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Maternal Sensitivity and Patterns of Infant Respiratory Sinus Arrhythmia and Infant Distress in Response to Maternal Engagement and Disengagement

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Maternal Sensitivity and Patterns of Infant Respiratory Sinus Arrhythmia and Infant Distress in Response to Maternal Engagement and Disengagement

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Abstract

Patterns of respiratory sinus arrhythmia (RSA), an index of parasympathetic nervous system (PNS) activation, are crucial in socioemotional development (Porges & Furman, 2011). Polyvagal theory (Porges, 2007) posits that adaptive patterns of RSA are characterized by flexibility, such that, during challenge, infant RSA lowers, to actively attend to environmental demands and marshal resources to support the infant. When challenge is removed, as in normal social engagement with the mother, infant RSA increases, facilitating a shift towards the PNS and promoting relaxation. The Still-Face paradigm (SFP, Tronick et al., 1978) is useful for studying RSA during social engagement with the mother (2-min), interruption by challenge (2-min of maternal disengagement), followed by 2-minute reunion (maternal reengagement). On average, most infants show adaptive RSA patterns (high RSA, low RSA, high RSA). Group mean data, however, do not fit half of infants (Bazhenova et al., 2001; Moore & Calkins, 2004). The present study represents methodological advances over previous research, which have only examined group means for each episode of the SFP and episode-to-episode changes. The present study used growth mixture models to identify trajectories of RSA across the entire SFP and examine links between trajectories and maternal sensitivity. 197 6-month-old infants and their low-income (35%<$10,000, $10,000>18%<$30,000) mothers (38% African American, 16% White, 24% Multiracial, 13% Latina) participated in a larger study of maternal caregiving. RSA was extracted in 30-second epochs during episodes of the SFP (Porges, 1985). Sensitivity was reliably coded from tapes of normal play and reunion episodes of the SFP. Infant level of distress during the reunion episode was coded by reliable coders. A cubic growth mixture model was tested with mean RSA for each episode of the SFP as data points. Three unique trajectories emerged: *unchanging*, *moderate suppressors*, and *steep suppressor*. Maternal sensitivity predicted classes at levels nearing significance and infant distress predicted classes. The *unchanging* class contained infants whose RSA stayed around baseline levels over the entire course of the SFP. Compared to the other classes, the infants in the *unchanging* class had mothers who were highest in maternal sensitivity and infants who were low in distress. The *moderate suppressor* class contained infants whose RSA stayed in withdrawed levels throughout the SFP, indicating that they experienced the entire SFP like it was a challenge. Compared to the other classes, the infants in the *moderate suppressor* class had mothers who were lowest in maternal sensitivity and infants who were more distressed. The *steep suppressor* contained one infant whose RSA sharply withdrew throughout the SFP. This infant's mother was low in sensitivity and the infant was distressed. Ameliorations of unique and nuaned trajectories of vagal regulation are discussed, in light of the polyvagal theory. Implications for polyvagal theory and future research directions are discussed, specifically how to expand the knowledge about infant phsyiologial development that may not fit into predictions of polyvagal theory. Limitations and clinical applications are also discussed.

Chapter I

INTRODUCTION

Polyvagal theory posits that adaptive physiological and behavioral regulation in infancy is linked to emotion regulation skills in later life, and that sensitivity of maternal caregiving impacts the development of these systems in infants (Moore & Calkins, 2004; Moore et al., 2009; Propper et al., 2008; Porges & Furman, 2011). Therefore, it is possible that maternal sensitivity may explain unique variations in infant physiological regulation. Some research has examined the link between maternal sensitivity and infant physiological regulation (e.g., Conradt & Ablow, 2010; Moore et al., 2009), but results have been mixed. Methodological limitations have hampered efforts to interpret the meaning of the mixed results that have emerged. The present study will address gaps in existing research by using a person-centered (von Eye & Bogat, 2006), rather than the typically used variable-centered approach, to examine unique patterns of infant physiological regulation and how those are related to aspects of maternal caregiving.

Polyvagal Theory

The ability to physiologically and behaviorally regulate in response to environmental demands is crucial for socioemotional development in infancy. The sympathetic nervous system (SNS), which is a primitive division of the autonomic nervous system, prepares the body for stressful or emergency situations, in which the individual can mobilize behaviors that allow them to either fight or flee from a challenge (i.e., fight or flight behaviors). In contrast, the parasympathetic nervous system (PNS), a later developed autonomic system, controls the body during ordinary or relaxing situations, in which the individual can conserve and restore their energy.

Polyvagal theory focuses on the development of the PNS and PNS influence on the body, particularly the heart, via the vagus nerve (Porges, 2007). The vagus nerve is the tenth cranial nerve, which controls suppression of the sinoatrial node, which is the primary cardiac pacemaker (Porges, 2007). Through this vagal influence on the heart, the PNS can limit the rate at which the heart can beat and can functionally slow down heart rate (Porges & Furman, 2011).

Polyvagal theory posits that when the environment is perceived as calm and safe, the vagus nerve becomes activated in order to promote an autonomic shift towards the PNS and away from the SNS (Porges & Furman, 2011). When the environment is perceived as unsafe, the influence of the vagus nerve decreases, in order to promote a shift away from the PNS and towards the SNS (Porges & Furman, 2011). This shift allows the body to mobilize and activate, in order to respond adaptively to environmental stressors.

The vagus nerve is also connected to the emergence of social engagement behaviors, due to evolutionary connections between the vagus nerve and the muscles that control the face, head, and neck (Porges, 2007). When there is increased influence of the vagus nerve, individuals are able to engage socially, increase eye gaze, foster facial expression, and listen (Porges, 2007). When there is decreased influence of the vagus nerve, social communication and social behavior are reduced (Porges, 2007). Theory states that if the vagus nerve is not activated often (i.e., if the environment is mostly perceived of as a challenge) or if there are physical problems (i.e., prematurity or illness), then the young infant may develop diminished capacities for social engagement behaviors, as well as difficulties in behavioral state regulation and affective regulation (Porges & Furman, 2011).

The influence of the vagus nerve cannot be directly measured, and thus, is quantified by processes that represent its function, such as respiratory sinus arrhythmia (RSA). RSA provides a continuous measure of the functional influence of the vagus nerve on the heart. RSA is the naturally occurring variation in heart rate that is consistent with the frequency of spontaneous breathing. It can be measured by analyzing beat-to-beat heart rate variability (Bernston et al., 1997). RSA varies as a function of environmental conditions in which behavioral and physiological demands change (Porges, 2007).

RSA has been measured in numerous ways and has been widely researched (e.g., Graziano & Derefinko, 2013). RSA withdrawal (i.e., lowering of RSA) represents a reduction of PNS activity, allowing a shift towards sympathetic activation in order to provide the body with resources to respond to a challenge. Polyvagal theory suggests that RSA withdrawal in response to perceived challenge is an indicator of adaptive physiological regulation because it represents the ability to shift resources towards managing a stressor (Porges, 2007). In contrast, RSA augmentation in response to perceived environmental calmness is adaptive because it represents the ability to increase PNS activation, reserve energy, and relax.

Infant RSA in Response to Maternal Engagement and Disengagement

Aspects of the polyvagal theory have been assessed using the Still-Face Procedure (SFP; Tronick et al., 1978). The SFP is a widely used research method that involves a period of engagement and then deliberate disengagement between an adult and an infant. The task serves as a standardized way of examining infant RSA and behavior during a normal environmental period (i.e., social engagement with an adult) and during a challenge (i.e., disengagement from an adult; Tronick et al., 1978), followed by a return to social engagement. First, an adult and an infant engage in a normal play interaction episode for two minutes. Next, during the still-face episode, the adult disengages from the infant by becoming abruptly unresponsive and adopting a still, expressionless face for two minutes. This still-face episode is meant to serve as a moderately distress-eliciting experience for infants (Tronick et al., 1978). Finally, the reunion episode involves the adult reengaging with the child and resuming normal interactions for two minutes.

Theory would suggest that across the SFP, infants would show a pattern of RSA withdrawal in response to the challenge of the still face episode, followed by subsequent PNS activation (i.e., augmentation of RSA) during the reunion episode. The shift from the normal play interaction to the still-face episode is challenging for infants, so infants should show vagal withdrawal, which is a response consistent with a response to challenge. Such vagal withdrawal would indicate that infants are adaptively shifting away from PNS activation and towards SNS activation in order to mobilize resources to manage the challenge. During the shift from the still-face episode to the reunion episode, an infant would theoretically show RSA augmentation (i.e., RSA would increase), indicating that they are no longer dealing with a challenge, can increase PNS activation over the heart and body, and can relax. Over the entire course of the SFP, a flexible and changing pattern of RSA change would be expected.

Research has not examined changes in infant RSA across the SFP in such a person-centered way. Instead, research has focused on RSA changes in infant group RSA means from one episode to the next episode. For example, changes in infants' mean RSA has been examined during the shift from normal play interaction to the still face episode. Consistent with polyvagal theory, the well documented lowering of infant RSA (i.e., RSA withdrawal) in the shift from the normal play interaction to the still face episode suggests that, on average, infants find social disengagement challenging (Adamson & Frick, 2003; Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 1996). Groups of infants, on average, have shown increased expression of negative affect during this shift (Bazhenova et al., 2001; Ham &

Tronick, 2006; Moore & Calkins, 2004; Porges, 2007; Weinberg & Tronick, 1996). This increase of distress suggests that infants are communicating that they are experiencing stress and need help (Propper & Moore, 2006).

Changes in infant RSA have also been examined across the shift from the still face episode to the reunion episode. Consistent with polyvagal theory, the well documented increase in infant RSA (i.e., vagal augmentation) during the shift from the still face episode to the reunion episode suggests that, on average, infants find reengagement with an adult calming (Adamson & Frick, 2003; Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 1996). Groups of infants, on average, have shown decreased expression of negative affect and increased expression of positive affect (Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 1996). This decrease of distress suggests that infants are no longer experiencing stress (Propper & Moore, 2006).

Inconsistent with polyvagal theory, some researchers (Bazhenova et al., 2001; Moore & Calkins, 2004) have found groups of infants whose RSA changes from episode to episode in the SFP do not fit with the group mean. Both Bazhenova and colleagues (2001) and Moore and Calkins (2004) found a group of infants who did not show the typical pattern of vagal withdrawal in the shift from the normal play interaction to still face episode. Instead, these infants failed to show RSA withdrawal, yet displayed more negative behaviors. The fact that there was no RSA withdrawal means that the PNS was activated. Yet, despite PNS activation, these infants showed negative affect. This is not consistent with polyvagal theory.

Both Bazhenova and colleagues (2001) and Moore and Calkins (2004) also found a group of infants who did not show the typical pattern of increase in RSA in the shift from the still face episode to the reunion episode. Instead, these infants failed to show an increase in RSA. These infants continued to experience negative affect during this shift. The group mean approach limits the interpretations of these results because it is not clear which infants are showing vagal withdrawal or vagal augmentation in which of the two task changes (normal interaction to still face episode and still face to interaction). Thus it is not possible to ascertain whether there are any specific infants whose trajectory of RSA scores matches the trajectory expected by polyvagal theory. It is not possible to understand individual differences of RSA and behavioral responses during the SFP because of such methodological limitations.

Methodological Limitations of Previous Research

The methodological approaches used by previous research limits the understanding of atheoretical physiological and behavioral responses across the SFP. The variable-centered nature of previous research insinuates that the population of infants they are assessing are homogeneous, but, clearly, there is evidence that distinct subgroups of infants exist within these populations (Bazhenova et al., 2001; Moore & Calkins, 2004; von Eye & Bogat, 2006). Additionally, the group mean approach used by previous research does not allow for examination of individual differences and may obscure the RSA patterns of many infants who do not respond similarly to the group mean. Furthermore, by only measuring RSA change from one episode to the next episode, results miss out on patterns of infants' RSA over the entire procedure.

A person-centered approach could fill the gap of previous research by identifying unique response trajectories of infant RSA among the data. Using growth mixture models (GMM; Muthén & Muthén, 2006), the current study would be able to identify unique subgroups of infants who display similar or different trajectories of RSA across the entire SFP. Additionally, GMM would allow for the addition of a predictor of unique trajectories of RSA. Elements of maternal caregiving are important to add in as a predictor of RSA because polyvagal theory suggests that interactions with caregivers during early infancy are crucially important in autonomic development (Porges & Furman, 2011). Different experiences within interactions with caregivers during the first months of life, when the vagal nerve is developing rapidly, may contribute to differences in RSA across the SFP.

Maternal Caregiving and RSA

Maternal sensitivity, the degree to which a mother is able to accurately understand her infant's needs and respond quickly and appropriately within their social interactions (Ainsworth et al., 1978; NICHD Early Child Care Research Network, 1999), theoretically helps the infant develop adaptive physiological and behavioral systems (Moore & Calkins, 2004; Moore et al., 2009; Propper et al., 2008). Polyvagal theory posits that a sensitive and consistent mother-infant relationship will lead to the development of adaptive physiological and behavioral systems. In interactions with their sensitive mother, the infant will theoretically experience increased PNS activation and decreased distress because they will find this social interaction calming and relaxing. If they are experiencing challenge, infants will be able to use their mother as an external source of regulation, in that they can signal to her that they need help regulating physiologically, and she will be able to provide prompt and effective help to them. Infants of insensitive mothers may not have the ability to rely on their mother as a source of physiological and behavioral regulation. These infants may not be used to getting their emotional and physical needs met by their mother during times of distress (Slade, 2004). Thus, these infants may have more dysregulated physiological and behavioral responses due to the necessity of using alternative means to cope, like self-soothing. Thus, it is possible that variations in physiological and behavioral regulation may be linked to differences in maternal sensitivity.

Infants of sensitive mothers and infants of insensitive mothers should show different patterns of RSA across the SFP. During the shift from normal play interaction to the still-face episode, infants of sensitive and insensitive mothers would be expected to both show physiological and behavioral responses as if they are responding to challenge (i.e., vagal withdrawal and increased behavioral distress). During the shift from the still-face episode to the reunion episode, infants of sensitive and insensitive mothers would theoretically be expected to respond differently. Consistent with polyvagal theory, during this shift, an infant of a sensitive mother would theoretically show vagal activation and behavioral calmness, indicating that they are experiencing calmness upon reunion with their mother. Inconsistent with polyvagal theory, an infant of an insensitive mother would not theoretically show vagal activation or signs of behavioral calmness upon reunion with their mother because they will not be able to use her as a source of regulation or calmness. Over the entire course of the SFP, infants of sensitive mothers should theoretically show a flexible and changing pattern of RSA. For infants of insensitive mothers, their pattern of RSA across the entire course of the SFP may be less flexible and adaptive.

Research has not assessed the links between maternal sensitivity and infant RSA change across the SFP in such a person-centered way. Instead, previous research on maternal sensitivity has examined the link between maternal sensitivity and infant RSA and behavior through the use of group means and episode-to-episode differences. Studies have shown that sensitivity is not associated with changes in infant RSA or distress in the shift from normal interaction to still face (Conradt & Ablow, 2010; Moore et al., 2009). This makes theoretical sense because it reflects the fact that the still-face episode may be equally challenging for most infants (Adamson & Frick, 2003; Mesman, van Ijzendoorn, & Bakermans-Kranenburg, 2009).

In the shift from still face to reunion, both studies that measured this found that most infants behaviorally calmed down during this shift. One study (Conradt & Ablow, 2010) showed that infants of sensitive mothers showed an increase in RSA during this shift, which is consistent with theory. Contrasting to theoretical expectations, another study (Moore et al., 2009) showed that infants of sensitive mothers showed a decrease in RSA during this shift. It is important to note that Moore and colleagues (2009) measured maternal sensitivity during a non-distress task (i.e., freeplay task). Measuring maternal sensitivity during a task with such infrequent instances of infant distress may lead to questions about the validity of this sensitivity measure (Leerkes et al., 2009).

To ensure valid and consistent measurements of sensitivity, maternal sensitivity during the SFP task itself will be used in the present study so as to measure sensitivity at a time when the infant's distress is likely to be occurring and the mother's responses to distress will be more accurately displayed (Leerkes, et al., 2009). The proposed study will allow examination of whether maternal sensitivity is a predictor of different trajectories of RSA across the SFP and whether these trajectories differ on distress at reunion.

Overview of the Current Study

There are gaps in the literature about how to understand unique responses of infant RSA across experiences of maternal engagement and disengagement. Using a person-centered methodology, the current study will extend previous research that has only assessed group means and episodic changes of RSA across the SFP, in order to better understand individual differences in RSA. The current study will identify whether there are unique trajectories of infant RSA across the three episodes of the SFP by using GMM. Additionally, maternal sensitivity will be added as a predictor of infant RSA trajectories in order to assess the links between maternal sensitivity and the identified trajectories of infant RSA across the SFP episodes. If trajectories of RSA that differ based on maternal sensitivity are identified, this current study will examine whether these infants show different levels of distress at reunion. Trajectories are not expected to differ on distress during the still face episode because previous research has shown that most infants display distress at still face, regardless of whether or not they withdraw RSA. However, it is not clear whether trajectories would be expected to differ on levels of infant distress at reunion. For this reason, this current study will examine whether there are varying levels of distress among trajectories upon reunion. The results from the current study will be able to fill gaps in the literature and attend to the unique ways that infants respond physiologically and behaviorally, and how those responses are linked to aspects of early caregiving.

Chapter II

LITERATURE REVIEW

Polyvagal theory posits that adaptive RSA changes, in response to environmental demands, are linked to positive socioemotional outcomes (Graziano & Derefinko, 2013; Porges, 2007; Porges & Furman, 2011). Adaptive changes in RSA include increased vagal activation and behavioral relaxation during instances of environmental calmness, and vagal withdrawal and behavioral activation during instances of environmental stress (Porges, 2007). The SFP has been widely used in order to measure infant RSA in response to maternal social engagement (i.e., environmental calmness) and disengagement (i.e., environmental stress; Tronick et al., 1978). By assessing group means and episode to episode changes across the SFP, researchers have found that most infants show changes in RSA and in infant behavior that are consistent with polyvagal theory (i.e., vagal withdrawal in response to maternal disengagement during the still face episode and vagal activation in response to maternal re-engagement during the reunion episode; Adamson & Frick, 2003; Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 1996). Researchers, however, have found groups of other infants whose changes in RSA and behavior are inconsistent with polyvagal theory (Bazhenova et al., 2001; Moore & Calkins, 2004). Methodological limitations make it challenging to interpret these atypical findings. The current study will use GMM to overcome previous methodological limitations and to examine unique trajectories of infant RSA across the entire SFP. GMM will also allow for the inclusion of the predictor of maternal sensitivity, in order to assess whether differences in early maternal caregiving contribute to unique differences in infant RSA trajectories. Because of the associations between early maternal sensitivity and the development of the vagus, differences in RSA trajectories may be linked to different caregiving experiences

(Moore & Calkins, 2004; Moore et al., 2009; Propper et al., 2008). Previous studies of the links between maternal sensitivity and RSA have shown findings that were both consistent and inconsistent with polyvagal theory (Conradt & Ablow, 2010; Moore et al., 2009). The present study will address gaps in the literature to identify unique trajectories of infant RSA and clarify how those are related to maternal sensitivity and infant distress at reunion.

Polyvagal Theory

Autonomic nervous system

The autonomic nervous system is the part of the nervous system that is responsible for unconscious bodily functions, like breathing, heartbeat, body temperature, and digestive processes. The autonomic nervous system has two divisions, the SNS and the PNS. When the autonomic nervous system receives information about the body and the external environment, it responds through one of the two divisions.

Sympathetic nervous system. The SNS is the division of the autonomic nervous system that mobilizes and stimulates body processes. The SNS prepares the body for stressful or emergency situations, in which the individual can mobilize behaviors that allow them to fight the challenge or flee from the challenge (i.e., fight or flight behaviors). During SNS activation, parts of the body that are used to engage in fight or flight behaviors become activated. The SNS increases heart rate, increases the force of heart contractions, dilates the airways, and releases the body's stored energy. Other parts of the body that are less important in emergencies, like digestion and urination, slow down. The SNS is primitive, in that it begins developing in utero.

Parasympathetic nervous system. The PNS is the division of the autonomic nervous system that inhibits body processes. The PNS controls the body during ordinary or relaxing situations, in which the individual can conserve and restore their energy. The PNS slows down heart rate, decreases blood pressure, stimulates the digestive tract to process food and eliminate waste, and restores tissue. The PNS is less primitive than the SNS because it is developed later than the SNS. The PNS is partly developed in utero and is mostly developed within the first three months of life (Pereyra et al., 1992).

The vagus nerve. The polyvagal theory focuses greatly on the development of the PNS, through the influence of the vagus nerve (Porges, 2007). The vagus nerve is the tenth cranial nerve, which controls suppression of the sinoatrial node, which is the primary cardiac pacemaker (Porges, 2007). The vagus nerve has the ability to limit the rate at which the heart can beat and can functionally slow down heart rate. The vagus nerve develops to accommodate autonomic shifts towards and away from the PNS (Porges & Furman, 2011).

Polyvagal theory posits that when the environment is perceived as calm and safe, the vagus nerve becomes activated, in order to promote a shift towards the PNS (Porges & Furman, 2011). There becomes an increased influence of the myelinated vagal motor pathways, which inhibit fight or flight mechanisms of the SNS and slow down heart rate. This shift slows down the body and allows for a conservation of energy and resources. Polyvagal theory states that when the environment is perceived as unsafe, the influence of the vagus nerve decreases, in order to promote a shift away from the PNS and towards the SNS (Porges & Furman, 2011). This shift allows the body to mobilize and activate, in order to respond to environmental stressors.

Social engagement behaviors. The vagus nerve is also connected to the emergence of social engagement behaviors. There are evolutionary connections between the vagus nerve and the muscles that control the face, head, and neck (Porges, 2007). The Social Engagement System, which refers to these connections, is a part of the polyvagal theory that suggests that social engagement and communication can only be promoted at times of environmental calmness, when the vagus nerve is activated (Porges & Furman, 2011). Thus, when there is increased influence of the vagus nerve, individuals are able to engage socially, increase eye gaze, foster facial expression, and listen (Porges, 2007). When there is decreased influence of the vagus nerve, social communication and social behavior are incompatible (Porges, 2007). Thus, vagal nerve activation is important to social development, and especially important to the developing infant, who is reliant on engagement with their caregiver.

If the vagus nerve is not activated often (i.e., if the environment is mostly perceived of as a challenge) or if there are physical problems (i.e., prematurity or illness), then the young infant may develop diminished capacities for social engagement behaviors, as well as difficulties in behavioral state regulation and affective regulation (Porges & Furman, 2011). Additionally, atypical vagal development may also lower thresholds to negative or ambiguous environmental cues with the consequential use of mobilization behaviors (e.g., hyper-reactivity), which may severely limit the ability to self-soothe and calm (Porges & Furman, 2011).

Respiratory Sinus Arrhythmia (RSA): An Indicator of PNS Activation

Respiratory Sinus Arrhythmia

The influence of the vagus nerve cannot be directly measured, and thus, is quantified by processes that represent its function, like RSA. RSA can be quantified to provide a continuous measure of functional influence of the vagus nerve on the heart. RSA is the naturally occurring variation in heart rate that is consistent with the frequency of spontaneous breathing. It can be measured through analyzing beat-to-beat heart rate variability (Bernston et al., 1997). RSA is not constant and varies as a function of environmental conditions in which behavioral and physiological demands change. RSA corresponds to vagal activation, with higher levels of RSA related to greater vagal regulation and lower levels of RSA related to vagal withdrawal (Bernston et al., 1997). RSA has been widely measured as a research tool to measure the influence of the vagus nerve and has been used in many ways.

Baseline RSA. Researchers have measured RSA at baseline, or during periods of normal, unremarkable situations, in order to measure RSA during the absence of environmental challenge. Researchers used this method because they related the level of RSA at baseline to the capacity at which RSA could be regulated (Porges, 1996). According to polyvagal theory, higher RSA at baseline serves to promote growth and restoration and is considered adaptive during periods when the infant is not exposed to stress (Porges, 1995; Porges, Doussard-Roosevelt, & Maiti, 1994). Contrastingly, low RSA at baseline represents a vulnerability to stress (Porges et al., 1994).

High RSA at baseline has been related to positive social and emotional outcomes. In children, higher levels of baseline RSA were correlated with greater emotional expressivity (Cole et al., 1996), less temperamental difficulty (Stifter & Fox, 1990), more secure attachment (Izard et al., 1991), reduced risk for delinquency and externalizing psychopathology (Pine et al., 1998), and buffered effects from familial stress (Katz & Gottman, 1995). Low RSA at baseline has been related to risk factors. Low levels of RSA at baseline have predicted internalizing symptoms (Gentzler, Santucci, Kovacs, & Fox, 2009; Gentzler, Rottenberg, Kovacs, George, & Morey, 2012; Hopp, et al., 2013; Wetter & El-Sheikh, 2012), externalizing symptoms (Hinnant & El-Sheikh, 2013), and behavior problems (Calkins, 1997; Dale, et al., 2011) in children. Although baseline RSA has been shown to be a good general indicator of PNS regulation, research has also suggested that assessing change in RSA is also useful to represent PNS activation.

RSA Withdrawal. RSA withdrawal, a reduction of PNS activity in response to stress, represents a shift away from vagal activation and parasympathetic activation and towards sympathetic activation in order to provide the body with resources to respond to a challenge. Polyvagal theory suggests that RSA withdrawal in response to perceived challenge is an indicator of adaptive physiological regulation because it represents the ability to shift resources towards managing a stressor (Porges, 2007).

RSA withdrawal in response to challenge has been linked to positive outcomes. Specifically, research has shown a link between RSA withdrawal and higher soothability (Huffman et al., 1998; Stifter & Corey, 2001), more attentional control (Huffman et al., 1998; Suess, Porges, & Plude, 1994), and better emotion regulation (Calkins, 1997; Porges, Doussard-Roosevelt, Portales, & Seuss, 1994) in infants.

Infant RSA in Response to Maternal Engagement and Disengagement

Still Face Procedure

Components of the polyvagal theory and infant PNS activation in response to challenge have been assessed using the SFP (Tronick et al., 1978). The SFP is a widely used research method that involves a period of engagement and then deliberate disengagement between an adult and an infant. The task serves as a standardized way of measuring infant RSA and behavior during a normal environmental period (i.e., social engagement with an adult) and during a challenge (i.e., disengagement from an adult).

First, an adult and an infant engage in a normal play interaction episode for two minutes. Next, during the still-face episode, the adult disengages from the infant by becoming abruptly unresponsive and adopting a still, expressionless face for two minutes. This still-face episode is meant to serve as a moderately distress-eliciting experience for infants (Tronick et al., 1978).

Finally, the reunion episode involves the adult reengaging with the child and resuming normal interactions for two minutes.

Theory would suggest that across the SFP, all infants should show a similar pattern of RSA withdrawal and subsequent activation. Theoretically, from the normal play interaction to the still-face episode, an infant would show a response like they are responding to challenge. They would theoretically show vagal withdrawal, indicating that they are adaptively shifting away from PNS activation and towards sympathetic activation in order to mobilize resources to manage the challenge. During the shift from the still-face episode to the reunion episode, an infant should theoretically show vagal activation, indicating that they are not dealing with a challenge anymore, can increase PNS activation over the heart and body, and can relax. Over the entire course of the SFP, a flexible and changing pattern of RSA change would be expected. Research has not assessed the SFP in such a person-centered way. Instead, research has mostly looked at RSA changes among group means of infants from one episode to the next episode (e.g., from normal play interaction to still face and from still face to reunion).

RSA withdrawal has been examined during the shift from normal play interaction to still face episode. Consistent with polyvagal theory, the well documented change in RSA from RSA during normal play interaction to lowered RSA during the still face episode (i.e., RSA withdrawal) suggests that, on average, infants find social disengagement challenging (Adamson & Frick, 2003; Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 1996). The lowering of RSA during this shift indicates a deactivation of the PNS, which allows for an adaptive activation of the SNS, in order to cope and produce adaptive behavioral responses to response to stress. Groups of infants, on average, have shown increased expression of negative affect during this shift (Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Porges, 2007; Weinberg & Tronick, 1996). This increase of distress suggests that infants are communicating that they are experiencing stress and need help (Propper & Moore, 2006).

Infant RSA has also been examined during the shift from still face to reunion. Consistent with polyvagal theory, the well documented change in RSA from RSA during still face to increased RSA during the reunion episode (i.e., vagal augmentation) suggests that, on average, infants find reengagement with an adult as calming (Adamson & Frick, 2003; Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 1996). The increase in RSA during this shift indicates an adaptive activation of the PNS in response to a calm environmental state. The increase of vagal activation allows for regulation and reorganization of their physiological state and behavior. Groups of infants, on average, have shown decreased expression of negative affect and increased expression of positive affect (Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 1996). This decrease of distress suggests that infants are no longer experiencing stress (Propper & Moore, 2006).

Inconsistent with polyvagal theory, some researchers (Bazhenova et al., 2001; Moore & Calkins, 2004) have found groups of infants whose RSA changes from episode to episode in the SFP do not fit with the group mean. Both Bazhenova and colleagues (2001) and Moore and Calkins (2004) found a group of infants who did not show the typical pattern of vagal withdrawal in the shift from normal play interaction to still face. Instead, these infants failed to show RSA withdrawal, yet displayed more negative behaviors. The fact that there was no RSA withdrawal means that the PNS was activated. Yet, despite PNS activation, these infants showed negative affect. This is not consistent with polyvagal theory.

Both Bazhenova and colleagues (2001) and Moore and Calkins (2004) also found a group of infants who did not show the typical pattern of increase in RSA in the shift from still face to reunion. Instead, these infants failed to show an increase in RSA. These infants continued to experience negative affect during this shift. The group mean approach limits the understanding and interpretations of these results. It is challenging to interpret these results because it is not clear whether these infants continued to decrease in RSA (i.e., continued shift away from the PNS) or if these infants' RSA stabilized at a decreased level. All that is known is that these infants did not increase in RSA during reunion. It is also not clear about whether the infants in this group are the same infants as were in the other group of infants who responded in an atheoretical way during the shift from normal play interaction to still face. Some infants may have been showing an atypical response during the shift from one episode to another episode, but not an atypical response during both episodic changes. Some infants may have been showing an atypical response during the entire SFP. It is not possible to understand individual differences of RSA and behavioral responses during the SFP because of such methodological limitations.

The unique physiological and behavioral responses found by researchers like Bazhenova and colleagues (2001) and Moore and Calkins (2004) are not understood within the framework of polyvagal theory. The methodology used (i.e., group means and episodic changes) could be contributing to less understanding.

Methodological Limitations of Previous Research

The variable-centered and group-mean methods used by previous research limits the understanding of atheoretical physiological and behavioral responses across the SFP. The variable-centered nature of previous research insinuates that the population of infants they are assessing are homogeneous (von Eye & Bogat, 2006). Clearly, there is evidence that distinct subgroups of infants exist within these populations and that they differ on RSA and behavioral responses (Bazhenova et al., 2001; Moore & Calkins, 2004). Thus, it is important to take a person-centered approach in order to capture unique individual differences, as well as to be able to understand these unique responses.

Similarly, using a group mean approach is a limitation because averaging across infants' RSA in each episode does not allow for examination of individual differences. Because of the evidence that heterogeneous groups of infants exist within the data, using a group mean approach would miss out on many infants who do not respond similarly to the group mean. Using a group mean also would assume an artificial RSA score onto infants who, in fact, may not be displaying those results. It is important to monitor how each infant responds in their own unique way.

Additionally, by only measuring RSA change from one episode to the next episode, results miss out on patterns of infants' RSA over time. It is important to be able to examine RSA scores across the entire SFP, in order to get a sense of how infants change over the entire procedure.

A trajectory method could fill the gap of previous research methods by identifying the unique response trajectories of infant RSA among the data. A method that examines RSA trajectories would allow for a longitudinal approach to assessing RSA change across the entire SFP. It would also help to identify subgroups of infants who display similar or different trajectories of RSA across the SFP. At this time, no published research has used a trajectory method to assess RSA change over the SFP.

GMMs (Muthén & Muthén, 2006) is a statistical method that will allow for unique trajectories of infant RSA to be mapped across the entire SFP. Unlike other growth curve modeling, GMM reduces the assumption that the data contains a single population with common population parameters, and as such, it allows for the examination of several unique trajectories among the data (Acock, 2005). By modelling from individually-specific intercepts, slopes, and variance parameters, GMMs can represent trajectories of RSA change that optimally describe different subgroups of infants within the data. This statistical method allows for the identification of several different trajectories of infant RSA among the data.

GMMs also allow for the addition of a predictor. That means that there can be assessment of a predictor of individual differences and displays of unique trajectories of RSA. Elements of maternal caregiving are important to add in as a predictor of RSA because polyvagal theory suggests that interactions with caregivers during early infancy are crucially important in autonomic development (Porges & Furman, 2011). Different experiences within interactions with caregivers during the first months of life, when the vagal nerve is developing rapidly, may contribute to differences in RSA across the SFP.

Maternal Caregiving and RSA

The polyvagal theory stresses the importance of social communication with a caregiver during infancy in the development of the autonomic nervous system (Porges & Furman, 2011). Caregivers help infants regulate their internal experiences and reactions to the external world, before they are able to do so themselves (Black & Greenough, 1986). Maternal sensitivity, the degree to which a mother is able to accurately understand her infant's needs and respond quickly and appropriately within their social interactions (Ainsworth et al., 1978; NICHD Early Child Care Research Network, 1999), theoretically helps the infant develop adaptive physiological and behavioral systems (Moore & Calkins, 2004; Moore et al., 2009; Propper et al., 2008).

Polyvagal theory posits that a sensitive and consistent mother-infant relationship will lead to the development of adaptive physiological systems. In interactions with their sensitive mother, the infant will theoretically experience increased PNS activation because they will find this social interaction as calming and relaxing. If they are experiencing challenge, infants will be able to use their mother as an external source of regulation, in that they can signal to her that they need help regulating physiologically, and she will be able to provide quick and effective help to them. The ability to get the support they need from their sensitive mother would be associated with increased physiological calmness and vagal activation (Slade, 2004).

Polyvagal theory posits that a relationship with a sensitive mother will also contribute to the development of adaptive behavioral regulation. In times of challenge, infants of sensitive mothers are theoretically able to signal their sensitive mother that they are distressed, through distress behaviors and the expression of negative affect (De Wolff & van Ijzendoorn, 1997). A sensitive mother is theoretically able to understand her infant's signals and respond to them quickly and effectively. The infant's behavioral distress can lessen after their sensitive mother has met their needs and responded to them (Kogan & Carter, 1996).

Thus, it is possible that variations in physiological and behavioral regulation may be linked to differences in maternal sensitivity. Infants of insensitive mothers may not have the ability to rely on their mother as a source of physiological and behavioral regulation. These infants may not be used to getting their emotional and physical needs met by their mother during times of distress (Slade, 2004). Thus, these infants may have more dysregulated physiological and behavioral responses due to the necessity of using alternative means to cope, like self-soothing.

Infants of sensitive mothers and infants of insensitive mothers should theoretically show different patterns of RSA across the SFP. During the shift from normal play interaction to the still-face episode, infants of sensitive and insensitive mothers would be expected to both show physiological and behavioral responses as if they are responding to challenge. They would theoretically show vagal withdrawal, indicating that they are adaptively shifting away from PNS activation and towards sympathetic activation in order to mobilize resources to manage the challenge. Additionally, their behaviors would become more negative and distressed, indicating that they are signaling to their mother that they are experiencing a challenge and need help.

During the shift from the still-face episode to the reunion episode, infants of sensitive and insensitive mothers would theoretically be expected to respond differently, based on the different ways they can utilize their mother to respond to challenge. Consistent with polyvagal theory, in the shift from still face to reunion, an infant of a sensitive mother would theoretically show vagal activation and behavioral calmness, indicating that they are experiencing calmness upon reunion with their mother. Inconsistent with polyvagal theory, an infant of an insensitive mother would not theoretically show vagal activation or signs of behavioral calmness upon reunion with their mother because they will not be able to use her as a source of regulation or calmness. Over the entire course of the SFP, infants of sensitive mothers should theoretically show a flexible and changing pattern of RSA. For infants of insensitive mothers, their pattern of RSA across the entire course of the SFP may be less flexible and adaptive.

Research has not assessed the links between maternal sensitivity and infant RSA change across the SFP in such a person-centered way. Instead, previous research on maternal sensitivity has examined the link between maternal sensitivity and infant RSA and behavior through the use of group means and episode-to-episode differences. It is important to note that these studies did not use an RSA trajectory method, so it is difficult to ascertain information on individual differences or subgroups of infants within the data.

Studies have shown that sensitivity is not associated with changes in infant RSA or distress in the shift from normal interaction to still face (Conradt & Ablow, 2010; Moore et al., 2009). This makes theoretical sense because it reflects the fact that the still-face episode may be equally challenging for most infants (Adamson & Frick, 2003; Mesman, van Ijzendoorn, & Bakermans-Kranenburg, 2009). Because the SFP is so uniquely different than most interactions with an adult, in that is violates social norms, it may be consistently stressful for most infants. Therefore, the change in RSA and behavior during this shift may not differ based on maternal sensitivity.

In the shift from still face to reunion, both studies that measured this found that most infants behaviorally calmed down during this shift. One study (Conradt & Ablow, 2010) showed that infants of sensitive mothers showed an increase in RSA during this shift, which is consistent with theory. Contrasting to theoretical expectations, another study (Moore et al., 2009) showed that infants of sensitive mothers showed a decrease in RSA during this shift.

Conradt and Ablow (2010) found results that were consistent with polyvagal theory. They found that infants of sensitive mothers showed an increase in RSA, as well as attentional engagement behaviors, in the shift from the still face episode to the reunion episode, while infants of insensitive mothers failed to show this shift and showed greater behavioral resistance and less attentional engagement. Consistent with theory, these results suggest that only infants of sensitive mothers experienced reengagement with their mothers as a physiologically and behaviorally calming interaction.

Moore and colleagues (2009) found results that were inconsistent with polyvagal theory. They found that infants of the most highly sensitive mothers showed a decrease in RSA, but not behavioral signs of distress, upon reunion, suggesting that these infants did not find reunion with their sensitive mothers as physiologically calming (Moore et al., 2009). It is important to note that Moore and colleagues (2009) measured maternal sensitivity during a non-distress task (i.e., freeplay task). A majority of empirical work has measured maternal sensitivity during a play period, a time in which there is likely to be a small frequency and short duration of infant distress (Leerkes, Blankson, & O'Brien, 2009). Measuring maternal sensitivity during such infrequent instances of infant distress may lead to questions about the validity of this sensitivity measure (Leerkes et al., 2009).

Thus, the current study measured maternal sensitivity during the SFP in order to measure sensitivity at a consistent time when the infant's distress is likely to be occurring and the mother's responses to distress will be more accurately displayed (Leerkes et al., 2009). The proposed study examined whether maternal sensitivity is a predictor of different trajectories of RSA across the SFP and whether these trajectories differed on distress at reunion.

Questions and Hypotheses

Three main questions were addressed in the present study.

Are there different trajectories of infant RSA across the SFP? This study examined whether there are unique trajectories of infant RSA across the three episodes of the SFP (normal play, still face, and reunion) by using GMM. Using a person-centered methodology, the present study extended previous research that has only assessed group means and episodic changes across the SFP to better understand individual differences in RSA. It was hypothesized that more than one group of infants with unique trajectories of RSA across the SFP would be found. Specifically, it was hypothesized that one group of infants will show a trajectory of RSA that is consistent with polyvagal theory (Porges, 2007; Porges & Furman, 2011) and previous research (Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 1996). This group of infants' RSA trajectory was hypothesized to be adaptive and flexible, with vagal withdrawal in the shift from normal play to still face and vagal activation in the shift from still face to reunion.

It was also hypothesized that a group of infants would show an RSA trajectory across the SFP that is inconsistent with polyvagal theory. This group was hypothesized to show a pattern that is similar to patterns shown by groups of infants found by Bazhenova and colleagues (2001) and Moore and Calkins (2004). This group of infants' RSA trajectory is hypothesized to be less adaptive and flexible, and may not show RSA withdrawal or activation across the SFP.

Do the trajectories differ on maternal sensitivity? The present study also examined the link between maternal sensitivity and the identified trajectories of infant RSA across the SFP. Maternal sensitivity was added as a predictor of infant RSA trajectories in order to assess the link between maternal sensitivity and patterns of infant RSA. It was hypothesized that groups of infants with different RSA trajectories would differ based on maternal sensitivity. Specifically, it was hypothesized that infants who have more sensitive mothers would display trajectories of RSA across the SFP that are consistent with polyvagal theory. It was hypothesized that infants who have insensitive mothers would display trajectories of RSA across the SFP that are inconsistent with polyvagal theory.

Do the identified trajectories differ on distress at reunion? If trajectories of infant RSA were identified that differ based on maternal sensitivity, the current study would examine whether infants with differing RSA trajectories show different levels of distress at reunion. Trajectories were not expected to differ on distress during the still face episode because previous research has shown that most infants display distress at still face, regardless of whether or not they exhibit vagal withdrawal (i.e., lowering of RSA). No formal hypothesis were advanced about distress during the still-face episode because a null hypothesis cannot be tested.

It is not clear whether trajectories would be expected to differ on levels of infant distress at reunion. For this reason, a research question was advanced regarding differences in infant distress across trajectories of infant RSA. On the one hand, it is possible that identified trajectories that vary based on maternal sensitivity may differ on levels of infant distress at reunion. This is because mothers who are more sensitive may be more likely to be able to soothe and re-engage with their infants than mothers who are less sensitive. Thus, infants of more sensitive mothers may show lower levels of distress than the infants of less sensitive mothers. On the other hand, there may be no significant difference in infant distress at reunion across trajectories of infant RSA that vary based on maternal sensitivity. It may be that the effects of infant temperament will obscure the effects of maternal sensitivity in the two minutes during which infant RSA was assessed. It may be that even if infants of more sensitive mothers are more likely to be soothed than infants of less sensitive mothers, that the soothing of more negatively reactive infants may take longer than the two minutes of the reunion task. Thus, it is possible the two minutes of reunion may not demonstrates significant differences in infant distress across trajectories of infant RSA.

Chapter III

METHOD

Participants

The participants in this study included 197 infants and their low-income (35% < $10,000, $10,000 > 18% < $30,000) mothers (38% African American, 16% White, 24% Multiracial, 13% Latina). Mothers were recruited from agencies serving low-income families and participated in a larger study of maternal caregiving. The Principal Investigator (PI) developed a sustainable research partnership with the community in order to maintain enrollment and retention of minority group member families, as well as develop infrastructure to support research in the community, including hiring community members as lab staff, a community liaison, and quarterly meetings with a Community Advisory Board (CAB) that supported and provided feedback on research efforts in the community.

Mothers and their infants were assessed when the infants were 6 months of age. About 9% of infants were prematurely born. At the time of the laboratory visit, all infants were not yet crawling (infants who were crawling were excluded). Infants diagnosed with intellectual disabilities were excluded from participating in the study. Thirty-eight percent of the mothers reported not having other children besides their infant, and 60% reported having another child. Thirty four percent of mothers who had another child had two children, 17% had three children, 4% had four children, 2% had five children, and 2% had six children. Twenty percent of mothers reported high school education, 28% of mothers reported having a professional degree, and 52% of mothers reported some or completing college. Around 34% of mothers reported their relationship status as single, 27% reported being married, 11% reported being engaged, 22% reported being steadily dating but not married, and approximately 5% of mothers reported having a life partner. Mothers who were diagnosed with schizophrenia or other thought disorders were excluded from participating in the study.

Procedures

The procedures and measures utilized for the current study were part of a larger study on maternal caregiving. Participants completed a 2-hour standardized laboratory visit. The laboratory visit included a 5-minute baseline, in which the mother and infant sat and watched a relaxing video (i.e., Baby Einstein's *Lullaby Time*), the SFP (Tronick et al., 1978), a 10-minute free-play session, and an arm-restraint procedure from the Laboratory Temperament and Assessment Battery (Lab-TAB; Goldsmith & Rothbart, 1999). RSA from mothers and infants were collected during the duration of the laboratory visit. The present study focuses on infant RSA data collected during the SFP.

Still-Face Procedure

The SFP (Tronick, et al., 1978) was used. Mothers were given specific instructions for their behavior during each episode of the SFP, which included normal play interaction, still-face, and reunion episodes. First, mothers and infants engaged in a normal play interaction episode for two minutes. Next, during the still-face episode, the mother disengaged from the infant by becoming abruptly unresponsive and adopting a still, expressionless face for two minutes. Mothers were told to stare at a sticker on the wall with an expressionless face for the duration of this episode. Finally, during the reunion episode, the mother reengaged with the infant and resumed normal interactions for two minutes.

Measures

Infant RSA

RSA data were collected from infants during the entirety of the laboratory visit. Upon entering the laboratory, a research assistant placed three disposable pediatric electrodes in a modified Lead II placement, on the distal end of the right clavicle, lower left rib cage chest, and right rib cage chest of the infant. Electrodes were connected to Mindware Electrocardiograph (ECG) equipment, which acquired data through a computer, which was kept out of view of the mother and infant.

Porges' (1985) method for calculating RSA was used. The ECG signal was sampled continuously with low-pass filtering at 1000Hz and passed through an Analog-to-Digital converter. RSA values were derived from the interbeat interval series and resampled at 25 msec to create a stationary wave form. The integral of the power in the frequency band of respiration in infants (.24 to 1.04) was extracted to obtain the RSA statistic. RSA was extracted in 30-second epochs during each episode of the SFP. Trained research assistants used a Mindware editing program, Mindware HRV Version 3.0.22, to inspect the ECG data and screen for artifacts. They manually removed movement artifacts, errors in R spikes, arrhythmias, and estimated any missing beats using a mid-beat feature. Data that required editing of more than 10% of the data or were incomplete due to technical problems (e.g., electrode problems) were not included in the analyses. This included 7% of cases (n = 14). In analyses, change scores of RSA were used to capture the difference in task RSA from baseline RSA.

Maternal sensitivity

Maternal sensitivity was assessed from videotapes of the normal play interaction and reunion episodes of the SFP. Because the mother was instructed not to interact with the infant during the still-face episode, the still-face episode was not included in evaluations of maternal sensitivity. Maternal sensitivity was coded by two independent coders, who were unaware of any other participant data. They utilized the coding guidelines provided by the National Institute of Child Health and Human Development (NICHD Early Child Care Research Network, 1999). These coding procedures use Ainsworth et al.'s (1978) work on attachment theory as a guiding framework. Evidence for the validity of this widely used measure of sensitivity includes research demonstrating that sensitivity has predictive validity for infant attachment quality (Bakermans-Kranenburg, van Ijzendoorn, & Kroonenberg, 2004; NICHD Early Child Care Research Network, 2006) and optimal child outcomes (Barnett, Deng, Mills-Koonce, Willoughby, & Cox, 2008). Maternal behavior was coded on six subscales: sensitivity to distress, sensitivity to nondistress, intrusiveness, detachment, positive regard, and negative regard. Intrusiveness, detachment, and negative regard were reverse scored. Maternal behavior during each segment of the task was rated on a scale of 1 to 5, indicating the degree to which observed maternal behaviors assumed the characteristics of each subscale. Higher scores indicated higher levels of maternal sensitivity. For the purpose of this study, the mean ratings of sensitivity to distress, sensitivity to nondistress, intrusiveness (reverse scored), and positive regard were used as a sensitivity score. 20% of cases were randomly selected to be double coded to test for inter-rater reliability. Intraclass correlations (Cicchetti, 1994) between coders were .667. ICC values of less than 0.4 are indicative of poor reliability, values between 0.4 and 0.59 indicate fair reliability, values between 0.60 and 0.974indicate good reliability, and values greater than 0.75 indicate excellent reliability (Cicchetti, 1994). Therefore, reliability for the sensitivity coders was moderate.

Infant Distress

Infant level of distress were coded from videos of infants during the reunion episode of the SFP. Infant level of distress were coded by four independent coders, who were unaware of any other participant data. They utilized The Overview of Levels of Distress (Woodhouse, Boldebuck, & Cassidy, 2015) scale as coding guidelines for coding infant distress. These guidelines were used to represent what level of distress the infant was displaying. Procedures from Braungart-Rieker and Stifter's (1995) coding system for negative behavioral reactivity were used to parse the videos into 5-second segments. For each 5-second increment of the reunion episode of the SFP, coders rated infant displayed behaviors, indicating the degree to which observed infant behaviors displayed characteristics of each subscale. The rating scale spans from 0 to 3, with each rating corresponding to a different level of distress, and with higher scores indicating higher levels of infant distress. A score of 0 represented no negative or positive vocal or behavioral reactivity. A score of 1 represented mild negative reactivity, specifically a fuss, a mild, low vocalization of negative reactivity. A score of 2 represented moderate negative reactivity, specifically a cry, with an in-and-out vocalization. A score of 3 represented high negative reactivity, specifically a hard cry, which may have included screaming, wailing, or breath-holding. The scale also included a rating for positive reactivity, specifically if the infant displays positive affect and behavior, like smiling, bright eyes, or positive vocalizations. Epochs in which the infant's face could not be seen were given a not-applicable rating. Cases with more than 10% of non-applicable epochs were removed from analyses. For the purpose of this study, the mean ratings of infant level of distress were used as a distress score. There were three dyads of coders. At the time of this study, 20% of cases were randomly selected to be double coded to test for inter-rater reliability. Intraclass correlations between coders were .966, .982, and .947 respectively. Reliability for the coders of infant distress was excellent (Cicchetti, 1994).

Data Analysis

GMMs (Muthén & Muthén, 2006) were used to capture unique response trajectories of infant RSA across the episodes of the SFP, and link them with maternal sensitivity and infant distress. GMMs can locate clusters of individuals, or classes, by reducing the assumption that the data contains a single population with common population parameters (Acock, 2005). Using RSA scores across the episodes of the SFP, trajectories reflecting distinct patterns in RSA change were identified and associated with a class. Each class had its own growth parameters, including group-specific intercepts, slopes, and variance parameters, and expresses distinctly different patterns of RSA change across the SFP.

Based on Muthén and Muthén's (2006) guidelines, in order to use GMMs as a statistical method, there must first be evidence that more than one unique response trajectory exists within the data. Before beginning growth mixture modelling, an unconditional latent growth curve was modeled and found to be an ill fit for the data. An unconditional latent growth curve model assumes that the data only contains one linear growth curve, and that all of the data assumes the same curve. Therefore, if the data contained subgroups of infants who were responding differently, an unconditional latent growth curve model would provide ill model fit. Fit incides, including X^2, RMSEA, CFI, and TLI were used to examine model fit. Additionally, the unconditional latent growth curve model's growth parameters of variance and linear slope were examined to see how much the model accounts for variation in the trajectory. Because the unconditional latent growth curve provided ill model fit, there was justification to see if a GMM provides better model fit.

The first step of a GMM was to assess how many classes exist within the data. Utilizing theoretical knowledge, as well as five fit criteria, including Akaike (AIC), Bayesian Information

Criterion (BIC), sample size adjusted BIC (SABIC), entropy, and the Lo, Mendell, and Rubin (LMR) likelihood ratio test, the number of classes were deduced. Muthén and Muthén (2006) state that lower values of AIC, BIC, and SABIC suggest better model fit, and especially suggest the use of SABIC. Entropy is a measure of how clearly distinguishable classes are based on the distinction of each individual's estimated class probability (Acock, 2005). Entropy ranges from 0 to 1 and higher levels of entropy suggest higher probability that each individual belongs in only one class. The LMR likelihood ratio test utilizes a special distribution for estimating probability that indicates whether there is significant difference between using an identified number of classes and one less than the identified number of classes (Acock, 2005). Utilizing these fit indices, the number of classes within the data were selected. The number of infants within the sample who are estimated to belong to each class were also estimated. Classes were recommended to contain more than 4% of the sample (Kivlighan, 2006).

Once the number of classes was selected, maternal sensitivity was added into the model as a predictor variable to test hypotheses about the links between trajectories of infant RSA and maternal sensitivity. These results suggested whether certain RSA response patterns were more likely to be observed among infants who experience different levels of maternal sensitivity. Each class's intercepts, slopes, and variance parameters were examined as they relate to maternal sensitivity.

Because the model suggested that there were classes that differed based on maternal sensitivity, infant levels of distress was added into the model as a predictor variable to test hypotheses about the links between trajectories of infant RSA and infant distress at reunion. These results suggested whether certain classes of infants differed on levels of distress at reunion.

Each class's intercepts, slopes, and variance parameters were examined as they related to infant distress.

CHAPTER IV

RESULTS

Descriptive Statistics and Correlations

Descriptive statistics and correlations for all continuous study variables are shown in Table 1. Infant RSA in the baseline task, normal play interaction episode, still face episode, and reunion episode were positively associated with one other, as might be expected given that that the same child provided all cardiac data. Global maternal sensitivity was associated with significantly lower levels of infant distress at reunion. Both infant RSA during the still face task and infant RSA during reunion were inversely correlated with infant distress at reunion, such that lower levels RSA (i.e., lower levels of parasympathetic nervous system activation) were associated with higher levels of infant distress at reunion, as might be expected while the infant is coping with a stressor such as in the Still Face task. Neither infant RSA during baseline nor infant RSA during the normal play interaction were associated with level of infant distress during reunion.

Growth Curve Analysis

Using Mplus software (Muthén & Muthén, 2010), an unconditional latent growth curve analysis was first performed in order to model infant RSA across the three episodes of the SFP (normal play interaction episode, still face episode, and reunion episode). The unconditional latent growth curve provided a poor model fit ($X^2(1) = 27.28$, $p < .001$, RMSEA = 0.36, CFI = 0.82, TLI = 0.46) and suggested that the intercept (I = 0.26, $p < .001$) and slope (S = -0.24, $p < .001$) were all statistically significant (see Figure 1). In addition, there was significant variance around the intercept (I = 0.37, $p = .001$), indicating significant variation in the growth function between individuals. The variance for the slope was nearing significance (S = .11, $p = .08$), and based on the recommendations of Muthén (2003), slope variability may be better detected when covariates are added to the model. Together, the latent growth curve model's poor model fit and the significant variation of one of the growth functions provide evidence for the existence of heterogeneity in the longitudinal changes of RSA within the data. This evidence provides justification to test the fit of a growth mixture model on the data.

Growth Mixture Model of Infant RSA across the SFP

Next, a cubic growth mixture model analysis of infant RSA across the SFP was conducted. There were three freely estimated time points within the growth mixture model, including the normal play interaction episode, still face episode, and reunion episode of the SFP. Mean RSA for each of the three episodes of the SFP for each infant were calculated and used as data collection points within the model. The intercept was centered at the normal play interaction episode.

To determine the number of classes, the fit indices of BIC, AIC, SABIC, entropy, and the LMR likelihood ratio test were examined with different number of classes. There was clear improvement in the model fit when estimated for three classes, in terms of AIC, BIC, SABIC, and entropy, and the LMR test suggested improved model fit as well (see Table 2). A two-class model provided poorer model fit, as did a four-, five-, and six-class model. Thus, the three-class model solution was selected. To adjust fit for this model, the variance of slope was fixed to zero to account for a negative variance. This random intercept model can be used and analyzed because the residual variances were not significant and the sample size was small (Paxton, Curran, Bollen, Kirby, & Chen, 2001).

Figure 2 displays the growth trajectories of the three classes, with Table 3 containing growth parameters. The first class of infants was viewed as normative because of its size (93.9%

of the sample, $n = 185$) and was termed *unchanging*. These infants, who began the SFP with RSA levels slightly above baseline, remained at a consistent level of high parasympathetic activation throughout the entire course of the SFP. There was no significant difference in RSA levels at baseline and at the beginning of the SFP (F (179, 3) = 2.02, $p = .31$). These infants, as a group, experienced significant vagal withdrawal (S = -0.41, $p < .001$) towards baseline levels of RSA over the course of the SFP. It is notable that, as a group, these infants' mean RSA never significantly dropped below their mean baseline level. Using repeated measures ANOVA, there was a significant difference between RSA levels at the different episodes of the SFP (F (2, 182) = 26.51, $p < .001$). Post hoc analyses using the Bonferroni correction showed that there was a significant difference between RSA at the normal play interaction and the still face episode ($p < .001$), but no significant difference between RSA levels at the still face episode and the reunion episode ($p = .98$).

The second class was smaller (6.2% of the sample, $n = 11$) and was termed *moderate suppressors.* These infants, who began the SFP with RSA levels slightly, but not significantly, below their baseline, experienced decreased parasympathetic activation throughout the entire task. There was no significant difference in RSA levels at baseline and at the beginning of the SFP (F (9, 1) = .65, $p = .75$). As a group, they demonstrated significant vagal withdrawal across the course of the SFP (S = -1.39, $p < .001$). These infants, as a group, did not reach RSA levels shown either at the beginning of the task or at baseline when reunited with their mothers. This infant group was termed moderate suppressors because, even at reunion, these infants continued to experience decreased parasympathetic activation relative to baseline. Using repeated measures ANOVA, there was a significant difference between RSA levels at the different episodes of the SFP (F (2, 9) = 11.10, $p = .004$). Post hoc analyses using the Bonferroni correction showed that there was a significant difference between RSA at the normal play interaction and the still face episode (*p* = .002), but no significant difference between RSA levels at the still face episode and the reunion episode (*p* = 1.0).

Class 3 (0.05% of the sample, *n* = 1) was termed *steep suppressor* because it contained one infant (a boy) who began the SFP at an RSA level that was starkly lower than his baseline level, and who demonstrated a pronounced withdrawal of RSA over the course of the SFP (S = -3.26, *p* <.001). This infant demonstrated decreased parasympathetic activation even after being reunited with his mother. No repeated measures ANOVA could be done with a sample of one person, in order to assess significance of differences between RSA at the different episodes of the SFP. The infant in this class had a mean baseline RSA of 7.62. Based on the recommendations of Kivlighan (2006), this class cannot be interpreted further because it contains less than 4% of the sample.

Predictors of Trajectories of Infant RSA across the SFP

Once the GMM was established, the tests of categorical latent variable multinomial logistic regressions using the 3-Step Procedure (r3 step approach) in Mplus were used with class membership regressed on the binary and ordinal categorical predictors of class membership (i.e., gender, materal sensitivity, and infant distress). All pairwise comparisons were made (see Table 4). Additional analyses (ANOVA) were used to assess the potential covariates of class membership between Class 1 (*unchanging*) and Class 2 (*moderate suppressors*) (i.e., race, income, and basline RSA). These covariates were chosen to be included in analyses in order to control for demographic variables that may have had an impact on sensitivity or RSA. Research has found that race is linked to sensitivity (e.g., Huang, Lewin, Mitchell, & Zhang, 2010). Some researchers argue that any racial differences across maternal sensitivty diminish when controlling for income (e.g., Posada et al., 2016); thus both are included as covariates of the analyses. Baseline RSA was included as a covariate to control for the levels of RSA that infants began at baseline.

There were no significant differences in gender (B = -1.36, p = .20), income (B = -.01, p = .73), or race (B = .02, p = .06) between Class 1 (*unchanging*) and Class 2 (*moderate suppresors*). Baseline RSA was significantly different (B = .16, p <.001) in Class 1 (*unchanging*) and Class 2 (*moderate suppressors*). The infants in the unchanging class had lower mean baseline RSA (M = 3.46, SD = 0.84, range = 0.75 - 5.89) than the infants in the moderate suppressor class (M = 4.67, SD = 0.65, range = 3.85 - 5.91). No differences in gender, income, or race could be interpreted for membership in Class 3 (*steep suppresor*) due to the class size of Class 3. The infant in Class 3 (*steep suppressor*) was a male, had a mother whose annual income was $10,000 or less, and was identified as multiracial by his mother.

In comparison to Class 1 (*unchanging*), membership in Class 2 (*moderate suppressors*) was predicted by infant distress at reunion (B = 1.91, p = .003). Class 1 (*unchanging*) contained infants who were significantly less distressed at reunion (M = 1.05) than infants in the other classes. Class 2 (*moderate suppressors*) contained infants who were significantly more distressed at reunion (M = 1.77) than infants in Class 1. Likewise, compared to Class 1 (*unchanging*), membership in Class 3 (*steep suppressor*) was predicted by infant distress at reunion (B = 2.08, p <.001). Class 3 (*steep suppressor*) contained an infant who was very distressed at reunion (M = 2.05). The infant in Class 3 (*steep supressor*) was more distressed than the infants in Class 1. There was no significant difference in infant distress between Class 2 and Class 3.

The comparison between membership in Class 1 (*unchanging*) and membership in Class 2 (*moderate suppressors*) based on maternal sensitivity approached, but did not attain, conventional levels of significance (*B* = -.95, *p* = 0.07). Class 1 (*unchanging*) had mothers who were higher in maternal sensitivity (*M* = 0.05) than the mothers Class 2 (*moderate suppressors*) (*M* = -0.92). Mothers of infants in Class 1, as a group, exhibited an approximately average level of sensitivity for the sample as a whole. In contrast, mothers of infants in Class 2, as a group, demonstrated a level of sensitivity that was close to a standard deviation lower than the mean. Class 3 (*steep suppressor*) contained an infant whose mother was low in maternal sensitivity (*M* = -0.82).

In sum, infants in the unchanging class (Class 1) had mothers who were more sensitive and infants who were less distressed; in contrast, infants in the moderate suppessor class (Class 2) had mothers who were less sensitive and infants who were more distressed. The dyad in the steep supressor group (Class 3) had one mother who was low in sensitivity and one infant who was high in distress.

Chapter V

DISCUSSION

Theory and research show that the influence of the vagus nerve, specifically in its ability to withdraw and augment PNS influence on the heart, in response to environmental demands is important for socioemotional development in infancy (Porges, 2007; Porges, Doussard-Roosevelt, Portales & Greenspan, 1996; Porges & Furman, 2011). Flexibility in vagal influence on the heart is adaptive because it allows for infants to respond appropriately to environmental demands (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996). In times of environmental challenge, infants who withdraw vagal influence on the heart can respond to the challenge by mobilizing resources and attending to the environment. In times of environmental calmness or in social interactions, infants who augment vagal influence on the heart can experience increased PNS activation and calmness. Infants are not born with a completely myelinated vagal system and the vagal nerve develops rapidly within the first six months postpartum (Porges & Furman, 2011; Sachis, Armstrong, Becker, & Bryan, 1982). Vagal nerve development within infancy is linked to opportunities for social learning and social bonding over the lifespan (e.g., Social Engagement System, Porges, 2007; Porges & Furman, 2011). It is important to know what contributes to adaptive vagal nerve development in order to support infant socioemotional development effectively. The purpose of the present study is to identify unique patterns of vagal regulation among infants, and assess the links to maternal sensitivity and infant distress.

Theory suggests that maternal sensitivity supports vagal development and regulation (Hofer, 1987; Porges & Furman, 2011; Propper & More, 2006; Spangler & Grossman, 1993). Research support for theory has been mixed, in terms of how maternal sensitivity is linked to specific patterns of vagal responding. There have been methodological limitations in past research that must be acknowledged, and are discussed below. The present study was designed to address these earlier methodological limitations in order to better examine the link between maternal sensitivity and infant vagal responding proposed by polyvagal theory (Porges & Furman, 2011).

Polyvagal theory suggests that infants will experience increased physiological homeostasis (i.e., PNS activation) when interacting with a sensitive mother because she serves as a source of emotional support while infants negotiate environmental stimuli (Hofer, 1987), thus allowing infants to relax. Maternal sensitivity is theorized to help infants become flexible in regulation, such that they are able to shift their physiological resources towards and away from the PNS in times of environmental challenge or calmness, since they have their mother to help them organize their emotions and get through challenging experiences when needed (Hofer, 1987; Spangler & Grossman, 1993). Porges and Furman (2011) suggest that social interaction with a caregiver can facilitate greater myelination of vagal fibers and development of the vagal system. This can improve the modulation of physiological arousal and enable infants to engage in effective behavioral and attentional regulation and positive social interaction. Infants without sensitive mothers might not be as flexible in vagal regulation or engage in positive social interactions, since they are not using their mother as an external form of regulatory support.

Research using methods focused on episode-to-episode changes in group means in RSA during the SFP has found mixed results. Some of this research supports the theoretically based prediction that increased maternal sensitivity is linked to infant vagal flexibility in response to reunion with the caregiver during the SFP (Conradt & Ablow, 2010; Moore & Calkins, 2004), such that infants show decreased RSA (vagal suppression) during the challenge segment of the SFP but increased RSA (vagal augmentation) upon reunion. In contrast, Moore and colleagues

(2009) found that maternal sensitivity was linked to continued vagal withdrawal upon reunion with the caregiver during the SFP. These conflicting results raised a question about whether polyvagal theory was correct or not. In order to address such a question, it is important to address the methodological limitations while considering these differing results.

Methodological limitations of past research on vagal regulation within the SFP (Bazhenova et al., 2001; Conradt & Ablow, 2010; Moore & Calkins, 2004; Moore et al., 2009) include a focus on group means, as well as a focus on episode-to-episode changes in those group means, rather than a focus on individual differences in patterns of change across all episodes of the SFP. In contrast, an approach that examines individual differences in patterns of RSA over time, as was the case in the present study, allows for examination of the differences in patterns of physiological responding for subgroups of infants that react to maternal engagement and disengagement differently.

There was evidence in past research that distinct subgroups of infants existed within the population (Bazhenova et al., 2001; Moore & Calkins, 2004), so one possible explanation for the conflicting results might be that there may be individual differences in infant vagal regulation across different conditions. This possibility suggested that an individual level analytic approach may prove more fruitful than a variable level approach. Thus, the present study used an individual approach (von Eye & Bogat, 2006) to examine subgroups of infants who display unique trajectories of RSA across the SFP and whether those trajectories were predicted by maternal sensitivity. These methods allowed for measurement of individual infants' trajectories of RSA over time, instead of merely examining changes of group means only from one episode to the next episode. The methodology used in this study allowed for a different kind of result to emerge, as compared to previous research, because individual unique trajectories of change in RSA were examined directly.

Three unique groups of infants emerged from a GMM analysis within the present study. The *unchanging, moderate suppressors,* and *steep suppressor* classes all had uniquely different patterns of RSA across the SFP. Present results are different from much of the past research findings examining polyvagal theory. While there is substantial research evidence supporting polyvagal theory (Adamson & Frick, 2003; Bazhenova et al., 2001; Ham & Tronick, 2006; Moore & Calkins, 2004; Weinberg & Tronick, 2006), none of the trajectories of RSA found in the present study (*unchanging, moderate suppressors,* and *steep suppressor)* showed a pattern predicted by polyvagal theory (i.e., vagal withdrawal in the shift from normal play to still face and vagal activation in the shift from still face to reunion). Instead, all of the groups showed significant vagal withdrawal over the course of the SFP, and infants did not show vagal activation that matched RSA levels at the start of the still face task when reunited with their mothers. Such a vagal withdrawal means that all infants had been in a state of actively marshaling resources to attend to a challenge.

The prediction that maternal sensitivity would be linked to trajectories of RSA was supported, at least to some degree. Although maternal sensitivity did not predict the differences between classes at conventional levels of significance, it approached significance (i.e., p = .07). Infants with mothers with varying levels of sensitivity appeared to show different patterns of RSA response to the SFP.

Infants in the *unchanging* class, whose RSA levels remained near their baseline levels throughout the whole task, had mothers who were more sensitive than mothers in the *moderate suppressor* and *steep suppressor* classes. These infants started the SFP with RSA levels that were not significantly higher than their baseline levels. Although they demonstrated significant RSA withdrawal across the SFP, their RSA never dropped significantly below what their baseline RSA levels had been. This indicates that they were still continuing to experience parasympathetic activation at levels similar to those experienced during a neutral, calm baseline. It is possible that these infants were not highly challenged by the still-face episode. These infants of sensitive mothers may trust that when their mothers are not available for a while, that although they mobilize resources to cope with that, they are not highly challenged. It is possible that if RSA had been measured for a longer time after the SFP was over, these infants' RSA would have increased back to levels at the start of the SFP, indicating a physiological shift back towards greater PNS activation as the infant begins to relax.

It is also possible that these infants were experiencing challenge during the still-face episode, and the measurement of RSA at baseline also reflected infant RSA during challenge. Potentially, the experience of being in a laboratory setting could have been demanding for the infants and their caregivers. Ecological validity of parent-child interactions during the baseline task may have been jeopardized due to interactions in an artificial laboratory setting that are different than they may normally be at home. In other words, it is possible that the baseline task does not provide a true baseline because the novel environment of the laboratory provides some challenge to the infant that the infant must cope with. However, a review showed that being observed does not necessarily alter parent-child interactions if there is attention to the type of task imposed and the location of observations (Gardner, 2000). Precautions were taken to make the baseline task a non-directive and natural experience, with emphasis placed on allowing the parent and child to interact freely while watching a neutral video. Any data in which there were disruptions to the baseline task (e.g., the infant became visibly distressed) were excluded. While the potential challenge to the validity of RSA at baseline exists, this study did undertake the necessary precautions, and the baseline measurement will be interpreted as such.

In contrast to infants in the *unchanging* class, infants in the *moderate suppressor* class had mothers who were less sensitive (although it is important to note that this difference approached, but did not attain, conventional levels of significance). The infants in this class began the SFP with RSA levels that were slightly, but not significantly, lower than their baseline levels. As the task progressed, their RSA withdrew and they then remained in levels of RSA that were significantly below their baseline throughout the entire task. This indicates that they were actively marshaling their resources by reducing PNS activation throughout the task. These infants, as a group, did not reach RSA levels shown either at the beginning of the task or at baseline when reunited with their mothers. As opposed to infants in the *unchanging* group, who received sensitive caregiving and who remained at levels of PNS activation shown during the baseline task, the infants in the *moderate suppressor* group were responding to the task as if it were a challenging task.

The single dyad in the *steep suppressor* group, who showed pronounced RSA withdrawal throughout the entire SFP, had a mother who was low in sensitivity and an infant who was high in distress. This infant was responding to the SFP as if it was a challenging task, at a rate that was more striking than any other infants in the sample. Based on the recommendations of Kivlighan, Wewerka, Gunnar, & Granger (2006), the *steep suppressor* class cannot be interpreted because of its low sample size ($n = 1$). Thus, no interpretations about the links with predictors can be made in comparison to the *steep suppressor* class. Nevertheless, taken together, the results indicated that maternal sensitivity is linked, as expected, to unique individual trajectories of RSA. Sensitivity predicted, at near-conventional levels of significance, infants' vagal regulation such that infants with mothers who were lower in sensitivity tended to show a higher degree of vagal withdrawal (i.e., lowered RSA) in response to maternal disengagement than did infants of mothers who were higher in sensitivity. In sum, the current study did not find a pattern that matched the predictions of polyvagal theory (i.e., there was no evidence of the expected infant vagal withdrawal in the shift from normal play to still face and the expected infant vagal activation in the shift from still face to reunion). Instead, results of the current the study found that sensitivity may predict the unique ways that infants can physiologically respond to maternal engagement and disengagement, specifically in the degree of vagal withdrawal.

Additionally, our hypothesis that infants of more sensitive mothers would show lower levels of distress than infants of less sensitive mothers was supported. The *unchanging* class contained infants who were significantly less distressed than infants in the *moderate suppressor* class and the *steep suppressor* class. It may be that sensitive mothers are better able to soothe and reengage with their infants during the task, resulting in lower levels of infant distress. It may also be that infants parented by sensitive mothers simply became less distressed throughout the task. It is possible that infants of sensitive mothers become less distressed by the SFP because they are accustomed to mothers who anticipate their needs and respond when needed and so have acquired a habit of low distress. Alternatively, it could also be that there are temperamental differences between children in the groups, with infants in the *moderate suppressor* and *steep suppressor* groups being more negatively reactive than infants in the *unchanging* group, and that the more negatively reactive infants drew out more negative (i.e., less sensitive) caregiving from mothers (Stifter & Fox, 1990). Unfortunately, the design of the present study does not allow for examination of the direction of causality. More research would be needed in order to examine whether temperamental differences explain the apparent link between maternal sensitivity and infants' trajectories of RSA.

Qu and Leerkes (2018) conducted a study that assessed infant RSA across the SFP using GMM. They found four classes. One class of infants showed RSA withdrawal across the SFP, and showed a pattern similar to the moderate suppressors in the present study. Qu and Leerkes titled this class "highly distressed, but regulating." These infants displayed a mixed pattern of outcomes, including higher defiant behaviors, better attachment outcomes, and higher behavior problems than the infants in the other classes. They also found three other classes with different combinations of physiological and behavioral changes over the course of the SFP. It is important to note that they found a class that was also found in this study, and suggests the usefulness of GMM for further research on infant RSA.

The results that were captured by GMM in the current study were different than expectations from polyvagal theory. A repeated measures ANOVA was conducted using past methodology that researchers have used, including group means and episode to episode changes, in order to see if similar results would emerge. When the results were assessed for the whole sample, a similar pattern to past research emerged, such that the whole sample on average, showed vagal withdrawal from normal play interaction to the still face episode, and vagal augmentation from the still face episode to the reunion episode. Using past methodology, the results of past research were replicated. This shows that the group mean approach neglects the individual differences that were captured when GMM were used. Future research should utilize GMM to be able to fully capture the unique individual differences in physiological regulation.

The present study was not without its limitations. The first limitation was the sample size. Increasing the sample of the study could potentially allow for the emergence of additional classes of infants with unique trajectories of RSA. Statistical power increases as the number of person-by-time observations increases (Curran, Obeidat, & Losardo, 2010). Thus, a higher number of participants in the study would be beneficial in promoting statistical power.

Another limitation is that the cubic growth mixture model only provides growth factors for the trajectories, globally (e.g., slope and intercept across the entire SFP), instead of growth parameters for each episodic change across the SFP (e.g., slope and intercept for the shift from normal play interaction to the still face episode, and slope and intercept for the shift from the still face episode to the reunion episode). A piecewise GMM would be able to provide the episode-to-episode growth factors. This would allow for interpretation of the rate of change of RSA across episodes. A piecewise GMM was not modeled for this data because when class-specific variances are permitted, the likelihood function becomes uninhibited and class separation and interpretation can be compromised (Wu, Zumbo, Siegel, 2011). Because the purpose of this study was to interpret unique classes within the data and assess RSA change across the entire SFP, using a cubic growth mixture model was better for testing the hypotheses of the present study.

Although this study is part of a larger study that assessed child outcome variables, the current study did not include outcome variables. This means that there is no telling how outcomes (e.g., infant mental health, infant attachment) might vary based on the trajectory of RSA. Similarly, it is impossible to ascertain whether some trajectories are adaptive or maladaptive, in terms of links to later infant outcomes. Past research has suggested that a lack of RSA augmentation at reunion is maladaptive (Bazhenova, 2001; Moore & Calkins, 2004), at least based on a group means approach. It would be helpful for future research to include outcome variables, like the Infant-Toddler Social and Emotional Assessment (ITSEA, Carter &

Briggs-Gowan, 1993), to be able to make an assessment about which trajectory is more adaptive in terms of infant development.

Another limitation is the potential effects that coming into a laboratory has on the validity of parent-child interactions. It possible that mothers altered the sensitivity of their behavior due to being in a laboratory setting (Gardner, 2000). One way to accommodate for that is to integrate sensitivity data from interactions within the home with sensitivity data from within the laboratory. Future research could examine composite sensitivity scores in order to have a more reliable measure of maternal sensitivity.

One potential confound could be that maternal sensitivity was measured during the SFP task itself. Infants who become more distressed might elicit more negative parenting behaviors because it might be more challenging to comfort and calm them. Therefore, infant distress and maternal sensitivity during the SFP might be confounding each other. Future research should assess sensitivity in a more global way, across contexts or observations. Such future research could incorporate more global assessments of maternal sensitivity measured during home visits or in different tasks during the laboratory visit so as to remove this potential confounding effect.

Future research should also assess infant distress across other episodes of the SFP. This study only assessed infant distress at reunion because the reengagement between infants and mothers was the point of interest. Future research should examine infant distress across the entire SFP in order to see whether past research, which has found that most infants show behavioral distress during the still-face episode (Weinberg & Tronick, 1996), is true, and to see whether distress levels at previous points during the SFP are linked to distress at reunion. It would be interesting for future researchers to use a GMM approach to examine at trajectories of infant distress across the entire SFP.

Clinical Implications

The current study has important implications for clinical work with infants and families. The present study had a very diverse sample, in terms of race, ethnicity, and socio-economic status (SES), with a large representation of low-SES families. Most research on parenting has been done on White, middle class families. Thus, the present study allows for a better understanding of the physiological development of diverse and low-SES infants, and in particular of the links between maternal sensitivity and vagal regulation within diverse and low-SES families. The findings of this study add to the knowledge about ethnically, racially, and socioeconomically diverse families. Some researchers suggest that families should not be compared across SES because financial stress impacts parents' ability to sensitively parent children (Posada, 2016). Therefore, it is important to compare results of the present study to other research that has assessed families who experience similar SES backgrounds. One study examined growth mixture models of infant RSA across the SFP among low-income families (Conradt, 2011). In her unconditional growth mixture model, she found that 93% of the sample were in a "low stable" RSA group. Conradt's "low stable" group is reminiscent of this study's "unchanging" group. Although no other research has been done using growth mixture modeling to map out infant RSA across the SFP, there is some evidence to suggest that the trends found in this study could be replicated. It is not clear whether results of the present study apply only to primarily low-SES mother-infant dyads, or whether similar results would be found with higher-SES samples. More research will be needed to address this question.

The results from this study suggest that maternal sensitivity may be linked to unique individual trajectories of RSA, in diverse, low-SES families. Although the present study cannot make claims about which trajectories are most adaptive in terms of later outcomes, future research could examine vagal regulation trajectories as potential mediators of the known link between maternal sensitivity and later infant outcomes, such as social and emotional development and attentional and behavioral control. It would also be interesting to investigate how infant RSA trajectory could be used in longitudinal research to assess for such links between sensitivity and child outcomes in toddlerhood and childhood. If RSA trajectories are shown to be linked to child outcomes in future research, then changes in RSA trajectories could be used to assess the effectiveness of intervention. Results of the present study suggest, however, that it may be helpful to support mothers and other caregivers through parenting interventions that focus on sensitivity so that infants can experience more stable PNS activation and lower distress, even in the context of environmental demands. This could include interventions that aim to reduce parents' other stressors (e.g., financial stress, oppression) so they can provide more sensitive parenting. Our primarily low-SES sample, in particular, may face multiple risk factors and so it is important to advocate for culturally appropriate and effective programming to support ethnically and racially diverse, low-income families (McLoyd, 1998). Altogether, parent interventions should focus on supporting parents and increasing sensitive and responsive caregiving, because there appear to be links between sensitive caregiving and both infant vagal regulation and infant distress when infants are six months old.

In conclusion, using a person-centered methodology, the study was able to elucidate more nuance and individual differences in RSA trajectories. The results were not in line with predictions of polyvagal theory. Using advanced methodology, individual differences of physiological regulation emerged. Past researchers split their samples based on whether infants suppressed RSA or not, in the shift from normal play interaction to the still face episode, and analyzed their two groups separately ("poor" or "efficient" regulators in Bazhenova, 2001;

“suppressor” and “nonsuppressor” groups in Moore & Calkins, 2004). Using a person-centered approach and growth mixture modeling, the present study was able to assess our sample without splitting, and could parse out trajectories in a more deliberate manner, ameliorating such groups like *unchanging, moderate suppressors,* and *steep suppressor* groups. This expands knowledge about unique and nuanced individual differences in infant regulation. Additionally, it is helpful in order to better understand what may be normative and to test predictions of polyvagal theory. Results of the present study suggest that polyvagal theory is not representative of the regulatory responses of infants and it is important for future research to continue expanding the information about physiological development and regulation in diverse, low-income infants. A reformulation of polyvagal theory appears to be indicated, in particular with regard to theoretical propositions about what vagal regulation is expected to look like in different contexts (e.g., social interaction vs. non-interaction), as well as with respect to the intersection between physiological development and the caregiving environment (i.e., quality of maternal caregiving) in which infant physiological regulation develops.

First, polyvagal theory predicts a normative V-shaped pattern, such that RSA decreases from the normal play interaction episode to the still face episode, and then increases from the still face episode to the reunion episode. This pattern is not what was found in the normative group found in this study. Instead, the normative group in this study showed RSA levels that remained relatively stable and unchanging across the episodes of social interaction, disruption of social interaction, and resumption of social interaction. Clearly, in the present study, use of a person centered analytic approach indicated that the normative group of infants showed a pattern that is quite different than what the polyvagal theory would suggest as normative. These findings suggest that polyvagal theory may need to be revised so as to remove the notion that vagal regulation should increase during social engagement and decrease during withdrawal of social engagement. It appears instead that withdrawal of vagal regulation, rather than reflecting removal of social engagement, can be thought of as reflecting simply marshalling of resources to cope with a stressor. Most infants do not appear to experience a momentary break in social engagement with their mothers as a stressor that requires marshalling of resources to cope with a stressor. Similarly, there does not appear to be a normative increase in vagal activation upon the resumption of social engagement. The normative response appears to be maintenance of vagal regulation as a consistent level across interactive conditions.

Moreover, polyvagal theory does not mention differences in physiological development based on caregiving context; nevertheless, data from the present study suggested that in fact there may be differences in trajectories of RSA depending on the quality, or sensitivity, of maternal caregiving. Polyvagal theory may need to be revised to account for findings of the present study showing that whether or not vagal withdrawal occurred when mothers suspended social engagement was linked to the quality of maternal caregiving. Those infants who were being raised by the more sensitive caregivers showed RSA that never dropped below their baseline levels; their RSA pattern was stable across the SFP. In contrast, infants with less sensitive mothers showed ongoing vagal withdrawal. Therefore, it is important to consider the possibility that parental caregiving quality as a source of individual differences in vagal regulation should be incorporated into polyvagal theory. The nature of the attachment relationship may impact the development of infants' physiological systems, and consequently may need to be included within polyvagal theory. Although additional research is yet needed, the present study suggests revision of polyvagal theory is an intriguing possibility that should continue to be explored.

Exploring unique individual differences in infant vagal regulation is an emerging area within research on infant development. These findings broaden our understanding of how unique patterns of vagal regulation are linked to maternal sensitivity. As such, these results suggest support for the promotion of sensitive parenting in order to support the social and emotional development of infants within their first months of life and beyond.

Table 1
Means, Standard Deviations, and Correlations of All Continuous Study Variables

Variable	1	2	3	4	5	6
1. Baseline RSA	-	-	-	-	-	-
2. Normal Play Interaction RSA Change Score (Task RSA – Baseline RSA)	-.31**	-	-	-	-	-
3. Still Face Episode RSA Change Score (Task RSA – Baseline RSA)	-.41**	.49**	-	-	-	-
4. Reunion Episode RSA Change Score (Task RSA – Baseline RSA)	-.43**	.43**	.60**	-	-	-
5. Global Sensitivity	-.01	-.03	.03	.08	-	-
6. Infant Distress	.10	-.10	-.30**	-.44*	-.28**	-
MARE$	3.55	0.33	-.22	-.15	.01	1.12
SD	.92	.84	1.00	1.16	0.83	.98

* $p < .05$ ** $p < .001$

Table 2

Relative Model Fit by Number of Latent Classes

Classes	Class size (*n*)	Entropy	AIC	BIC	SABIC	LMR
1	198	-	1558.07	1584.38	1559.04	-
2	192, 6	0.97	1509.24	1542.12	1510.44	$p = 0.48$
3	**184, 12, 1**	**0.93**	**1493.73**	**1536.47**	**1495.29**	$\boldsymbol{p < 0.01}$
4	2, 1, 185, 10	0.93	1494.62	1547.24	1496.55	$p = 0.33$
5	1, 9, 149, 3, 36	0.80	1493.91	1556.39	1496.20	$p = 0.49$
6	3, 36, 13, 140, 5, 1	0.74	1495.94	1568.28	1498.58	$p = 0.53$

Note. AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; SABIC = sample size adjusted BIC; LMR = Lo, Mendell, Rubin Likelihood Ratio test. Values in bold represent the best fitting class.

Table 3

Growth Parameters for Each Class

Class # (% of sample)	Intercept b (*SE*)	Linear slope b (*SE*)
1 (93.9%)	0.40** (0.06)	-0.41** (0.07)
2 (6.2%)	-0.55** (0.55)	-1.39** (0.39)
3 (0.05%)	-2.91** (0.05)	-3.26** (0.32)

**$p < .001$.

Table 4

Logistic Regression Parameters Predicting Class Membership: Normative profile as comparison

Comparison Category = 1	1 *Unchanging* b (*SE*)	2 *Moderate suppressors* b (*SE*)
2 (*Moderate suppressors*)		
Male[a]	-1.36 (1.07)	-
Maternal Sensitivity	-0.95^ (0.53)	-
Infant Distress	1.91* (0.65)	-
3 (*Steep suppressor*)		
Male[a]	1** (0.0)	1** (0.0)
Maternal Sensitivity	-0.81* (0.39)	0.14 (0.46)
Infant Distress	2.08* (0.34)	0.18 (0.59)

Note. [a]Male = 1, Female = 2. ^ $p < .10$, * $p < .05$, ** $p < .001$

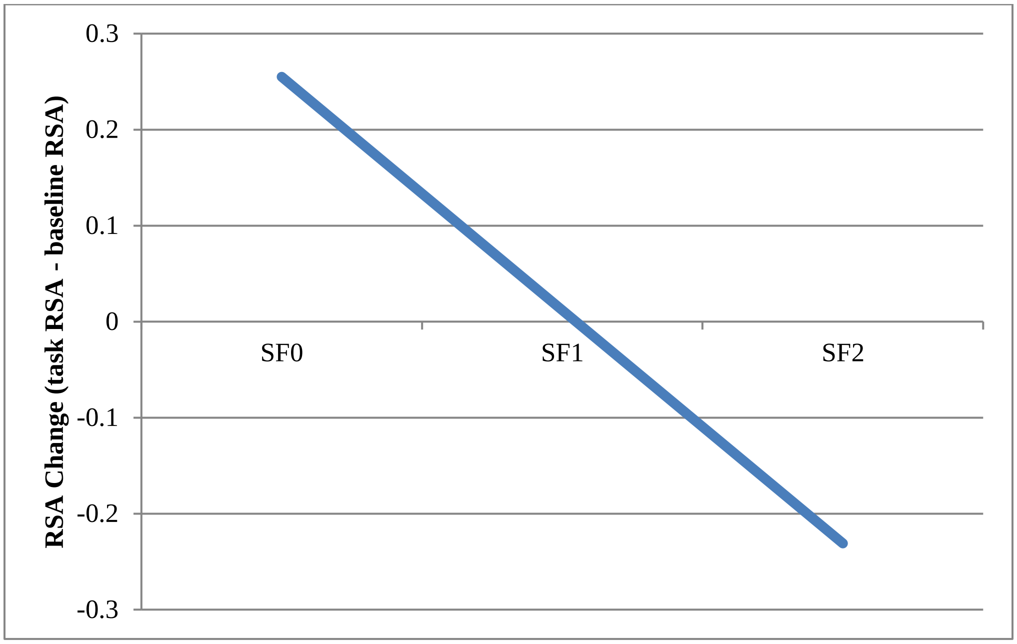

Figure 1. Growth curve of RSA across the Still Face Procedure. $X^2(1) = 27.28$, $p < .001$, RMSEA = 0.36, CFI = 0.82, TLI = 0.46. Intercept = 0.26, $p < .001$, Slope = -0.24, $p < .001$

Figure 2. Growth mixture model of infant RSA across the Still Face Procedure.

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