the appearance of an orienting response may yield insights into mother-infant interactions and the mother-infant relationship. For example, an infant who has built an expectation of sensitive and responsive interactions from mother may experience an orienting response when mother violates those expectations by holding the infant's arms. On the other hand, an infant who has built an expectation of an unresponsive or insensitive mother may not experience bradycardia, because no expectation of interaction has been violated. In other words, the infant may not be surprised at the MAR-SFP. While past research has helped us understand the relationship between an infant's intensity of behavioral and physiological reactions to the MAR-SFP (Porter, Jones, Evan & Robinson, 2009; Porter and Jones 2011), the physiological reaction -known as bradycardia- has not been examined from the aspect of the mother-infant relationship.

The first aim of the current study is to explore if an infant exhibits bradycardia at the onset of maternal arm-restraint at 6 months, then it may be likely that these dyads experience more symmetrical or asymmetrical patterns of co-regulation at 6 or 9 months. Whereas, infants who do not experience bradycardia at 6 months may experience less symmetrical or perhaps even more unilateral, disruptive, or unengaged patterns of co-regulation. If bradycardia is related to a violation of the expected social interaction, then it seems likely that bradycardia will also be related to the quality of the mother-infant relationship. The second aim of the current study is to explore if an infant experiences bradycardia at the onset of the maternal arm-restraint protocol at 6 and 9 months of age, then it may be likely that these infants are categorized as securely attached to their mothers at 12 months of age, whereas infants who do not exhibit bradycardia may be categorized as insecurely attached at 12 months of age.

This paper will begin with a review of literature to provide a foundation for understanding the research related to bradycardia, co-regulation and attachment. This will be followed by justification for the two hypotheses. Finally, this paper will conclude with a presentation of a plan of analyses.

Review of Literature

Bradycardia

When animals are presented with a stimulus that is new or unexpected, they have an involuntary reaction called an “orienting response.” This response is a way for organisms to focus attention on novel stimuli and quickly determine the nature of the stimuli. The orienting response has long been studied and considered to be a necessary evolutionary adaptation for survival in animals (Friedman, Cycowicz, & Gaeta, 2001; Graham & Clifton, 1966) and can be thought of as the precursor to the "fight or flight" phenomenon. In other words, before an animal behaves aggressively toward a threat or flees from the threat, it will experience an orienting response. The stimulus engages the consciousness of the individual and triggers an evaluation of the stimulus' meaning, so that the individual is able to organize an appropriate response (Friedman, Goldman, Stern, & Brown, 2009). Friedman and colleagues (2009) concluded that the key components of the orienting response include extracting meaning from a stimulus, determining its significance, and then taking behavioral action.

Physiological research has shown that behavioral orienting responses in mammals, including humans, are linked to brief periods of heart rate deceleration, or bradycardia (Anderssen, Nicolaisen, & Gabrielsen, 1993; Sokolov & Cacioppo, 1997). The parasympathetic nervous system is controlled by the vagus nerve and acts to regulate physiological arousal. Activation of the parasympathetic nervous system often results in heart rate deceleration (Porges, 1990a, 1990b). It is suspected that the purpose of brief bradycardia during parasympathetic activation may be to redistribute blood flow, which in turn may aid in processing novel stimulation (see Anderssen, Nicolaisen, & Gabrielsen, 1993; Campbell, Wood, & McBride, 1997). In this period of processing during orientation, mammals focus on whether to attend to or react to the stimuli. Attending to the stimuli may require prolonged activation of the parasympathetic system and regulation of heart rate. On the other hand, reacting to the stimuli would be in the form of a fight or flight response, which would likely cause activation of the sympathetic system resulting in increased heart rate (Beauchaine, 2001).

Past researchers have commonly elicited the bradycardia phenomenon by presenting a novel visual or auditory stimulus. For instance, Bohlin, Lindhagen, and Hagekull (1981) presented an auditory stimulus to both adults and infants and discovered that infants have longer and more dramatic orienting responses than adults. Also important to note is the work of Brotsky and Kagan (1971) who demonstrated the stability of the orienting response across auditory and visual modalities and over time.

While past research has elicited bradycardia in infants by presenting them with an auditory or visual stimulus, there is another way to elicit bradycardia which may be informative to the social and emotional development of the infant. More recently, Porter and Jones (2011) studied the presence of bradycardia at the onset of a socially-disruptive task, namely an arm-restraint protocol coupled with a still-face performed by the mothers. While past research has commonly focused on the presence of bradycardia using novel auditory or visual cues, Porter and Jones (2011) found that a majority of infants also exhibited bradycardia at the onset of a novel disruption to social interaction. Interestingly, infants who experienced bradycardia during arm-restraint had shorter latencies to distress, were less oriented towards their mothers and exhibited more attempts to escape the arm-restraint. Furthermore, bradycardiac infants also cried more intensely and longer after mothers released the infants' arm than infants who did not exhibit bradycardia. Porter and Jones (2011) hypothesized that for an infant who experienced bradycardia, the mother's unusual behavior was likely viewed as more novel in relation to the infant's typical expectations about their social interactions, thus increasing the infant's distress. However, what is not clear from this previous research is why some infants demonstrated bradycardia while others did not or what factors may have contributed to the presence of bradycardia in some infants and not in others. Therefore, this study was designed to specifically address the issue of whether the presence of bradycardia in infants during the arm-restraint is related to ongoing patterns of interactions in the mother-infant dyad and possibly to the quality of the attachment with mother.

Arm-restraint has often been used as a moderate frustration perturbation to study distress reactivity in infants. During this procedure the restrainer gently holds an infant's arms down to her/his side until the child becomes distressed for a brief period of time, or until a set time has passed. The arm-restraint protocol provides information about infants' behavioral distress responses. These behaviors include latencies to distress, intensity and duration of distress, facial and vocal responses. In addition, physiological responses, such as heart rate, are collected during this frustration paradox (e.g., Bennett, Bendersky & Lewis, 2002; Fox, 1989; Porter, Jones, Evans, & Robinson, 2009; Scaramella & Conger, 2003; Stifter & Jain, 1996).

In addition to arm-restraint, mothers were asked to maintain a "still face" during the initial phase of the restraint protocol. Tronick and colleagues developed the Still Face Paradigm (SFP) to test infants' sensitivity to the disruption of normal social exchanges with the understanding that infants are active participants in social interactions (Tronick, Als, Adamson, Wise, & Brazelton, 1978). A meta-analysis by Mesman, van IJzendoorn, and Bakermans-Kranenburg (2009) confirmed that infant reactions to the SFP are associated with various outcomes including maternal sensitivity and attachment. A greater degree of maternal sensitivity predicted infant positive affect and consequently, a greater degree of infant positive affect predicted secure infant attachment. Specifically, in one study 12 out of 13 infants who attempted to elicit reaction from their mothers at 6 months were securely attached at 12 months. Conversely, out of the four children who did not try to elicit reaction from mothers at 6 months, none were securely attached at 12 months (Tronick, Ricks, & Cohn, 1982). This demonstrates the predictive nature of an infant's response to a disruptive social interaction. Therefore, combining the two frustration paradigms of arm-restraint with still face was thought to be a more effective way of eliciting a brief bradycardia.

Co-Regulation

Researchers have also increasingly examined the nature of mother-infant interactions in order to better understand developmental contributions to infant development (e.g., Belsky, Taylor, & Rovine, 1984; Cohn & Tronick, 1987; Crockenberg & Smith, 2002; Lester, Hoffman, & Brazelton, 1985; Martin, 1981; Stern, 1971). Traditionally, mother-infant interactions have been observed as a collection of separate behaviors between individuals (e.g., Isabella, et al., 1989). Recently, Fogel (2000) and his colleagues (e.g., Fogel & Branco, 1997) have reconceptualized mother-infant interactions within a more complex framework called the "relational communication system." This new framework was based on Fogel's (1977) previous work where he observed that the mother-infant interaction as developed spontaneously as both individuals were active in the exchange instead of simply signaling and responding. Fogel (2000) began to speculate that communication patterns are unique to dyads and go beyond the discrete behaviors of each individual in a process called co-regulation. Similar to current dynamic systems models (e.g., Thelen & Smith, 1998), co-regulation is understood as a communicative interaction between two individuals where each is altering his or her behaviors according to the behaviors of the other (Fogel 1993, 2000). Co-regulation implies a creative dynamic between partners and, when optimal, results in a fluid and flexible communicative "dance." Through co-regulation, mother and infant "are mutually affecting each other…, thereby forming cooperative units, or coordinative structures, that have unique properties that transcend the individual components" (Fogel and Garvey, 2007). Hsu and Fogel (2001) developed the Relational Coding

System (RCS) that identifies five observed co-regulated interaction states between mother and child: symmetrical (mutual and coordinated participation to create the interaction), asymmetrical (mutual attention, but only one individual creates the interaction), unilateral (one individual attempts to engage the other, who is not paying attention to the interaction), disruptive (one individual disrupts the activity of the other in order to gain interaction), and unengaged (neither are interacting with each other).

Porter (2003) found that infant cardiac vagal tone was positively linked to symmetrical patterns of co-regulation. Porter (2003) concluded that there is a potential relation between the infants' physiological reactions, as measured by vagal tone, and relational mother-infant interactions. More recent research supports the findings by Porter (2003) by showing that infant vagal tone is a function of maternal sensitivity (Moore, Hill-Soderlund, Propper, Calkins, Mills-Koonce, & Cox, 2009). Maternal sensitivity was operationalized by rating mother-infant free play with a coding system used by the NICHD (National Institute of Child Health and Human Development) Study of Early Care. Infants of sensitive mothers showed a decrease in vagal tone, indicating self-regulation, during a disrupted social interaction (Moore, Hill-Soderlund, Propper, Calkins, Mills-Koonce, & Cox, 2009). Findings from these studies demonstrate connections between infant physiology and mother-infant social interactions. Considering that vagal tone is related to more positive social interactions, bradycardia, the physiological phenomenon indicating an orienting response, may be indicative of symmetrical or asymmetrical, but not unilateral, disruptive, or unengaged, co-regulation patterns. Not only do symmetrical and asymmetrical interactions indicate maternal sensitivity, but they capture a specific dimension of maternal sensitivity that takes into account the participation of both the mother and infant.

Evans and Porter (2009) recently demonstrated that the Relational Coding System is predictive of attachment patterns in infants. Symmetrical co-regulation patterns at 6 months predicted secure (Group B) attachment at 12 months (Evans & Porter, 2009). However, little is known about the potential linkages between co-regulation and bradycardia. The present study was, therefore, designed to examine potential linkages between earlier observed patterns of co-regulation and infant orienting response during maternal arm-restraint. I hypothesized that co-regulation patterns may provide insight about the types of relational expectancies that are emerging among mother-infant dyads. Specifically, it is believed that when dyads engage in patterns of interaction characterized by symmetrical or asymmetrical co-regulation patterns that these states may be predictors of bradycardia.

Attachment

Attachment is a unique social-emotional relationship between a caregiver and child. Ainsworth (1989) defines attachment as an affectional bond between these individuals. This affectional bond is “a relatively long-enduring tie in which the partner is important as a unique individual and is interchangeable with none other…[and the infant has] at least an intermittent desire to reestablish proximity and interaction” (p. 711). Although it is possible for attachment to be formed between an infant and any adult, this bond will not be created with any individual at random. An infant creates this attachment with a “clearly identified individual who is conceived as better able to cope with the world” (Bowlby, 1988. p. 27). Attachment between parent and child is rooted in the availability of the parent to nurture and protect and also the responsiveness of the child toward its parent.

John Bowlby (1969) developed attachment theory in his work as a psychoanalyst with children. Bowlby built theories through extensive work with troubled youth and their parents focusing specifically on the parent-child relationship in relation to separation (Bretherton, 1992). Bowlby theorized that infants need a consistent, nurturing mother in order to have healthy social and emotional development into adulthood. Building upon ethological theory, Bowlby laid the foundation for attachment theory as a phenomenon. He made an essential contribution to attachment theory by describing the Behavioral Control System (BCS) and the developmental changes within this system (Marvin & Britner, 1999). The BCS is the behavioral system that underlies the parent-child bond. Attachment theory focuses on four behavioral systems: attachment, fear/wariness, exploration, and sociability. Several behaviors exist in the behavioral system including: proximity-seeking (moving or indicating a desire to be close to their attachment figure), signaling (crying and smiling), following, contact maintaining (clinging, hugging), and distance interaction (calling or vocalization directed towards the attachment figure). Each of these behaviors serves a biological function by either ensuring survival or ensuring reproductive success. For example, proximity-seeking ensures survival by keeping the vulnerable infant close to the adult which keeps him/her safe from harm. These behaviors are indications that the underlying behavioral system has been activated (Marvin & Britner, 1999). For instance, an increase in signaling behaviors, such as crying, may indicate that the fear/wariness behavioral system has been activated in the infant. A principle feature of the BCS is that once it is activated, the way in which it is deactivated can vary depending on the intensity of the activation. If the attachment system is slightly activated, merely a vocal reassurance from mother may deactivate it and calm the infant. On the other hand, if the attachment system has been intensely activated, nothing but prolonged physical closeness will calm the infant.

As the mother sensitively, appropriately, and warmly responds to these behaviors over the course of time the child begins to view the parent as being both emotionally and physically available, resulting in increased feelings of security in their relationship with that person. The history of these interactions then leads to the organization of an attachment relationship. If the mother fails to adequately respond or responds too intrusively then the child learns to organize his/her attachment in ways that may indicate avoidance or ambivalence in their relationship (Bowlby, 1969).

The formation of attachment is multi-faceted. It utilizes both biological and environmental influences. Bowlby (1969) writes that attachment develops “within the infant as a result of his interaction with his environment of evolutionary adaptedness, and especially of his interaction with… his mother” (pp. 179-180). Similarly, Ziv, Aviezer, Gini, Sagi and Koren-Karie (2000) showed that a mother’s emotional availability was associated with her infant’s attachment security. However, attachment is not completely a result of social interactions. Ainsworth (1989) states that “key changes in the nature of attachment may be occasioned by hormonal, neurophysiological, and cognitive changes and not merely by socioemotional experience” (p. 710). Therefore, when studying attachment, researches might take into account physiological indicators, such as bradycardia, to learn about how the infant’s biological characteristics relate to attachment.

Ainsworth, a colleague of Bowlby, added a methodological approach to examining the nature of the child’s attachment organization towards their attachment figure. Building on Bowlby’s early theoretical work, Ainsworth (1989) writes that attachment “evolved through a process of natural selection because it yielded a survival advantage” (p. 709). The infant is more likely to survive if it is close to its mother for both nourishment and protection. As described earlier, bradycardia is believed to be a physiological precursor to the “fight or flight” response which is also believed to yield survival advantages. If bradycardia has adapted as a survival advantage and if that attachment also promote human survival, then it stands to reason that bradycardia that occurs in the context of violated relationship expectancies may be predictive of later attachment outcomes.

Is attachment more than just a survival mechanism in humans? Bowlby answers this question. He states, “For a person to know that an attachment figure is available and responsive gives him a strong and pervasive feeling of security, and so encourages him to value and continue the relationship” (Bowlby, 1988, p. 27). Sroufe (2005) made it clear that attachment is the core relationship “around which all other experience is structured” (p. 353) and it is “vital in the formation of the person” (p. 365). Attachment has lasting effects on a child’s development. Lamb (1982) summarizes that an infant who is securely attached to his/her parents is more likely to develop optimally when compared with an infant who has an insecure relationship with his or her parents “particularly if the parent’s behavior and circumstances remain reasonably consistent over the years” (p. 208).

In their groundbreaking research, Ainsworth, Blehar, Waters, and Wall (1978) explored how attachment is formed in human infants both in Ghana and in Baltimore. Through home observations and longitudinal studies, Ainsworth et al. noticed that mothers that were responsive to their infants’ cues had infants who developed security and trust knowing that their mothers would take care of their needs as they arose. Conversely, mothers that were non-responsive or inappropriately responsive to cues had infants who were anxious about their own and others’ emotions. Ainsworth et al. (1978) maintain that there are four general characteristics of maternal interactions with infants. These include sensitivity (mother is adept at perceiving her infant’s needs and responding appropriately), acceptance (mother is able to accept infant’s positive and negative feelings without feeling resentful), cooperation (mother does not interfere with infant’s autonomy and she respects him/her as a separate person), and accessibility (mother attends to infant's signals despite other demands on her attention and does not ignore the infant) (Ainsworth, Blehar, Waters, & Wall, 1978). Ainsworth's main hypothesis was that attachment was dependent upon maternal sensitivity (Ainsworth et al, 1978). Maternal sensitivity is associated with the mother infant relationship (Bates, Maslin, & Frankel, 1985; Egeland & Farber, 1984; Grossman & Grossman, 1985; Smith & Pederson, 1988). Bell and Ainsworth (1972) report that mothers who were highly responsive to newborn crying have babies that tend to cry less in later months, because they rely on the communication, gestures, and vocalizations of the mother. Similarly, when mothers were accessible and provided physical touch to their newborn infants, the infants sought less contact, yet the quality of the contact was more satisfying and affectionate (Ainsworth, Bell, Blehar, et al., 1971). The explanation for the shift in the infant's behaviors lies in the infant's expectations of the mother based on previous experiences (Ainsworth et al., 1978). Through experience, expectations of mothers are created and these are observable in the infants' behaviors. Therefore, we may also find a physiological indication, in the form of bradycardia, when the infant's social expectations of mother have been violated.

One question inherently raised by the research from Bowlby is how attachment between mother and infant is measured. Bowlby (1973) determined that "separation from mother figure is a key variable in determining a child's emotional state and behavior" (p. 22) and a child's behavior when the mother is present as compared to when the mother is absent will certainly be informative. Ainsworth (1978) used a separation between mother and child as her key variable to develop the Strange Situation Procedure (SSP). The SSP is a procedure used to observe, measure, and classify attachment in one-year-old infants. The SSP is conducted in a laboratory setting and consists of eight episodes of infant-mother separations and reunion which will be described in detail in the Methods section of this proposal. The most important behaviors indicative of attachment are the infant's proximity-seeking behaviors during the reunion episodes (Ainsworth et al, 1978).

The most important behaviors indicative of attachment is the infant's behavior during the reunion episodes in the fifth and eighth phases. Ainsworth et al. (1978) identified eight attachment categories, but this study will focus on three: avoidant (Group A), secure (Group B), and anxious-resistant (Group C). Group A infants generally do not cry in the separation episodes, and in the reunion episodes they avoid the mother even to the extreme of ignoring her. Group B infants are comfortable exploring the environment with their mother nearby. They are likely to be distressed in the separation episodes and readily seek contact or proximity with the mother during the reunions, so as to calm themselves. Group C infants are also distressed during the separation episodes, but they are not as capable of exploration with the mother nearby as Group B infants are. Also, Group C infants are not as adept at settling upon return of the mother and mix contact-seeking behaviors with resisting contact (Ainsworth, 1979).

Current Study

A review of bradycardia was presented to lay the foundation for understanding the current study, the crux of which is eliciting bradycardia through a frustration paradigm during a disrupted social interaction. This technique should provide insight into the mother-infant relationship. Dovetailing on Porter and Jones' (2011) findings, an infant may experience bradycardia when his/her expectations about the nature of on-going social interactions with his/her mother are violated. This study will employ a longitudinal methodology to examine three hypotheses. First, do unique patterns of mother-infant co-regulation behaviors at 6 or 9 months of age predict the presence of bradycardia during the maternal arm restraint at 6 or 9 months? More specifically, I predict that more positive patterns of co-regulation will increase the likelihood of bradycardia while more negative patterns of co-regulation will decrease the likelihood of bradycardia. Second, does the presence of bradycardia during the maternal arm restraint at 6 or 9 months of age predict attachment classification during the Strange Situation Procedure at 12 months? More specifically, I predict that the presence of bradycardia will be associated with secure attachment patterns and the lack of bradycardia will be associated with insecure attachment patterns. Third, does an interaction between bradycardia and co-regulation predict attachment? More specifically, I predict that an interaction between bradycardia and symmetrical or asymmetrical co-regulation will predict secure attachment. Also, I predict that an interaction between bradycardia and unengaged or disruptive co-regulation will predict insecure attachment.

Methods

Subjects

The overall sample consisted of 101 mothers and their first-born infants (53 females). Participants were recruited from a Mountain-West semi-urban community by means of public birth records, pediatrician offices, and local advertising. Infants were delivered full-term and healthy without any major complications. Mothers ranged from 20 to 40 years of age with a mean of 25 years. The mothers averaged between 2-3 years of college education. The majority of mothers were White of non-Hispanic background; although, Latino, Asian or Pacific Islander and White Hispanic ethnicities were also represented (For descriptive statistics of demographic variables, see Table 1). The initial data was collected when the infants were 6 months of age and follow ups were conducted at 9 and 12 months. For this study, complete data was available for 56 infants and their mothers at 6 and 9 months and 47 infants and their mothers at 6, 9 and 12 months. Because there is some attrition between follow-ups, the data was analyzed to understand any potential differences in demographics between the subjects that remained and those that dropped out of the study. Simple mean comparison indicate that participants who dropped out of the study between 6 and 12 months did not differ demographically from those who remained in the study.

Mothers and their 6-month old infants attended a 1-hour laboratory session when their infants were 6, 9, and 12 months of age in which they participated in a maternal arm-restraint protocol and a 15-minute free play session where the mothers were provided with developmentally-appropriate toys and were asked to play with their child naturally, as though they were at home.

Procedures

Maternal arm-restraint and still-face procedure (MAR-SFP). The SFP-MAR experiment includes four phases. First, the mother and child are positioned face to face and the mother interacts normally with the child. Second, the mother was asked to hold the infant's arms gently at their sides for 90 seconds and then release. During the 90 seconds, the mothers maintained a neutral face and refrained from any other interactions. Third, the mother released the infant's arms and the mother maintained a still-face for an additional 90 seconds. Fourth, the mother resumed normal interaction with the child. The child's reactions during the second and third phases were then analyzed.

Bradycardia. Electrocardiogram (EKG) data was collected for 3 minutes prior to arm-restraint to establish a baseline, and then during arm-restraint. The baseline EKG was evaluated for Porges’ (1985) cardiac vagal tone index (a measure of Respiratory Sinus Arrhythmia, a measure of the change in heart rate between inspiration and expiration) and average heart period (HP, the interbeat interval measured in millisecond) using MxEdit software and established parameters for 6-month old infants (see Porter et al., 1995). In order to detect bradycardia as an orienting response, a digital marker was used to determine the beginning of the arm-restraint protocol. The EKG data were digitized online via a Delta-Biometrics Vagal Tone Monitor (Model VTM-1). To edit and examine outliers, MXedit software (Delta-Biometrics, Inc.) was used for visual display of HP data. Research assistants, trained by Porter, visually inspected each heart rate file for presence or absence of orienting bradycardia. Graham et al. (1970), found that the typical time frame for detecting bradycardia as an orienting response in infants was during the first 20 seconds of a stimulus. Using this time frame as a guideline, those infants who demonstrated a slowing of heart rate in the first 20 seconds of arm-restraint were suspected to be exhibiting bradycardia. All other infants were determined to not have experienced an orienting response. To establish inter-rater reliability for the presence of bradycardia, 20% of all EKG files were randomly selected. These files demonstrated 94% inter-rater agreement on the presence or absence of orienting bradycardia. For cases in which there were disagreements between raters, the files were jointly inspected and raters came to a consensus. In order to easily see the slowing heart rate pattern, HP was reverse-scored by subtracting the HP value by 1000 *ms* and then graphed using Microsoft Excel. Upon inspection, 41 infants in the sample used in this study were determined to have experienced bradycardia.

Co-regulation. The mother-infant dyads participated in 15 minutes of videotaped free play. The mothers were instructed to play with their children as they do at home. Developmentally-appropriate toys were provided for their use. The videotapes of the play episodes were coded using Fogel's (1994) Relational Coding System (RCS) which identifies five patterns of interaction including, symmetrical, asymmetrical, unilateral, disruptive, and unengaged. Behaviors were coded that lasted at least 2 seconds or longer.

Symmetrical co-regulation (mutual and coordinated participation to create the interaction): Both partners are engaged in the interaction, which allows the interaction to develop in a co-creative process. They continuously change their reactions based on the information they receive from their partner. An infant participates in symmetrical co-regulation in the form of active or excited body movement, reaching, eye contact, or vocalizations.

Asymmetrical co-regulation (mutual attention, but only one individual creates the interaction): One partner is bidding for, and innovating to gain, the other's attention. The other is observing or attending to what the partner is doing, but he/she will not take an opportunity to innovate in return.

Unilateral regulation (one individual attempts to engage the other, who is not paying attention to the interaction): One partner is bidding for, and innovating to gain, the other's attention. The other is not attending to partner.

Disruptive (one individual disrupts the activity of the other in order to gain interaction): The key to this code is the visible disruption wherein the partner abstains from adjusting for, or attempting to mend, the other's negative emotion.

Unengaged (neither are interacting with each other): There is no cooperation or interaction between partners despite the opportunity.

Dr. Alan Fogel trained previous coders on the co-regulation coding system. When disagreements arose between observers during training, a consensus was achieved through discussion. Additional training corrected disagreements to result in 90% inter-observer agreement. To assess inter-rater reliability, 20% of the play episodes were selected at random for comparison. Inter-rater agreement for duration and sequencing of co-regulated patterns was adequate (M = 89.24%) with an average inter-rater kappa of .85 across co-regulation categories. Raters were instructed to identify a co-regulation interaction only if it lasted two seconds or longer. Proportion scores were created for each co-regulation category by adding the amount of time a dyad spent in each category and then dividing it by the total duration of play session. The current analyses use these proportion scores.

Laboratory Strange Situation. At 12 months of age, the dyad participated in the Strange Situation Procedure (SSP). The SSP was conducted in a laboratory setting and consisted of eight episodes as delineated by Ainsworth (1979). Prior to the experiment, the mother was briefed about the complete procedure and what is expected of her (Ainsworth, 1979, Appendix 1: Instructions to Mother). She signed a consent form for participation.

Episode One - The mother and infant are introduced into the laboratory room which is set up with two chairs and a play area with developmentally appropriate toys. The experimenter exits the room. Duration of episode one is 30 seconds.

Episode Two – The infant is allowed to explore the room. The mother plays with the baby if necessary. Duration of episode two is 3 minutes.

Episode Three – A stranger enters the room. For the first minute the stranger is silent, for the second minute the stranger converses with the mother, for the third minute, the stranger approaches the infant. After three minutes the mother exits the room. Duration of episode three is 3 minutes.

Episode Four – The stranger allows the infant to explore the room. If the infant becomes distressed the stranger makes attempts to comfort and distract the infant. Duration of episode four is 3 minutes or less (if the infant becomes too distressed).

Episode Five – The mother returns to the room and the stranger exits. The mother comforts the infant and engages him in play. The mother exits the room. Duration of episode five is 3 minutes.

Episode Six – The infant is alone in the room and allowed to explore. Duration of episode six is 3 minutes or less (if the infant becomes too distressed).

Episode Seven – The stranger enters the room, comforts the infant and engages him in play. Duration of episode seven is 3 minutes or less.

Episode Eight – Similar to episode five, the mother returns to the room and the stranger exits. The mother comforts the infant and engages him in play. Duration of episode eight is 3 minutes.

The SSPs were videotaped and coded by research assistants trained at the University of Minnesota Child Development Center. The coders rated the infants according to avoidant, secure, or resistant (A, B, C) attachment categories. Approximately 95% inter-rater agreement was achieved.

Analysis

Preliminary Analyses

Individual characteristics of the mother and child, including demographic variables, were analyzed to examine potential associations with outcome variables of interest. Infant gender, maternal education, maternal age, ethnicity and family income were not correlated with either of the outcome variables; neither bradycardia nor attachment (See Table 2). Therefore, they were not controlled for in any of the analyses.

Testing Hypothesis One

Parts A and B. *More positive patterns of co-regulation at six months will increase the likelihood of bradycardia at six months and more negative patterns of co-regulation at six months will decrease the likelihood of bradycardia at six months.*

To test the first hypothesis, I examined the outcome variable, Bradycardia, which is whether the infant experienced bradycardia at the onset of the MAR-SFP (1 = yes, 0 = no), with the five co-regulation categories (Symmetrical, Asymmetrical, Unilateral, Disruptive, and Unengaged) coded during the 6-months 15-minute free play episode. Descriptive statistics for each variable are available in Table 3.1, 3.2, and 3.3 and zero order correlations between variables are found in Table 2.

To account for multicollinearity, I adopted an established protocol of running multiple models while dropping variables sequentially that are highly correlated to examine individual contributions of variables unconstrained by multicollinearity (see Bajpai, 2010; Center for Statistical Technical Support, 2011; UCLA Academic Technology Services, 2011). Symmetrical and Unilateral were highly correlated ($r = -.944$ $p < .01$) which aided my decision in determining which variable to drop. I decided to drop unilateral co-regulation from the first model and symmetrical co-regulation from the second model. Since unilateral co-regulation is somewhat a “neutral” state between the dyad, meaning it is not clearly positive or negative, omitting unilateral from the model first makes theoretical sense when considering positive versus negative communication patterns and their relationship to the orienting response.

The first model (Model A) is a four-predictor logistic model with unilateral co-regulation dropped. The model was fitted to the data to test the research hypotheses regarding the relationship between 1) the likelihood that symmetrical and asymmetrical co-regulation categories will be predicted by the presence of bradycardia and 2) the likelihood that disruptive and unengaged co-regulation categories will be predicted by the absence of bradycardia.

Cook's D standardized residuals were calculated to inspect the data for possible outliers or influential observations. There were four high leverage values (See Figure 1 and Table 4 for details). It would be reasonable to omit observation if the data had overarching common characteristics that would exclude them from the other data. These data did not qualify; therefore the following regressions were calculated using robust standard errors. Robust regressions are a useful and acceptable tool for minimizing the influence of outliers, because it "reweights the observations so that highly influential ones are down-weighted" (Hoffman, p. 16, 2004). The logistic regression analysis was carried out by the Logistic procedure in Stata® version 11.1 (StataCorp, 2009) in the Windows 7 environment. The logistic regression equation showed that

Predicted logistic of (Bradycardia) = .147881 + (.0007057)Symmetrical + (.0607329)Asymmetrical + (-.5505315)Disruptive + (-.7947043)Unengaged

According to the model, the log of the odds of a child experiencing bradycardia was positively related to asymmetrical co-regulation ($p \leq .05$) and negatively related to unengaged co-regulation ($p < .05$; Table 5). In other words, the higher the percentage of asymmetrical co-regulation in a dyad, the more likely it is that the child would experience an orienting response at the onset of MAR-SFP. In fact, each 1% increase in asymmetrical co-regulation is associated with a 6% increase in the odds of experiencing bradycardia. In addition, the higher the percentage of unengaged co-regulation in the dyad, the less likely it is that the child would experience an orienting response. More specifically, each 1% increase in unengaged co-regulation is associated with a 55% decrease in the odds of experiencing bradycardia. In other words, as asymmetrical co-regulation increases, the chances the infant will experience bradycardia increases. As unengaged co-regulation increases, the chances that the infant will experience bradycardia decreases. Symmetrical (p = 0.94) and disruptive (p = 0.11) co-regulation were not significant in the model. Even though symmetrical co-regulation was insignificant, the coefficient is positive, which indicates that the relationship is trending in a direction consistent with the hypotheses. Similarly, even though disruptive co-regulation is insignificant, the coefficient is negative, which indicates that the relationship is trending in a direction also consistent with the hypothesis.

The second model, Model B, included unilateral and dropped symmetrical co-regulation from the predictors. The four-predictor logistic model was fitted to the data to test the research hypotheses regarding the relationship between 1) the likelihood that asymmetrical and unilateral co-regulation categories will be predicted by the presence of bradycardia and 2) the likelihood that disruptive and unengaged co-regulation categories will be predicted by the absence of bradycardia. The logistic regression analysis was carried out by the Logistic procedure in Stata® version 11.1 (StataCorp, 2009) in the Windows 7 environment. The logistic regression equation showed that

Predicted logistic of (Bradycardia) = .1498773 + (.0598912)Asymmetrical + (.0005146)Unilateral + (-.5462968)Disruptive + (-.7898807)Unengaged

Consistent with the previous model, asymmetrical ($p < .05$) and unengaged ($p < .05$) co-regulation are significant and disruptive ($p = 0.1$) and unilateral ($p = .95$) are not significant in the model.

Testing Hypothesis Two

Part A. *The presence of bradycardia will predict secure attachment patterns.*

A one-sample chi-square test was conducted to assess whether the absence or presence of bradycardia at the onset of MAR-FSP at 6 months is related to secure or insecure attachment at 12 months. Descriptive statistics are available in Table 3.2 and zero order correlations between variables are in Table 2. The analysis was carried out by the chi-square procedure in Stata® version 11.1 (StataCorp, 2009) in the Windows 7 environment. The results of the test were insignificant, $\chi^2(1, N = 65) = 0.15$, $p > .05$. The absence or presence of bradycardia at 6 months is not related to secure or insecure attachment at 12 months.

Part B. *The lack of bradycardia will predict insecure (avoidant or resistant) attachment patterns.*

Considering the second part of Hypothesis Two, where the attachment categories are divided in three classifications, a multinomial logistic regression is used because the response variable assumes more than two categories (Chatterjee & Hadi, 2006).

A multinomial logistic model with robust standard errors was fitted to the data to test the research hypothesis that bradycardia at 6 months is related to three attachment classifications at 12 months. The outcome variable, Attachment, was a categorical variable including three attachment classifications (1 = avoidant, 2 = secure, 3 = resistant), and the predictor was whether or not the infant experienced bradycardia at the onset of the MAR-FSP at 6 months (1 = yes, 0 = no). The regression addressed two hypotheses, 1) the likelihood that the presence of bradycardia will be predicted by secure attachment, and 2) the likelihood that the absence of bradycardia will be predicted by avoidant or resistant attachment. The multinomial logistic regression analysis was carried out by the multinomial logistic procedure in Stata® version 11.1 (StataCorp, 2009) in the Windows 7 environment.

According to the model, bradycardia at 6 months is not significantly related to avoidant ($p > .05$), secure ($p > .05$), or resistant ($p > .05$) attachment classifications at 12 months (See Table 8).

Testing Hypothesis Three

Parts A and B. *An interaction between bradycardia and symmetrical or asymmetrical co-regulation will predict secure attachment. An interaction between bradycardia and unengaged or disruptive co-regulation will predict insecure attachment. Separate analyses for 6 months and 9 months are presented.*

Interaction effects between bradycardia at 6 months and co-regulation at 6 months were evaluated with an eight-predictor logistic model, Model D, to test the research hypotheses regarding the likelihood that an interaction between bradycardia and co-regulation would predict attachment. The logistic regression analysis was carried out by the Logistic procedure in Stata® version 11.1 (StataCorp, 2009) in the Windows 7 environment. The results showed that

Predicted logistic of (Attachment) = .8977289 + (-.6479268)Bradycardia + (.0212316)Symmetrical + (-.103997)Asymmetrical + (-.8586454)Disruptive + (.1247603)Unengaged + (-.0100722)(Bradycardia x Symmetrical) + (.1103185)(Bradycardia x Asymmetrical) + (-.7436743)(Bradycardia x Unengaged)

According to the model, the log of the odds of a child having a secure attachment with their mother at 12 months was negatively related to disruptive co-regulation ($p \leq .05$; Table 9). In other words, after accounting for bradycardia, co-regulation, and the interactions between them, the higher the percentage of disruptive co-regulation in the dyad at 6 months, the less likely it is that the child would be securely attached at 12 months. More specifically, each 1% increase in disruptive co-regulation is associated with a 42% decrease in the odds of secure attachment. As disruptive co-regulation at 6 months increases, the chances that the infant will be securely attached at 12 months decreases. Bradycardia ($p = .59$), Symmetrical ($p = 0.09$), Asymmetrical ($p = .32$), Unengaged ($p = .72$), Bradycardia/Symmetrical interaction ($p = .60$), Bradycardia/Asymmetrical interaction ($p = .33$), and Bradycardia/Unengaged interaction ($p = .33$) were not significant in the model. The Bradycardia/Disruptive interaction predicted success perfectly and was automatically dropped from the model. Even though symmetrical co-regulation was insignificant, the coefficient is positive and the p value is close to the .05 cutoff, which indicates that the relationship is trending in a direction consistent with the hypotheses.

Interaction effects between bradycardia at 6 months and co-regulation at 9 months were evaluated with an eight-predictor logistic model, Model E, to test the research hypotheses regarding the likelihood that an interaction between bradycardia and co-regulation would predict attachment. The logistic regression analysis was carried out by the Logistic procedure in Stata® version 11.1 (StataCorp, 2009) in the Windows 7 environment. The results showed that

Predicted logistic of (Attachment) = 2.914 + (-2.489937)Bradycardia + (-.0806995)Symmetrical + (.5036443)Asymmetrical + (-.0954301)Unengaged + (.0883565)(Bradycardia x Symmetrical) + (-.4972368)(Bradycardia x Asymmetrical)

According to the model, the log of the odds of a child having a secure attachment with their mother at 12 months was positively related to asymmetrical co-regulation ($p \leq .05$; Table 10). In other words, after accounting for bradycardia, co-regulation, and the interactions between them, the higher the percentage of asymmetrical co-regulation in the dyad at 9 months, the more likely it is that the child would be securely attached at 12 months. More specifically, each 1% increase in asymmetrical co-regulation is associated with a 65% increase in the odds of secure attachment. In other words, as asymmetrical co-regulation at 9 months increases, the chances that the infant will securely attached at 12 months increases. Bradycardia (p = .58), Symmetrical (p = 0.38), Unengaged (p = .71), Bradycardia/Symmetrical interaction (p = .91), Bradycardia/Asymmetrical interaction (p = .36), and interaction (p = .33) were not significant in the model. The Bradycardia/Disruptive interaction predicted failure perfectly and the Bradycardia/Unengaged interaction predicted success perfectly, so these two variables were automatically dropped from the model.

Discussion

Summary of Research Questions, Hypotheses, and Results

The data analyses revealed several significant and non-significant findings. Four of the findings are of particular interest. First, negative dyadic communication patterns are related to the absence of an infant orienting response during a perturbed social task between mother and infant. Second, positive dyadic co-regulation patterns are related to the presence of an infant orienting response during a perturbed social task between mother and infant. Third, there is no significant difference between the infants who experience an orienting response at 6 months during the perturbed social task and their attachment to their mothers at 12 months. Fourth, accounting for interactions between the infant orienting response and co-regulation, disruptive co-regulation at 6 months predicts insecure attachment and asymmetrical co-regulation at 9 months predicts secure attachment. It is important to note that although the fourth finding may be due to a type 1 error, valuable information can be gleaned from them. Below are a complete summary of the findings.

Research Question #1. Are unique patterns of mother-infant co-regulation behaviors at 6 or 9 months of age related to the presence or absence of the infant orienting response during the maternal arm restraint and still face procedure (MAR-SFP) at 6 months?

Hypothesis. The hypotheses for the first research question were: (a) More positive patterns of co-regulation at six months will increase the likelihood of bradycardia at six months, and (b) More negative patterns of co-regulation at six months will decrease the likelihood of bradycardia at six months.

Results. Findings indicate linkages between six months asymmetrical co-regulation and an increasing likelihood that the infant will experience an orienting response. Additionally, findings also showed that as unengaged co-regulation increases, the chance of the infant experiencing an orienting response decreases. These findings supported my hypotheses. Bradycardia is a physiological indicator of an orienting response. The infants who exhibited an orienting response during MAR-SFP were orienting to the novel experience of having their arms restrained by mother while she maintained a neutral face expression. The finding indicates that infants are more likely to exhibit an orienting bradycardia when they have high levels of asymmetrical co-regulation (i.e., positive interactions with their mother) during free play. This confirms the hypothesis of Porter and Jones (2011) that the infant's orienting may be an indicator that the infant finds the restraint interaction as a departure from the norm, because their interactions with mother are generally positive. The second finding, that unengaged co-regulation is related to the lack of bradycardia, greatly enhances the first finding. Those infants that generally experience negative interactions with mother seem to find the maternal arm-restraint less novel than those who experience positive interactions. These finding expand upon previous research, which showed a decrease in infants' vagal tone (as measured by Respiratory Sinus Arrhythmia) during the still-face procedure (Moore, Hill-Soderlund, Propper, Calkins, Mills-Koonce, & Cox, 2009). Interestingly, infants of sensitive mothers did not return to baseline vagal tone upon reunion during the still face, but remained at a lower level of RSA, indicating residual distress. These previous findings may suggest that the still-face procedure was more distressing for infants of sensitive mothers, because it violated infants' relational expectancies based on their history of interaction with their caregivers (Moore, Hill-Soderlund, Propper, Calkins, Mills-Koonce, & Cox, 2009). The finding from the current study may extend this conclusion and show that the infant's physiological response to the arm-restraint still-face procedure is influenced not only by maternal sensitivity, but by the dynamic co-regulated features of interactions that occur in mother and infant relationships.

Research Question #2. Does the presence of bradycardia during the maternal arm restraint at 6 months of age predict attachment classification during the Strange Situation Procedure at 12 months?

Hypothesis. The hypotheses for the second research question were: (a) The presence of bradycardia will predict secure attachment patterns and (b) the lack of bradycardia will predict insecure (avoidant or resistant) attachment patterns.

Results. Findings did not support a link between bradycardia at 6-months and subsequent attachment classification at 12 months.

There were no significant differences on attachment outcomes based on whether an infant exhibited a brief bradycardia during the arm-restraint procedure at 6-months of age. Because the orienting response is an evolutionary physiological reflex to a novel stimulus, I anticipated that it would be related to the Behavioral Control System (BCS). According to Bowlby (Marvin & Britner, 1999) the BCS evolved to help promote human survival therefore, I had anticipated that an orienting response during a socially disruptive task and a phenomenon that precedes “fight or flight” responses, might also serve as proxy for infants’ relationship expectancies and predict subsequent attachment organization. It is possible that these variables are not statistically significant in my analyses, because of the length of time between the 6 month and 12 month measures. During the first year, the history of interactions between infant and mother will contribute to the organization of the attachment outcome. Past work suggests that the organization of the attachment system is “not a random phenomenon but [is] logically related to factors affecting the progression of the mother-infant relationship” (Egeland & Farber, p. 769, 1984). Therefore, while bradycardia was linked to concurrent measures of co-regulation at 6-months, it may not be sufficient to capture the range of experience in the intervening months that produce the attachment outcome measured at 12 months. I suspect that if bradycardia had been measured again concurrently with attachment that it may have been a better indicator of the current relationship status resulting in a potential link to attachment organization. An alternative explanation is that there may be additional factors that mediate the relationship between orienting response and attachment. This possibility is discussed in the third research question, below.

Research Question #3. Is the interaction between the orienting response and co-regulation related to attachment?

Hypothesis. The hypotheses for the third research question were: (a) An interaction between bradycardia and symmetrical and asymmetrical co-regulation predicts secure attachment, (b) An interaction between bradycardia and unengaged and disruptive co-regulation predicts insecure attachment.

Results. Interactions between bradycardia and co-regulation were not significant predictors of attachment. Although, accounting for those interactions in the analyses created new findings. Evans and Porter (2009), analyzed co-regulation and attachment and found that symmetrical co-regulation at 6 months predicted secure attachment and unilateral co-regulation predicted insecure attachment. In the current study, after accounting for interactions, disruptive co-regulation at 6 months predicted insecure attachment and asymmetrical co-regulation at 9 months predicted secure attachment. Introducing the interactions between co-regulation and bradycardia unveiled significant predictors of attachment. This may be because the interactions are taking into account both physiological and social influences. Because co-regulation predicts bradycardia and co-regulation predicts attachment, there may also be a relationship between bradycardia (ie: infant physiology) and attachment. Bradycardia is a very brief physiological phenomenon, therefore, it may not have the robustness to inform us about a mother-infant interaction measured months later. A more salient physiological predictor may be vagal tone which recent research has shown to be related to attachment (Hill-Soderlund, et al., 2008).

Another interpretation of the interaction model is that this may be a Type I error, where the analyses reported a rejection of the null hypotheses, when it should not have been rejected. In other words, the results were a false positive. According to Peduzzi, Concato, Kemper and et al. (1996), the appropriate number of events per variable in order to predict accurate results is 10 or more. If less than 10, the regression coefficients may be biased in both a positive or negative direction. Also, the variance may be over and under estimated and the 90% confidence intervals may be inaccurate. Peduzzi, Cancato, Kemper and et al. (2003) state that less than 10 events per variable "can lead to major problems" (p. 1373). In my regression model, there are 11 variables. Therefore, it would be optimal to have at least 110 participants. Unfortunately, there are only 63 participants. Although I chose to interpret these findings with extreme caution, as they may not be considered reliable, I find it valuable to examine the relationship between bradycardia, co-regulation, and attachment. These findings teach us that the infant's physiology is responding to their social environment in a complex way and vice versa. It is widely accepted that "there is a two-way interplay between individuals and their environments," (Rutter, et al., 1997, p. 38). Pianta and Egeland (1994), for example, demonstrated that stress increases occurrences of depression, but also that occurrences of depression can lead to higher levels of stress. As bradycardic and co-regulation elements interact, it seems possible that positive dyadic interactions predict secure attachment and negative dyadic interactions predict insecure attachment.

Conclusions

The evolution of animals, including humans, developed physiological and behavioral mechanisms that provide the greatest advantage for survival and reproduction. One physiological survival mechanism is the orienting response, marked by brief bradycardia, which preps the vagal system for arousal or maintaining baseline. Another survival mechanism, this one behavioral, is an affectional bond known as attachment. Orienting response and attachment may have environmental components that encourage their efficiency. This research study examined the relationship between orienting response, attachment, and the co-regulation of mother-infant social interactions.

The disrupted nature of the Maternal Arm Restraint – Still Face Procedure (MAR-SFP) yielded several insights about mother-infant interactions and the mother-infant relationship.

Findings suggest that as asymmetrical states increased (partners positively oriented toward each other and actively observing the other), the odds of experiencing bradycardia (orienting response) at the onset of the maternal arm-restraint also increased. For these infants, a mild disruption in their normal interaction with their mothers was novel enough to elicit a physiological response. It is not merely a positive social interaction that is associated with bradycardia. If that were the case, symmetrical co-regulation should have also been significantly associated with bradycardia, and it was not. It is specifically the asymmetrical interactions that are associated with the orienting response. This is because an asymmetrical interaction consists of a mother who is engaging the infant and the infant is observing her with interest. The infant has built an expectation around this pattern of mother engaging him/her. During the MAR-SFP, the mother behaves in exact opposition of the asymmetrical co-regulation pattern. Thus providing a novel interaction for the infant; this increases the likelihood of bradycardia. High amounts of unengaged states (partners not oriented toward each other) indicated greater odds of not experiencing bradycardia. For these infants, lack of orientation to maternal arm-restraint may suggest that maternal disruption of infant activity is less likely to induce a bradycardiac event during the mild frustration task.

Since bradycardia is related to the violation of expected social interactions, it follows that bradycardia will also be related to attachment, which measures the mother-infant relationship. Co-regulation states were only significant predictors of infant attachment when interactions between bradycardia and co-regulation were accounted for. When interactions are considered, disruptive states (one partner interfering with the other’s intention) at 6 months predicted insecure attachment at 12 months. In addition, asymmetrical states at 9 months predicted secure attachment at 12 months.

This study demonstrated that mother infant interactions create an expected pattern of behavior for infants. When these expectations are violated, the infant has a physiological reaction. Furthermore, considering both the physiology and environment of the infant, dyadic positive and negative interactions affect the quality of the mother-infant relationship several months later.

Recommendations for Further Research

There are several key ideas that may be elaborated on in future research. First, having a measure of bradycardia at 9 and 12 months would help us understand how the infant's physiology changes or remains stable over time. Second, having longitudinal bradycardia measures along with co-regulation data would allow us to analyze the direction of effects between physiology and environment. Third, an emerging area of attachment study is the sub-group of disorganized attachment. It would be useful to understand the physiological reactions along with the co-regulation states of those infant who are categorized as disorganized.

Limitations

The majority of this sample was white and well-educated. This limits the generalizability to other ethnicities and socio-economic groups. When trying to run the interaction model, the power was very low, therefore, a larger sample size would ensure accurate and dependable results. There was no concurrent measure of bradycardia at 9 and 12 months, therefore, I relied on distal rather than proximal variables to predict attachment.

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Appendices

Tables

Table 1

Descriptive Statistics of Demographic Variables

Maternal Education at 6 Months

Education	Numeric	Freq.
Some high school	1	8
Graduated from high school	2	10
Some college (1-2 years)	3	12
Completed 2 year technical or assoc. degree	4	12
Graduated from college 4 year degree	5	22
Some post-graduate education	6	24
Completed post-graduate education	7	5
Missing	.	8

Maternal Age at 6 months

	Mean	Standard Dev.	Minimum	Maximum
Age	25.14	3.66	20	40

Child Ethnicity

Ethnicity	Numeric	Freq.
American Indian or Alaskan Native	1	0
Asian or Pacific Islander	2	1
Black or African American	3	0
Latino or non-white Hispanic	4	1
White of Hispanic Origins	5	3
White not of Hispanic Origins	6	87
Other	7	1
Missing	.	8

Table 2

Correlations of Dependent and Independent Variables

	Bradycardia 6 months	Attachment 12 months	Symmetrical 6 months	Asymmetrical 6 months	Unilateral 6 months	Disruptive 6 months	Unengaged 6 months	Symmetrical 9 months	Asymmetrical 9 months	Unilateral 9 months	Disruptive 9 months	Unengaged 9 months
Bradycardia 6 months	1											
Attachment 12 months	-.048	1										
Symmetrical 6 months	-.046	.218*	1									
Asymmetrical 6 months	.143	-.059	-.285**	1								
Unilateral 6 months	.022	-.218*	-.944**	-.037	1							
Disruptive 6 months	-.078	-.002	-.106	.130	.048	1						
Unengaged 6 months	-.217	.035	-.081	.203*	-.031	.097	1					
Symmetrical 9 months	-.055	.051	.020	-.092	.000	-.031	.006	1				
Asymmetrical 9 months	-.045	-.092	.184	.028	-.201	-.051	.022	-.144	1			
Unilateral 9 months	.120	-.036	-.035	.088	.026	-.005	-.163	-.944**	-.092	1		
Disruptive 9 months	-.342**	-.037	-.044	.134	-.005	-.053	-.069	.065	.145	-.138	1	
Unengaged 9 months	-.146	.097	.143	-.042	.113	.274*	.735**	.184	-.083	-.361**	-.055	1

*. Correlation is significant at the .05 level (two-tailed).

**. Correlation is significant at the .01 level (two-tailed).

Table 3.1

Co-Regulation as a Percentage of Session

Variable		Mean	Standard Dev.	Minimum	Maximum
Symmetrical	6 months	38.25	28.95	0	96.87
	9 months	45.23	15.01	18.79	90.07
Asymmetrical	6 months	7.95	8.9	0	41.12
	9 months	2.51	4.11	0	14.92
Unilateral	6 months	52.68	28.21	2.35	96.05
	9 months	50.37	15.70	8.31	79.00
Disruptive	6 months	.13	.54	0	3.92
	9 months	.09	.33	0	1.64
Unengaged	6 months	.47	1.5	0	12.2
	9 months	1.16	3.33	0	25.93

Table 3.2

Co-Regulation Frequencies – How many dyads experienced a co-regulation category

Variable		Freq.
Symmetrical	6 months	70
	9 months	70
Asymmetrical	6 months	88
	9 months	29
Unilateral	6 months	101
	9 months	70
Disruptive	6 months	8
	9 months	5
Unengaged	6 months	20
	9 months	26

Table 3.3

Frequencies of Dependent and Independent Variables

Bradycardia

	Numeric	Freq.
No	0	33
Yes	1	45
Missing	.	23

Attachment

	Numeric	Freq.
Insecure	0	27
Secure	1	57
Missing	.	17

Attachment Categories

	Numeric	Freq.
Avoidant	1	14
Secure	2	57
Resistant	3	12
Missing	.	18

Table 4

Regression High Leverage Values

ID	Leverage	Brady	Symmetrical	Asymmetrical	Unilateral	Disruptive	Unengaged
3	.37	Yes	29.29	26.66	41.53	2.52	0
4	.26	Yes	15.31	36.69	45.94	2.06	0
71	.23	No	65.76	16.86	13.65	0	3.74
100	.44	No	1.21	0	94.86	3.92	0

Note. Leverage values were calculated from Cook's D standardized residuals to look for possible outliers or influential observations in the data.

Table 5

Logistic Regression – Model A – Co-regulation at 6 Months predicting Bradycardia

Variable	Coeff.	Standard Error	z	p	95% Conf. Interval	
Symmetrical	.0007057	.0087911	0.08	0.936	-0.0165245	0.0179359
Asymmetrical	.0607329	.0311533	1.95	0.051	-0.0003265	0.1217922
Disruptive	-.5505315	.3444482	-1.60	0.110	-1.225638	0.1245746
Unengaged	-.7947043	.3453858	-2.30	0.021	-1.471648	-0.1177606

Table 6

Logistic Regression Output – Model B – Co-regulation at 6 Months Predicting Bradycardia (With Unilateral Co-regulation in place of Symmetrical)

Variable	Coeff.	Standard Error	z	p	95% Conf. Interval
Asymmetrical	.0598912	.0289659	2.07	0.039	.0031191 to 0.1166634
Unilateral	.0005146	.0088218	0.06	0.953	-.0167759 to 0.0178051
Disruptive	-.5462968	.3396555	-1.61	0.108	-1.212009 to 0.1194157
Unengaged	-.7898807	.3439642	-2.30	0.022	-1.464038 to -0.1157233

Table 7

One Sample Chi Square Test – Bradycardia Predicting Attachment

Bradycardia	Attachment		Total
	Insecure	Secure	
No	8	19	27
Yes	13	25	38
Total	21	44	65

Pearson chi2(1) = 0.1515, p = 0.697

Table 8

Multinomial Regression Output – Bradycardia Predicting Attachment Categories

Odds Comparing Alternative 1 to Alternative 2	Coeff.	z	p
A to C	0.69315	0.741	0.459
A to B	0.41871	0.612	0.540
C to A	-0.69315	-0.741	0.459
C to B	-0.27444	-0.356	0.721
B to A	-0.41871	-0.612	0.540
B to C	0.27444	0.356	0.721

Table 9

Logistic Regression Output - Model D – Interactions at 6 Months Predicting Attachment

Variable	Coeff.	Standard Error	z	p	95% Conf. Interval
Bradycardia	-.6479268	1.20179	-0.54	0.590	-3.003392 to 1.707539
Symmetrical	.0212316	.0124909	1.70	0.089	-.0032502 to .0457133
Asymmetrical	-.103997	.104794	-0.99	0.321	-.3093895 to .1013954
Disruptive	-.8586454	.3920289	-2.19	0.029	-1.627008 to -.0902829
Unengaged	.1247603	.3475299	0.36	0.720	-.5563859 to .8059065
Brady*Sym	-.0100722	.0190373	-0.53	0.597	-.0473847 to .0272403
Brady*Asym	.1103185	.1140279	0.97	0.333	-.1131721 to .3338091
Brady*Disr	(dropped)				
Brady*Uneng	-.7436743	.7662049	-0.97	0.332	-2.245408 to .7580596

Table 10

Logistic Regression Output - Model E - Interactions at 9 Months Predicting Attachment

Variable	Coeff.	Standard Error	z	p	95% Conf. Interval
Bradycardia	-2.489937	4.518978	-0.55	0.582	-11.34697 to 6.367098
Symmetrical	-.0806995	.0920239	-0.88	0.381	-.2610631 to .0996641
Asymmetrical	.5036443	.2408157	2.09	0.036	.0316541 to .9756344
Disruptive	(dropped)				
Unengaged	-.0954301	.259277	-0.37	0.713	-.6036037 to .4127434
Brady*Sym	.0883565	.0953265	0.93	0.354	-.0984801 to .275193
Brady*Asym	-.4972368	.2676101	-1.86	0.063	-1.021743 to .0272694
Brady*Disr	(dropped)				
Brady*Uneng	(dropped)				

Figures

Figure 1

Regression Leverage Values