DIFFERENTIAL SUSCEPTIBILITY TO REARING INFLUENCES:

THE ROLE OF INFANT AUTONOMIC FUNCTIONING

by

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The Differential Susceptibility Hypothesis and the related Biological Sensitivity to Context theory contend that individuals with "susceptible" traits reap the benefits of positive rearing environments and exhibit better outcomes compared to their less susceptible peers. Studies have largely focused on physiological reactivity as an index of this susceptibility in children and adults, and most have measured physiology by grand mean changes from baseline to a stressor. The goal of this dissertation was to examine baseline Respiratory Sinus Arrhythmia (RSA) and RSA stress reactivity by taking advantage of analytical techniques modeling growth over time, as well as individual differences in this growth, using Latent Growth Modeling (LGM) and Growth Mixture Modeling (GMM), respectively.

Maternal sensitivity at 5 months and the quality of the attachment environment at 17 months were used as indicators of environmental conditions that might interact with infant susceptibility. Problem behavior and social competence were assessed at 17 months as measures of child well-being. Consistent with the theory of differential susceptibility, there were no significant differences in problem behavior or social competence among infants with low baseline RSA, but infants with high baseline RSA exhibited the lowest levels of problem behavior if reared in an environment that fostered security and more competence if their mothers exhibited greater sensitivity. Contrary to hypotheses, LGM analyses revealed that withdrawal of infant RSA appeared to buffer the impact of being reared in an environment that fostered disorganization, as infants with disorganized attachment histories exhibited the lowest number of problem behaviors. Two distinct groups of children were identified by GMM analyses: a class of infants with low RSA that decreased across the still-face episode, and a class of infants with high RSA that increased across this episode. Class by maternal sensitivity interactions were significantly predictive of social competence, with the high increasing class emerging as the group most susceptible to environmental influences, consistent with the differential susceptibility hypothesis. This dissertation adds importantly to both the sharpening and extension of theories of differential susceptibility.

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To my nephew, Austin. I look forward to watching you bloom.

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CHAPTER I

INTRODUCTION

Why do some infants, developing under chronic conditions of stress, exhibit impaired cognitive, social, and emotional functioning, while others appear unaffected? In the last decade a rather consistent, intriguing, and, on the surface, puzzling, set of findings have emerged which have identified a discrete group of children who, despite similar biobehavioral susceptibilities, either wither or bloom developmentally depending on how rearing environments provide for them. Both the Differential Susceptibility Hypothesis (Belsky, 1997; Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2007) and the related theory of Biological Sensitivity to Context (Boyce & Ellis, 2005) contend that individuals with "susceptible" traits who reap the benefits of positive rearing environments might well achieve levels of adaptation that significantly exceed those of their less susceptible, i.e., more hardy peers. However, if born into environments that afford constant diets of adversity, these susceptibilities will function principally as vulnerabilities that predispose such children to many of the worst outcomes possible. Given the transformative nature of such theorizing, the search is on both for specific susceptibilities, be they genetic, physiological, or behavioral, as well as specific environments that foster or fetter such traits. Although reasonably new, tests of these theories in the human literature have been limited mostly to children aged three and older and to assessments of harmful, adverse environments. The present study investigated infants' physiological susceptibilities in the context of what is arguably the most important early human environment, the primary attachment relationship.

Historically, infant reactive temperament, or the latency and intensity of response to stimuli, was the focus of work testing the hypothesis of differential susceptibility (Belsky & Pluess, 2009; Rothbart & Bates, 2006). It was thought that, when reactive infants are paired with a supportive, sensitive caregiver, who, upon soothing, facilitates infant engagement with the environment, positive adaptation results (Klein, 1984; Suomi, 1997). However, when these reactive infants are paired with a less sensitive caregiver these infants do not receive the same benefits of soothing, resulting in more maladaptive outcomes. As we move toward more valid behavioral, markers of susceptibility, such as infant reactive temperament, it is important to identify the underlying physiological markers of susceptibility. The idea that these physiological traits may be early prognosticators of the expression of psychopathology speaks to the importance of identifying these markers in infancy. The goal of this dissertation is to examine infant autonomic functioning as a susceptibility factor in infancy, when the physiological stress response is being formed.

The Differential Susceptibility Hypothesis

Belsky (1997, 2005) contends in his Differential Susceptibility Hypothesis (DSH) that some infants are more susceptible to both harmful and supportive rearing environments than others, resulting in both positive and negative outcomes (Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2007). Belsky's hypothesis stems from evolutionary theorizing that a parent's reproductive success would be enhanced if their offspring varied with regard to how vulnerable they were to environmental, specifically, rearing, influences (Belsky, 2005). The behavioral traits of a child who is more susceptible to rearing influence would be adaptive in environments in which the parenting supported these particular behavioral qualities, whereas parenting would be less influential among children who are less susceptible to this environment (Belsky, 2005). Thus, parents' reproductive success would be enhanced if they, unconsciously, "hedged their bets" by producing offspring with a diversity of behavioral characteristics that made them more or less susceptible to the rearing environment (Belsky, 2005; Gallagher, 2002).

In support of Belsky's DSH hypothesis, many studies suggest that environmental variables, such as parenting, exert their effects only among children with particular behavioral characteristics; specifically, infants who are temperamentally more reactive and negative. Belksy has found that these infants, who exhibit greater levels of negative emotionality, who are more active, intense, and less adaptable, are more susceptible to the rearing environment (for reviews, see Belsky, 2005, Belsky & Pluess, 2009; and Gallagher, 2002). For example, Pluess and Belsky (2009) tested the hypothesis that these infants would exhibit more behavior problems and less social competence at 54 months if they attended a lower quality daycare (e.g. one in which their primary caregiver was less sensitive) for longer periods of time, and fewer behavior problems and more social competence if placed in a high-quality daycare. Their results supported this hypothesis, as they found that children scoring high in negative emotionality at 1 and 6 months (assessed via maternal report) exhibited more behavior problems and less social competence at age 54 months, but only if they were placed in lower quality daycare, and fewer behavior problems and more social competence if they were placed in high quality care (Pluess & Belsky, 2009). While studies examining the DSH are largely correlational, experimental evidence using both animal models (Suomi, 1997) and humans (van den Boom, 1994) suggests a causal relation between the rearing environment and the susceptibility factor (Belsky, 2005).

Suomi (1997) investigated the effects of nurturing caregiving on the development of anxious and fearful infant macaques. Infants identified as high and low in anxiety were cross-fostered with both highly nurturing and "average" mothers. The anxious infants who were raised by highly nurturing mothers exhibited more exploration of the environment and less distress at weaning than both the anxious infants raised by average mothers and the less anxious infants raised by both nurturing and average mothers (Suomi, 1997). In another experimental study conducted by van den Boom (1994), temperamentally irritable newborns and their mothers were randomly assigned to an intervention group, where they received training on how to interact sensitively with their irritable infants, while mothers assigned to the control group did not receive this training. Consistent with what would be predicted by the DSH, a higher proportion of irritable infants whose mothers received sensitivity training, and who were later observed to be more sensitive, were coded as securely attached at 12 months (van den Boom, 1994). Thus, experimental evidence suggests that infants with susceptibility traits exhibited better outcomes when raised in a more supportive, nurturing environment.

Belsky and colleagues (Belsky et al., 2007) outline several important steps researchers must take when testing whether a particular susceptibility x environment interaction is supportive of differential susceptibility. First, there must be statistical evidence of moderation; specifically, that there is no significant association between the susceptibility factor and predictor, and no significant association between the susceptibility factor and outcome. Importantly, there must be a cross-over interaction between the susceptibility factor and predictor. Individuals who exhibit the susceptibility factor, and who are reared in "positive" environments should have significantly better outcomes than individuals with the susceptibility factor and who are reared in "negative" environments *and* individuals who do not exhibit the susceptibility factor. Alternatively, individuals with the susceptibility factor and who are reared in "negative" environments should have significantly poorer outcomes than individuals without the susceptibility factor, and individuals with the susceptibility factor but who are reared in "positive" environments. These steps will be followed in this dissertation when examining whether individual differences in infant autonomic functioning support the theory of differential susceptibility.

While the focus of this dissertation is on testing and extending the theory of differential susceptibility, it is important to describe a related theory which influences this work, that of Biological Sensitivity to Context (BSC; Boyce & Ellis, 2005). BSC is related to differential susceptibility as Boyce and Ellis (2005) theorize that individuals who are more physiologically reactive to stress are the ones who are most susceptible to environmental effects – it is these individuals who reap the benefits of positive rearing environments over and above their less susceptible peers. The theory of BSC, however, has moved beyond behavioral indices of vulnerability towards the physiological level of specification. BSC also furthers our understanding of susceptibility factors by explaining *why* more reactive individuals might be more susceptible to the environment (explained in more detail below). Therefore, while the theory of differential susceptibility guides all three aims, as it provides a more global theoretical context in which to interpret the results, it should be noted that results from Aims 2 and 3 will also be interpreted and discussed in the theoretical framework of BSC, as the theory of BSC adds to our understanding of why infant physiological reactivity can be considered a susceptibility factor.

In all three aims of this dissertation, quality of attachment and maternal sensitivity were examined as indices of the rearing environment. The majority of the previous work examining differential susceptibility has largely examined caregiver report of the environment, which has focused on *adverse* environments, as opposed to a *range* of environmental qualities (Belsky & Pluess, 2009, and see Bakermans-Kranenburg & van Ijzendoorn, 2006; Bradley & Corwyn, 2008; and Gilissen, Bakermans-Kranenburg, van Ijzendoorn, & van der Veer, 2008, for exceptions). Environments in which the infant develops a secure attachment, as well as infants with mothers who were more sensitive, were studied as indices of a "positive" environment, while "harmful" environments were conceptualized as those in which infants develop disorganized attachments, or have mothers who are less sensitive. Because this dissertation relied on observations of infant and maternal behaviors to understand the environment in which the infant was reared, one strength of this dissertation is that the environmental variable was less biased by caregiver report.

Quality of Attachment as an Index of the Environment

One of the well-known tenets of attachment theory is that it is in the attachment relationship that caregiver and infant learn to co-regulate emotions, with individual differences in co-regulatory styles having profound implications for later adaptation and socio-emotional development (Schore, 2001; Sroufe, 2000). The thousands of interactions between caregiver and infant, oftentimes very subtle, consisting of bi-directional signals and responses, are theorized to develop into patterns that, for the infant, are internalized, predictable, and, at least in infancy, adaptive. The long-term consequences of these patterns, however, permeate into multiple areas of functioning, and impact psychological health, intellectual development, peer group formation, and social competency (Antonucci & Levitt, 1984; Fearon, Bakermans-Kranenburg, van Ijzendoorn, Lapsley, & Roisman, 2010; Lundy, 2002).

The attachment relationship is the context in which caregivers and infants co-regulate during and following stress, at both biological and behavioral levels (Boyce & Ellis, 2005; Hofer, 2006). In this dissertation, strange situation classifications at 17 months were used to index the quality of the infants' early rearing environment. These classifications are thought to be the product of the multitude of interactions that have occurred during the infant's first 12 months of life. A great deal of literature supports the idea that specific caregiving interactions that have occurred during the infant's first year are predictive of strange situation classifications (Ainsworth et al., 1978; de Wolff & van Ijzendoorn, 1997). Specifically, a child who grows up in a secure environment is thought to have a caregiver that responds to infant negative emotionality in a sensitive, responsive, and appropriate manner. A child who is more susceptible, and presumably exhibits greater reactivity, is more likely to use social referencing and actively signal their needs for caregiver support (Cassidy, 1994). Upon appropriate caregiver response, this infant will receive the external organization necessary for regulation, resulting in greater positive engagement with the environment (Calkins & Hill, 2007; Klein, 1984; Suomi, 1997).

Infants reared in an environment which fosters disorganization, however, are thought to live in an environment that denies this developing infant the opportunities to consolidate self-regulatory systems because of insensitivity, fear, and/or frightening caregiving (Main & Hesse, 1990), including environments that are abusive (Lyons-Ruth, Repacholi, McLeod, & Silva, 1991). When this reactive infant is paired with a caregiver who exhibits insensitivity, and even threatening or frightening behavior, the infant is robbed of an appropriate source of external regulation. When stressed and in need of caregiver support, this infant might exhibit a range of unusual behaviors, including initial approach and subsequent avoidance of the caregiver, freezing, or other behaviors that suggest this infant regards his/her caregiver as a source of fear. Thus, it is theorized that this infant does not have an "organized" repertoire of behaviors that allow for adaptive coping, at least in the context of the caregiving relationship in infancy, and instead exhibits a breakdown of coping strategies. In addition, this infant might rely more heavily on physiological mechanisms to regulate, leading to the chronic over-activation of the autonomic system (Hill-Soderlund et al., 2008), and, ultimately, burn-out. By the time this infant becomes a child, he will have to depend on other, more maladaptive methods of coping, including aggression (Fearon et al., 2010).

One recent study provides evidence that a specific caregiving behavior associated with a disorganized attachment, anger, might rob the infant of appropriate methods of physiological regulation. Moore (2009) found that infants exposed to anger, as opposed to other emotions, such as excitement, exhibited greater withdrawal in response to a social stressor, suggesting a greater need to actively cope during stress. Exposure to negative, potentially threatening emotions, may lead to an increased need to regulate physiologically. This method of coping, however, is taxing, and may lead to “wear and tear” of the physiological system, with psychological and health consequences later in childhood (Hill-Soderlund et al., 2008; McEwen & Wingfield, 2010). Indeed, studies show that disorganized infants exhibit greater externalizing behavior as school age children (van Ijzendoorn, Schuengel, & Bakermans-Kranenburg, 1999), although this effect size was small, $r = .29$, suggesting that not all disorganized infants exhibit problem behavior later in life. Additional variables, such as infant biological susceptibilities, might therefore be involved in the relation between a disorganized attachment history and later problem behavior.

One study formally testing the differential susceptibility hypothesis examined the attachment environment as an index of the quality of the environment (Gilissen et al., 2008). The Emotional Availability Scales and the Attachment Story Completion Task were used as an index of the quality of the attachment relationship at age 4 and 7 years, respectively. Children rated as temperamentally more fearful were more susceptible to the quality of their relationships with their parents, as evidenced by a significant interaction between a fearful temperament and the attachment relationship. Children who were rated as temperamentally more fearful, and who were insecure, exhibited greater skin conductance level reactivity to a fear-inducing film clip than infants who were secure and fearful, while children rated as temperamentally less fearful had skin conductance level reactivity scores that did not vary depending upon the quality of the environment (secure or insecure) in which they were reared. Thus, this study provides preliminary evidence that the attachment environment is a plausible index of the quality of the early rearing environment of the child, and might provide a window into which researchers can observe how susceptibilities impact later development.

Some researchers suggest that the consequences of attachment security have more of an impact when the environment consists of multiple risk factors (Belsky & Fearon, 2002; Kobak, Cassidy, Lyons Ruth, & Ziv, 2005). This idea is especially important in this dissertation, where quality of attachment was assessed in a low-income sample of women, all of whom were at risk for parenting problems and/or psychopathology. Belsky and Fearon (2002) hypothesize that quality of attachment will be a stronger predictor of later outcomes in high-risk contexts rather than in low-risk contexts. They theorize that, in high-risk samples, the quality of attachment should be examined in risk and protective terms – with an insecure or disorganized attachment being risky in high-risk environments, and secure attachments being protective in high – risk environments. It is also plausible that the level of environmental insensitivity commonly associated with insecure attachment relationships may not affect a young infant's susceptibility to this environment. Instead, caregiving extremes may prey more heavily on infant physiological susceptibilities in this high risk environment, with behaviors that foster disorganization heralding even more severe outcomes than in environments in which there are more external resources. Therefore, while secure, insecure (avoidant and resistant), and disorganized attachment relationships were examined in this dissertation, it is hypothesized that effects will be more pronounced among infants with disorganized attachment histories, rather than insecure histories.

In sum, the attachment relationship appears to be a viable index of the quality of the early environment, and provides a context through which to examine how early susceptibilities may confer adaptation and maladaptation. When infants who are both more behaviorally and physiologically reactive interact with caregivers who can appropriately channel that excess activity into greater engagement with the environment, the infant benefits by both learning to regulate and by learning from the environment. But when these same infants are paired with caregivers who respond insensitively or in a frightening manner, these infants do not learn appropriate methods of regulation, and instead may over-rely on physiological systems to self-regulate. This process might be more pronounced in high-risk samples, where the benefits of being securely attached are protective, and an absence of security may be particularly risky.

Maternal Sensitivity as an Index of the Environment

Maternal sensitivity, defined as a mother's ability to detect and respond to her child's cues in a warm, supportive, responsive, and accurate manner (Ainsworth, Blehar, Waters, & Wall, 1978; Pianta, Sroufe, & Egeland, 1989), has been identified as an important caregiver characteristic that supports not only positive emotional development (Crockenberg & Leerkes, 2000; de Wolff & van Ijzendoorn, 1997) but also positive cognitive (Lemelin, Tarabulsy, & Provost, 2006; Stams, Juffer, & van Ijzendoorn, 2002) and social development (Stams et al., 2002). An inverse relation has been identified between maternal sensitivity and infant irritability and reactivity, as greater infant negative emotionality was associated with lower levels of maternal sensitivity and responsivity (Wachs & Bates, in press). However, among mothers who are able to respond sensitively to their reactive infants, positive adaptation may result. Tarabulsy and colleagues (2003) found that greater levels of maternal sensitivity were related to lower levels of negative affect during a social challenge, and that this effect was stronger for infants with more difficult temperaments. In addition, as reviewed above, maternal sensitivity is responsive to intervention, particularly among infants who are more irritable (Van den Boom, 1994). A recent review by Rothbart and Bates (2006) also suggests that infants who display more negative emotions (e.g. irritability and fearfulness) are more likely to develop internalizing and externalizing disorders, but only if their parents are unsupportive or intrusive.

Less is known about the interaction between caregiver sensitivity and infant physiological reactivity and recovery. In their recent investigation of maternal behaviors, Moore and Calkins (2004) found no differences in maternal behavior between infants who exhibited vagal withdrawal in response to a social stressor compared to infants who did not exhibit a decrease in RSA in response to stress. However, these researchers did find that infants in the former group were part of a dyad characterized by greater dyadic coordination, an indication of greater synchrony. Calkins and colleagues (Calkins, Graziano, Berdan, Keane, & Kegnan, 2008) found that children with poorer quality relationships (as indexed by a global warmth/positive affect, sensitivity/responsiveness score, and maternal encouragement score) at age 2 exhibited significantly lower RSA suppression in response to laboratory tasks. Haley and Stansbury (2003) provide evidence of an association between maternal sensitivity and physiological regulation during a valid social stressor in infancy, the Still-Face Paradigm (SFP; Tronick, Als, Adamson, Wise, Brazelton, 1978). They found that infants of mothers who were more responsive during normal play and the first of two reunion episodes of their modified SFP expressed less negative affect and had lower heart rates during the second reunion.

In sum, the research suggests maternal sensitivity may be particularly important for infants who are more reactive. Behaviorally, these infants exhibit lower levels of negative affect during stress, develop secure attachment relationships, and are less likely to develop internalizing and externalizing disorders, but only if their mothers are more sensitive. Less is known about whether physiologically reactive infants are as susceptible to the benefits of sensitive parenting. If the same relations hold for infants who are more physiologically reactive, this could lead to greater specificity in interventions designed to enhance caregiver sensitivity.

Socio-emotional Functioning in Toddlerhood: Problem Behavior and Competence

The differential susceptibility literature focuses heavily on negative outcomes, such as physical illness, internalizing and externalizing symptoms. This is in part because, historically, support for differential susceptibility emerged when researchers were attempting to identify risk factors for later psychopathology (Belsky & Pluess, 2009). In order to further current theory, it is important to examine a range of relevant childhood outcomes, to determine whether a susceptibility factor confers both disadvantage in harmful environments, but also greater benefits in supportive ones. In this dissertation, both problem behavior and social competence will be examined as outcomes. The goal is to determine whether there is support for the hypothesis that specific patterns of physiological functioning are indicators of susceptibility, so that objective markers can be identified before the development of psychopathology.

Individual differences in biological response to stressors are strongly implicated in the development of psychiatric disorders (Boyce & Ellis, 2005, Boyce, Quas, Alkin, Smider, Essex, & Kupfer, 2001; Hinnant & El-Sheikh, 2009; Porges et al., 1996). Children, age 6-7 years old, who exhibited high levels of autonomic reactivity to stress were significantly more likely to fall in the top 20% of caregiver and teacher-rated reports of internalizing symptoms, while less reactive children were more likely to exhibit greater externalizing symptoms (Boyce et al., 2001). In addition, children with low baseline RSA and greater RSA suppression in response to social and problem – solving challenges were more likely to exhibit externalizing symptoms (Hinnant & El-Sheikh, 2009). Furthermore, low baseline RSA is also related to internalizing (Forbes et al., 2006) and externalizing symptoms (Beauchaine et al., 2007). As will be reviewed below, it may be inaccurate to pinpoint specific physiology-psychopathology associations without taking into account the environment in which these relations are studied.

Physiological functioning in childhood is related both to greater engagement with the environment as well as social competence (Beauchaine, 2001). Specifically, higher levels of baseline RSA in preschool and grade school are related to prosocial behavior, greater social skills, and better emotion regulation, all indices of greater social competence (Beauchaine, 2001). Social competence is thought to be comprised three broad dimensions of behavior: (1) agreeableness and interest in others; (2) fluid social interaction; and (3) the ability to self-regulate and inhibit prepotent responses in efforts to promote goal-related activity (Van Hecke et al., 2007). Social competence can be reliably examined, already in toddlerhood (Briggs-Gowan & Carter, 2001). It is hypothesized that infants who are more engaged with the environment, and who are reared with sensitive caregivers who can better foster that engagement and provide an external source of regulation, will subsequently be better regulated and exhibit more social competence.

Methodological Context and Overview of Aims

The Still-Face Paradigm (SFP; Tronick, Als, Adamson, Wise, & Brazelton, 1978) is the context in which infant physiological reactivity will be examined. The SFP has become a standard laboratory procedure for evaluating infant emotion regulatory strategies and dyadic interactive characteristics by assessing the infant's response to violations of expected social norms. The SFP comprises three episodes: a face-to-face play episode; a still-face episode, during which the caregiver does not respond to the infant while holding a neutral expression; and a reunion episode, when the caregiver resumes interaction with her infant, often with a distressed child.

Studies examining infant physiological response to the stress of the still-face episode have found that, relative to tonic levels or in response to the play episode, infants typically exhibit greater cardiac arousal to the still face episode in the form of increased heart rate (Bazhenova, Plonskaia, & Porges, 2001; Conradt & Ablow, in press; Haley & Stansbury, 2003; Moore & Calkins, 2004; Weinberg & Tronick, 1996). Infants also exhibit a decrease in RSA from baseline (Bazhenova et al., 2001; Conradt & Ablow, in press; Moore & Calkins, 2004) or the first play episode (Weinberg & Tronick, 1996) to the still face episode, indicating that infants are attempting to actively cope during this episode. This evidence indicates that the SFP is indeed a reliable and valid stressor in infancy – one that elicits the expected physiological response to acute stress.

In this dissertation, both basal levels of infant autonomic functioning as well as autonomic reactivity to stress were examined as susceptibility factors to a range of environmental influences; specifically, the infant's attachment history as well as maternal sensitivity, and a range of socio-emotional outcomes; specifically, infant problem behavior and social competence. First, infant baseline RSA was examined as a susceptibility factor, because of its aforementioned associations with greater engagement with the environment, in order to extend the current theory by examining physiological measures of susceptibility in infancy. In aims 2 and 3, infant reactivity to a valid social stressor, the Still-face Paradigm, was examined as a measure of susceptibility. As discussed in the next sections, previous work has examined reactivity in the form of grand mean changes from a baseline to a stressor. In this dissertation, newer statistical techniques were used that allowed for more dynamic models of change over time;

specifically, the heterogeneity in physiological reactivity to this stressor was examined, and distinct trajectory classes of physiological reactivity to this stress were modeled. The trajectory classes were then subjected to tests of differential susceptibility. The results of this dissertation will extend current theory by examining physiological susceptibilities to a range of environmental contexts, and with regard to a range of outcomes, already in infancy. This will further our understanding of which infants might be most vulnerable to early environmental effects, and the parenting features which may nurture these susceptible infants, with important implications for early childhood interventions.

CHAPTER II

BACKGROUND AND LITERATURE REVIEW

In this chapter, the background, review of the literature, and hypotheses specific to each of the three aims will be discussed. Because aims 2 and 3 focus on infant reactivity, there will be some overlap with respect to the background and literature review, but issues specific to these aims will be examined.

Aim 1: Baseline RSA as a Susceptibility Factor

Baseline RSA

The Autonomic Nervous System is composed of two subsystems: The Sympathetic and Parasympathetic Nervous System. The Parasympathetic nervous system (PNS) helps the organism return to periods of homeostasis and it is related to restorative functions, such as digestion and the slowing of Heart Rate following a stressor. In short, it promotes rest, healing, growth, and also social communication (e.g. eye-to-eye contact), self-soothing, and self-regulation (Porges, 2007). One measure of the Parasympathetic Nervous System response is Respiratory Sinus Arrhythmia (RSA). RSA is a cardiac index of parasympathetic activation and is related to the rhythmic increase and decrease of the heart that coincides with respiration. It is reflective of parasympathetic influence on heart rate variability via the vagus nerve. Specifically, RSA results from increases in vagal efference, or withdrawal of vagal input, during exhalation, which causes heart rate to decelerate, and decreases in vagal efference during inhalation, which accelerates heart rate (Berntson, Cacioppo, & Quigley, 1993). Across multiple studies, it is used as an index of an organism's ability to self-regulate in response to positive and negative environmental demands (Beauchaine, 2001; Porges, 2001, 2003).

Higher resting levels of RSA in childhood and adulthood are associated with positive outcomes: lower levels of psychopathology, such as externalizing behavior and depression, as well as greater social competence, empathy, cognitive functioning, and appropriate emotion regulation (Beauchaine, 2001; Calkins, Graziano, & Keane, 2007; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996; Staton, El-Sheikh, & Buckhalt, 2008). Although in childhood and adulthood, higher resting levels of RSA are considered adaptive, the picture is more complex in infancy. Infants with higher baseline RSA have been observed to express more negative reactivity to an arm restraint, cry more in response to the presentation of geometric shapes, and exhibit more pain reactivity in response to circumcision (Fox et al., 2000). With regard to behavioral observations, infants with higher levels of baseline RSA exhibited more negative reactivity to an arm restraint, cried more in response to the presentation of geometric shapes, cried more in response to a pacifier withdrawal procedure, exhibited more pain reactivity in response to circumcision, and exhibited greater cortisol responses to a heel-stick procedure relative to infants with lower levels of baseline RSA (Calkins & Fox, 1992; Fox, 1989; Gunnar, Porter, Wolf, Rigatuso, & Larson, 1995; Porter, Porges, & Marshal, 1988).

Other studies suggest that high resting RSA is reflective of more than just negative emotionality and difficulty, but also positive emotionality and reactivity. For instance, infants with higher RSA expressed more interest and positivity towards a stranger (Fox et al., 2000), and took less time to smile and smiled more during a puppet game (Calkins, 1997). Higher levels of RSA were also associated with greater levels of maternal rated approach at 14, 20, and 26 weeks (Richards & Cameron, 1989), more positive reactivity during peek-a-boo with mothers and strangers (Fox, 1989), and greater sustained visual attention (Richards, 1985, 1987). Specifically, infants with higher levels of RSA are less likely to be distracted, and they look at unfamiliar stimuli for longer periods of time (Richards, 1987; Linnemeyer & Porges, 1986).

Rather than characterize higher resting RSA in infancy as globally “good” or “bad”, current theorizing suggests that it is rather reflective of greater engagement with the environment (Beauchaine, 2001; Calkins, Graziano, & Keane, 2007; Fox et al., 2000). Infants with higher resting RSA might be more attuned to the environment and sensitive to minor environmental perturbations or fluctuations. Thus, it is plausible that these infants might exhibit more engagement with the environment when they receive appropriate soothing following an environmental perturbation, but persist in negative reactivity when they are not receiving an appropriate external source of regulation. An empirical test of this hypothesis will be conducted in this aim of the dissertation, examining baseline RSA as a susceptibility factor.

Baseline RSA and Differential Susceptibility

Interestingly, many of the behavioral descriptions of infant negative temperament in infancy are similar to descriptions of infants with higher baseline RSA. While researchers conceptualize “difficult” temperament in a myriad of ways, most agree that infants with more difficult temperaments exhibit more anger proneness, distress to limitations, fussiness, irritability, and negative mood. In laboratory studies, these infants typically respond to acute stressors and novel stimuli with an increase in motor behavior and crying (Rothbart & Bates, 2006). In addition, at 9 months, high RSA was predictive of maternal ratings of difficult temperament (Porges et al., 1994).

Belsky and colleagues have amassed a great deal of evidence suggesting that infant negative temperament is a behavioral trait that predisposes these infants to the positive and negative aspects of their environment (see Belsky & Pluess, 2009, for a review). They suggest one plausible mechanism for the expression of negative temperament: a sensitive nervous system. The goal of this aim is to examine infant baseline RSA as an index of this sensitive nervous system.

The central nervous system mediates the distribution of metabolic output needed during period of rest, and when environmental demands are placed on the organism (Porges et al., 1996). Specifically, when the organism is at rest, the vagal system is involved in restorative functions such as digestion. The "vagal brake" is engaged, which inhibits sympathetic influences on the heart and keeps heart rate slow. However, in the context of threat, or, more generally, when environmental demands are placed on the organism, the vagal brake is released, allowing for innervation of sympathetic influences and increased metabolic output, resulting in "fight or flight" activity. All of this activity is monitored and regulated by the central nervous system. Porges (Porges et al., 1996) argues that engagement and disengagement with the environment is reflective of appropriate regulation of the vagal brake – that is, a release of the vagal brake during times of stress, and the engagement of the vagal brake during times of rest. It is therefore plausible that a particularly sensitive nervous system would be more susceptible to environmental perturbations, resulting in more vagal withdrawal or greater resting levels of RSA, an index of vagal functioning, during periods of rest. Indeed, recent studies suggest that baseline RSA in childhood is a trait that predisposes children to the harmful and beneficial aspects of their environment.

Though quite small, the literature suggests that baseline RSA confers risk or protection, depending upon the environment (Blandon, Calkins, Keane, & O'Brien, 2008; El-Sheikh, Harger, & Whitson, 2001). El-Sheikh and colleagues (2001) examined both baseline vagal tone and change in vagal tone from baseline to a challenging task as a moderator of marital conflict on 8-12 year-old children's reports of their own anxiety. There was a positive relation between self-reported anxiety and exposure to verbal marital conflict among children with low vagal tone. Among children with high vagal tone, however, there was no significant relation between self-reported anxiety and exposure to verbal marital conflict. These results suggest that children with lower, but not higher, vagal tone were more susceptible to verbal marital conflict.

Blandon and colleagues (2008) provide contrasting results. Baseline RSA, assessed at age 4, and maternal depressive symptomatology were measured as predictors of emotion regulation, measured at age 7. They found that greater maternal depressive symptomatology was associated with lower levels of emotion regulation, but only among children with high baseline RSA; there was no significant relation between maternal depressive symptomatology and emotion regulation among the children with low baseline RSA. Thus, it appears in this study that higher levels of baseline RSA predisposed 4 year-olds to the negative effects of maternal depressive symptomatology. Because of the equivocal nature of these results, it is unclear whether baseline RSA can be considered a susceptibility factor, and at specifically which age(s) this might be the case.

Aim 1: Study and Hypotheses

The goal of Aim 1 was to examine baseline RSA as a susceptibility factor, or moderator of the relation between the quality of the environment, and socio-emotional outcomes; specifically, problem behavior and competence. It was hypothesized that infants with higher levels of baseline RSA and who were reared in an unsupportive environment (one that fostered disorganization or one in which the mother was less sensitive) would exhibit significantly more problem behaviors and less competence than: (1) infants with lower levels of baseline RSA and (2) infants with higher levels of baseline RSA and who were reared in an environment that fostered security or one in which the mother was more sensitive. The opposite would be true of infants with higher levels of baseline RSA and who were reared in a supportive environment (the quality of attachment was secure and the mother was more sensitive). These infants would exhibit significantly fewer problem behaviors and more competence than: (1) infants with low baseline RSA or (2) infants with high baseline RSA and who were raised in a harmful environment.

Aim 2: RSA Reactivity as a Susceptibility Factor

Autonomic Reactivity to Stress

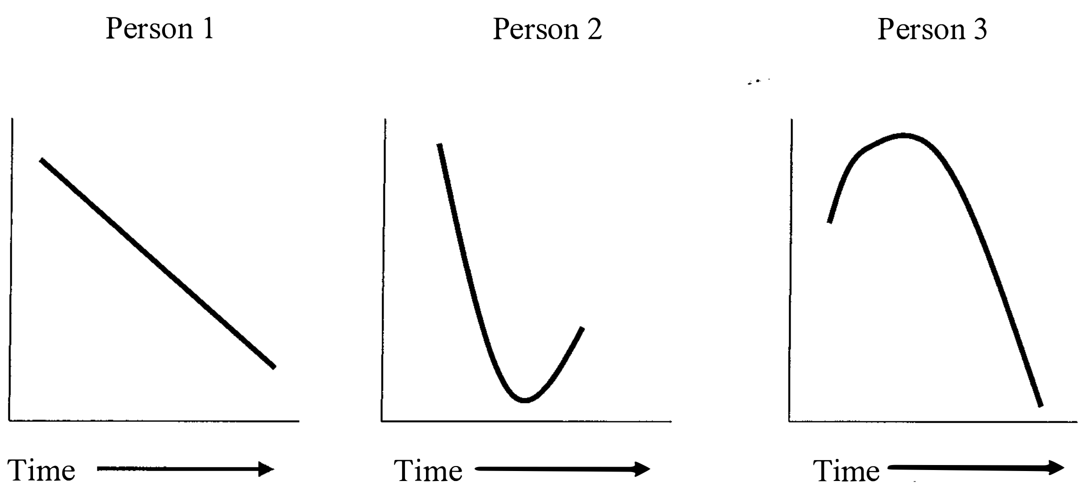
Autonomic reactivity to stress is a complex, integrated neurobiological response system that is designed to prepare the organism for threat. Across multiple studies, autonomic reactivity is emerging as a plausible candidate for differential susceptibility

(Boyce et al., 1995; El-Sheikh et al., 2007; El-Sheikh et al., 2001; Gannon et al., 1989; Obradović et al., 2010). This dissertation focused on parasympathetic, specifically, RSA reactivity in response to stress. RSA reactivity is defined as a decrease, or withdrawal of RSA from a baseline, in response to a stressor. Under conditions of stress, parasympathetic withdrawal allows for sympathetic activation and mobilization of the organism to respond to the stressor. Decreases in RSA are associated with greater sustained attention and better emotion regulation in toddlerhood (Calkins, 1997). Furthermore, decreases in RSA in response to an adult argument buffered children from the effects of marital conflict on the development of externalizing problems among boys (El-Sheikh et al., 2001). However, among kindergarten children, decreases in RSA have been associated with greater internalizing symptoms in a normative sample of children (Boyce et al., 2001), and behavior problems in a clinical sample of adolescents (Crowell, Beauchaine, McCauley, Smith, Stevens, & Sylvers, 2005). These inconsistent findings might be due to age effects, the environmental context in which reactivity is measured, or both.

There are a myriad of ways one can measure autonomic reactivity. Most often researchers measure the magnitude, or peak intensity, of a response (Jemerin & Boyce, 1990). By far the most prevalent manner of assessing magnitude of response is a change or difference score from baseline to the stressor (e.g. a resting score subtracted from a mean response during stress). An individual's score using this approach, however, tends to be correlated with their baseline score, resulting in biased "reactivity" estimates. Additionally, individuals who respond to stress in different ways might be grouped in the same category when using a difference score approach. For example, Person 1 might respond to stress with a decrease in RSA that continues to decline during the stressor, while Person 2 has RSA levels that decline at first, and then begin to increase towards the end of the stressor, while Person 3 might have RSA levels that increase, and then decrease towards the end of the stressor (see Figure 1). These individuals might have similar difference scores, but the shape of their response is quite different. These individuals could have experienced the stress in different ways, with their response profiles predicting different outcomes. Using the difference score approach, however, they would be placed in similar groups. A less biased, and more informative approach is to measure the course or shape of the individual's response to stress as it unfolds (Jemerin & Boyce, 1992); although, this approach has not been used in tests of differential susceptibility thus far.

Figure 1

Illustration of Hypothetical RSA Reactivity Profiles



The purpose of this second aim was to examine RSA reactivity in response to stress as a susceptibility factor, by capitalizing on recent statistical advances in the field of growth modeling. In growth modeling, individual differences in initial status (intercept) and growth rates (slopes) in infant RSA are modeled across time. This methodology is more sensitive to detecting effects given the increased power associated with modeling continuous time points nested within individuals. This dynamic approach to studying changes in the parasympathetic stress response will aid in our understanding of whether individual differences in the physiological stress response predispose the organism to the advantages and disadvantages of the environment, the central tenet of the theory of Biological Sensitivity to Context.

RSA Reactivity and Biological Sensitivity to Context

Both the Biological Sensitivity to Context theory and the Differential Susceptibility Hypothesis contend that individuals with "susceptible" traits who can reap the benefits of positive rearing environments might well achieve levels of adaptation that significantly exceed those of their less susceptible peers. Boyce and Ellis (2005) argue that individual differences in autonomic reactivity to a stressor are suggestive of a system that is biologically sensitive to the rearing environment. Central to their theory of Biological Sensitivity to Context is the idea that individuals expressing greater reactivity to stress are more susceptible to the adaptive effects of a supportive environment, as well as the maladaptive psychological and health consequences of a highly stressful environment. Boyce and Ellis (2005) hypothesize that early exposure to both highly stressful environments and highly adaptive environments results in up-regulation of the child's sensitivity to that environment. The child who is reared in a stressful/threatening environment learns that he/she must be increasingly responsive to potential risks in order to survive. Likewise, it is presumably also adaptive for children with susceptible traits, who later become securely attached, to take advantage of a caregiving environment that promotes positive adaptation. Thus, early in life, Boyce and Ellis hypothesize that the organism learns to adjust stress reactivity levels in order to enhance survival in a threatening context, or thrive in a supportive one.

There is a growing literature supporting the theory of Biological Sensitivity to Context (Belsky & Pluess, 2009), among adults and children, age 3-12. These studies have largely focused on sympathetic and parasympathetic nervous system reactivity (Boyce et al., 1995; El-Sheikh, Harger, & Whitson, 2001; El-Sheikh, Keller, & Erath, 2007; Gannon, Banks, Shelton, & Luchetta, 1989), although one recent study has also found support for RSA and cortisol reactivity as a susceptibility factor (Obradivić, Bush, Stamperdahl, Adler, & Boyce, 2010). In this paper, there was a significant, negative relation between exposure to environmental adversity and later prosocial behavior and school engagement, but only among children with greater decreases in RSA from a baseline to a stressor. In addition, there was a significant and negative relation between cortisol reactivity and later prosocial behaviors, but only among children with high (as opposed to low) cortisol reactivity.

In a population of college students, participants who exhibited greater Heart Rate reactivity during a laboratory paradigm exhibited higher rates of depression under conditions of stress, but lower than average rates under conditions of low stress (Gannon et al., 1989). An interaction between autonomic reactivity and environmental context was also demonstrated among 4-6 year-old children. Those who exhibited greater autonomic reactivity (as indexed by an average of RSA and pre-ejection period response to stress), and who were interviewed in a supportive manner, exhibited significantly better memory than children with high autonomic reactivity who were interviewed in an unsupportive manner, and among children with low autonomic reactivity (Quas, Bauer, & Boyce, 2004). These results suggest that individuals exhibiting greater autonomic reactivity predispose children to positive health and cognitive benefits when in a supportive, lower stress environment, relative to a high stress, unsupportive environment.

Studies demonstrating interaction effects between autonomic reactivity and environmental context have largely been conducted among adults and children. Surprisingly, there have been no published studies examining these interactions among infants. This is an important direction for research, as, by childhood, the environment may have already exerted long-lasting effects on the physical and psychological health of children. It has been demonstrated that individual differences in RSA reactivity in response to stress is related concurrently to negative affect (Moore & Calkins, 2004), and to later psychological health (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996). Less clear, however, is whether the level and growth of RSA in response to stress could predispose children to positive and negative aspects of the environment, the goal of this second aim.

Aim 2: Study and Hypotheses

The goal of Aim 2 was to examine whether the level and growth of RSA in response to a social stressor can be considered a susceptibility factor that predisposes the infant to the harmful and beneficial aspects of their environment. Latent Growth Modeling (Duncan, Duncan, & Strycker, 2006) was used to examine individual differences in infants' physiological response to the still-face episode, to determine whether the interaction between these responses and the quality of the environment was predictive of socio-emotional functioning; specifically, problem behavior and competence.

It was hypothesized that infants who were more reactive; that is, those who showed a larger decrease, or withdrawal of RSA during the stress of the still-face episode, would be more vulnerable to a supportive environment (where the quality of attachment was secure, or the mother was more sensitive), and harmful environment (where the quality of attachment was disorganized or the mother was less sensitive). Specifically, infants who exhibited larger decreases in RSA and who were reared in an unsupportive environment (one that fostered disorganization or one in which the mother was less sensitive) would have significantly more problem behaviors and less competence than: (1) infants who exhibited less change in RSA, or those who exhibited increases in RSA and (2) infants who exhibited larger decreases in RSA and who were reared in an environment that fostered security or one in which the mother was more sensitive. The opposite would be true of infants who exhibited larger decreases in RSA and who were reared in a supportive environment (the quality of attachment was secure and the mother was more sensitive). These infants would exhibit significantly fewer problem behaviors and more competence than: (1) infants who exhibited less change in RSA, or those who exhibited increases in RSA and (2) infants who exhibited larger decreases in RSA and were raised in a harmful environment.

Aim 3: Testing Differential Susceptibility Using Profiles of Reactivity

Polyvagal Theory

Porges (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996) proposes that mammals have two vagal systems: a vegetative, "reptilian" system that is involved in the regulation of homeostasis during rest, and a neo-mammalian system that engages or releases the vagal "brake" when environmental demands are placed on the organism. The vagal influence on heart rate functioning is compared to a "brake" because it slows down heart rate under conditions of stress. Porges (Porges et al., 1996) argues that the ability to regulate cardiac vagal tone underlies the expression of appropriate social behavior, including the display of facial expressions and emotions. Specifically, successful adaptation to the environment results when the organism can release and engage the "vagal brake" during times of environmental demand and rest, respectively. The release of this vagal brake allows the organism to orient to external stimuli and engage with the environment.

There is a great deal of literature suggesting that infants who are appropriately able to withdrawal of RSA (e.g. release the vagal brake) during times of stress are more adaptive. As indicated in Aim 2, withdrawal of RSA during stress is related to better self-soothing, attentional control, and sociability (Calkins, 1997; de Gangi et al., 1991;

Huffman et al., 1998). Studies have also found predictive relations of withdrawal of RSA and later risk for psychopathology. Porges and colleagues (1996) found that 9 month-old infants with greater decreases in RSA in response to a cognitive assessment had fewer problem behaviors at age 3 years. Calkins and Dedmon (2000) found that 2-3 year-olds whose RSA decreased in response to emotionally and behaviorally challenging tasks were at lower risk for aggression problems. Among 5-13 year-olds, greater vagal withdrawal in response to a sad film clip predicted lower levels of depressive symptoms and greater parent-reported emotion regulation (Gentzler, Santucci, Kovacs, & Fox, 2009).

"More", RSA suppression, however, is not necessarily "better". For instance, more extreme RSA suppression was associated with greater internalizing symptoms (Boyce et al., 2001). In addition, Calkins and colleagues (Calkins, Graziano, & Keane, 2007) found that children with the greatest decreases in RSA exhibited more internalizing and externalizing symptoms. Donzella and colleagues (Donzella, Gunnar, Krueger, & Alwin, 2000) found that 3-5 year-old children with the greatest decrease of RSA during a stressor exhibited the most anger. In examining RSA suppression in conjunction with baseline RSA, a more complex picture emerges. Hinnant and El-Sheikh (2009) found that the children (age 8) at highest risk for internalizing symptoms were those children with: (1) lower baseline RSA *and* exhibited the greatest RSA suppression in response to hearing an adult argument, and (2) children with higher baseline RSA *and* exhibited increases in RSA in response to hearing the argument. The children at the highest risk for externalizing symptoms exhibited the lowest levels of baseline RSA and showed an increase in RSA in response to a cognitive challenge.

There is very little research examining the behavioral and psychological concomitants of a physiological stress response pattern characterized by increases in RSA, though this pattern is considered atypical (Moore, 2009). Keller and El-Sheikh (2009) describe this type of a response as a, "failure to generate physiological resources that promotes engagement with stressors" (pg. 634). The two studies that have examined associations between this response profile and later psychopathology both found it to be predictive of externalizing behavior (Calkins & Dedmon, 2000; El-Sheikh et al., 2001). Moore and Calkins (2004) found that infants who did not exhibit a withdrawal of RSA in response to the still-face episode of the SFP were less positive during play interactions just prior to the still-face episode. These infants were also more physiologically aroused during this episode.

Only three studies report the distribution of these profiles (increases in RSA and decreases in RSA) in response to challenge (Bazhenova, Plonskaia, & Porges, 2001; Keller & El-Sheikh, 2009; Moore & Calkins, 2004), by examining grand mean changes from the baseline to the stressor. Seventy-three percent of 3rd grade children and 66% of 5th grade children exhibited decreases in RSA from a baseline to a cognitive stressor (a star-tracing task), and 49% of 3rd grade children and 55% of 5th grade children exhibited decreases in RSA in response to hearing an argument between experimenters. In a sample of infants, more than half (57%) responded to the stress of the still-face episode with an increase in RSA (Moore & Calkins, 2004). Bazhenova and colleagues (2001) reported that 45% of the infants in their sample exhibited an increase in RSA from looking at a toy to the start of the still-face episode with the experimenter. These response profiles suggest that in infancy and middle childhood, there is an approximately equal distribution among infants and children who exhibit a withdrawal of RSA and those who exhibit increases in RSA, at least when examined as a difference score.

Increases in RSA in response to stress are expected to be costly (Hill-Soderlund, Mills-Koonce, Propper, Calkins, Granger, Moore, Gariepy, & Cox, 2008). In the short-term, increases in RSA might be adaptive in the context of adversity. If an infant does not receive appropriate external support in regulation, the infant might need to rely more heavily on internal resources. Consistent with the theory of allostatic load, in the long-term, increases in RSA requires more vagal output. With increased use, the vagal system might "burn out" and/or increased "wear and tear" might lead to increased susceptibility to disease (Hill-Soderlund et al., 2008; McEwen & Wingfield, 2010).

Aim 3: Study and Hypotheses

The goal of this aim was to examine whether there were distinct subgroups of infants with different RSA response trajectories to stress. If subgroups emerged, then these subgroups were characterized based on relevant predictors (quality of attachment, maternal sensitivity, problem behavior, and competence). In addition, the subgroups were used to test the theory of differential susceptibility, to determine whether a particular subgroup was more susceptible to the rearing environment.

The third aim of this dissertation was exploratory, as there has been no literature examining whether one can identify distinct trajectories of growth in RSA. Growth

Mixture Modeling (GMM; Muthén, 2004; Muthén & Muthén, 2007; Nagin, 2005) was used to identify whether there were a subset of individuals whose growth trajectories of RSA were significantly different from the profile described in the literature that tests grand mean averages (grand mean of a baseline compared with a stressor). The results of this aim will provide clinically significant information related to the susceptibility of these infants to environmental influences. Because of the exploratory nature of this aim, it was hypothesized that: (1) there would be subgroups of infants, based on existing knowledge that some children and infants exhibit decreases in RSA while others do not; and (2) the infants who exhibited the largest decreases in RSA would be more susceptible to the environment, according to the theory of Biological Sensitivity to Context.

CHAPTER III

METHOD

Participants

Participants were recruited during their third trimester of pregnancy at local childbirth education classes, hospitals, and public assistance organizations as part of a longitudinal effort to identify psychobiological markers of risk for insensitive or unresponsive parenting ($N = 105$). Participants were screened using the Screening Scale for Problems in Parenting (SSPP; Avison, Turner, & Noh, 1986) and a 9-item version of the Center for Epidemiological Studies-Depression scale (CES-D; Radloff, 1977). Participants who scored 11 or above (out of a possible 25) on the SSPP and those who scored a 12 and above (out of a possible 36) on the CES-D were invited to participate in the prenatal laboratory visit. Participants (n = 95, 42 male and 53 female) returned to the laboratory again when their infants were 5-months old ($M = 20.99$ weeks, $SD = 2.55$), and again (n = 86, 38 male, 48 female) when their children were 17 months old ($M = 17.6$ months, $SD = 1.76$).

At the 5-month assessment, infants ranged in age from 16 to 32 weeks ($M = 20.99$ weeks, $SD = 2.55$). The mother's mean age was 24.11 years ($SD = 4.77$, range = 18-38). Approximately 93% of the sample had a personal income of less than $20,000. Approximately 80% attended some college or received a 2-year degree. Most of the mothers were either living with their partner (43.5%), or they were married (37.6%). Mothers were primarily European-Americans (81.0%), with 2.9% African American, 5.8% Hispanic, 3.8% American Indian, 1% Asian, and 5.7% identifying themselves as "another group."

Procedures

Time 1

When infants were 5 months, they and their mothers came into the laboratory as part of a larger assessment of dyadic interactions. The infants were first assessed with the Bayley Scales of Infant Development while their mother filled out questionnaires. Experimenters then attached heart rate and respiration monitoring equipment (described below) to both mothers and infants prior to the baseline episode. Although physiological data was collected on both mothers and infants, only the infant physiological data will be reported. Mothers then dressed their infants in a white sleeper so that the infant could not pull on the electrodes, and so the clothing would be gender-neutral. It was important to use gender-neutral clothing to avoid any bias the coder might have with regard to male and female behavior. The dyads then watched a 2-minute Baby Einstein video (© 2002, The Baby Einstein, LLC) while the infant sat on the mother's lap. This baseline physiology assessment was used to examine infant's RSA while in a neutral state.

Mother-infant SFP. Following the baseline, infants were placed in a high chair approximately 18 inches across from their mother. Experimenters introduced the mother to the SFP by explaining that they were interested in how babies behave when their parents are playing with them, and how they react when their parents are not responding to them. The experimenter then left the room, and communicated the specific procedures of the SFP over an intercom from a separate filming room. Specifically, mothers were asked to play with their babies (with no toys) for two minutes. Following SFP procedures, mothers were then signaled to turn to their left for 15 seconds, and then signaled to turn around with a neutral face for two minutes. Following this still-face episode, mothers were signaled to turn around to their left for 15 seconds, and then signaled to play with their baby again for one minute. This last episode constituted the reunion episode. This slightly modified version of the SFP was adapted from Lewinsohn (1996) as reported in Forbes, Cohn, Allen, and Lewinsohn, (2004). If the infants were fussy for more than 15 seconds at the start of the procedure, the interaction was stopped and the SFP was attempted again after the baby was soothed.

The SFP was video-recorded with one camera on the mother and one on the infant. A split-screen generator combined the images so that the mother and infant behaviors could be observed simultaneously. A time code was added to the recording so that physiology and behavior could be examined simultaneously in a second-by-second manner.

Coding of maternal behaviors. Maternal sensitivity was assessed during the reunion episode of the SFP using the Global Ratings of Mother-Infant Interaction (Murray, Fiori-Cowley, Hooper, & Cooper, 1996). Coders examined five dimensions of maternal behavior, coded on a scale from 1-5. Higher scores represented higher levels of the following five dimensions: Warmth, acceptance, responsiveness, demandingness (reversed), and sensitivity. *Warmth* was defined as the degree to which the mother expressed love and affection toward her baby; *acceptance* included the willingness and ability of the mother to follow the infant's lead; *responsiveness* was operationalized as both the mother's awareness of her infant's signals and response to them (regardless of the appropriateness of the response); *demandingness* was defined as the degree to which the mother required the infant to behave in a certain way; and *sensitivity* included the ability of the mother to identify her infant's signals and vary behavior appropriately.

A subset of tapes (32.6%) was coded to evaluate inter-rater reliability during the reunion episodes. Intraclass correlations between both coders for each of the five dimensions coded during reunion were, .89 (Warmth), .88 (Accepting), .91 (Responsive), .91 (Demanding, reversed), and .93 (Sensitivity). Because these five scales were highly intercorrelated, *mean* r = .71 (range = .46 to .91), each woman's score was averaged on all five dimensions, creating a single measure of maternal sensitivity during reunion.

Infant RSA and movement measures. Infant physiological responses were collected with 21-channel Bioamplifiers (model JCA-09). Film electrodes connected via alligator-clip electrode leads were used. Oil was removed from the skin with an alcohol wipe in order to improve electrode impedance. The experimenter placed electrodes axially on the left-rib and right-rib at the same elevation as the heart while the infant was seated on the mother's lap. The ground electrode was placed on the middle of the infant's back. The electrode lead was affixed using surgical tape so that an extra inch of slack was left to prevent from tugging of the electrode. The infant was then fitted with a gender-neutral color sleeper so that, although the infant's hands were free, she or he could not pull on the leads.

During the experimental session, physiological channels were sampled continuously with low-pass filtering at 1000 Hz. High pass filtering was recorded at 0.03

Hz. Artifactual epochs were edited manually for each channel. Consistent with previous research (Moore & Calkins, 2004), editing the files included the identification of outlier points relative to adjacent data and replacing them by determining the time between successive interbeat intervals. Data files that required editing more than 2-3% of the data were not included in the analyses. The data were then scanned graphically using the Statistical Analysis System (version 9.1) and outliers were removed. In addition, outliers that were more than 3 standard deviations above or below the mean were removed and replaced with the mean of the episode. Fifteen-second averages of infant RSA were calculated following Moore & Calkins (2004), in order to aggregate data for LGM and GMM analyses. Continuous measures of temperature and whole-body activity were also monitored, as movement could affect heart rate.

Interbeat interval (IBI) was first computed as the interval (in milliseconds) between successive R waves in the electrocardiogram (ECG). IBI was converted to instantaneous heart rate after editing R-R interval outliers due to movement artifacts or ectopic myocardial activity. RSA was computed using respiration and (IBI) data as outlined by Grossman's peak-valley technique (Grossman, 1983; Grossman, Karemaker, Wieling, 1991). The difference between the minimum IBI during inspiration and the maximum IBI during expiration, in seconds, was used to calculate RSA. The difference was computed twice for each respiration cycle; once for each inspiration and once for each expiration.

Using this method, RSA was computed without being impacted by arrhythmia due to baroreceptor, thermoregulation, and tonic shifts in heart rate.[1]

Movement was collected by placing a piezo-electric accelerometer (one axis) to the infant's high chair. The gain was adjusted to take into account stiffness of chair and the weight of participant. The average movement score was .0301 (range = 0 - .12), with higher scores indicating greater movement. A score of 0 indicated that no movement was detected.

Temperament. The Infant Behavior Questionnaire-Revised (IBQ-R; Gartstein & Rothbart, 2003) was used to assess, via maternal report, infant temperament. The IBQ-R is a 191-item questionnaire with items rated on a likert scale from 1 to 7, and comprised of 14 scales. The IBQ has demonstrated moderate inter-rater reliability between caregivers (r = .30-.71) and good internal consistency (range of Cronbach's alpha: .77-.90).

Time 2

Strange Situation Procedure. When toddlers were 17 months old they returned to the laboratory to complete the Strange Situation Procedure (SSP; Ainsworth, Blehar, Waters, & Wall, 1978). The SSP was used as an index of infants' relationship history with their primary attachment figure.

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[1] One issue regarding the calculation of RSA is whether or not it can be confirmed that what one infers to be respiration actually is respiration (rather than chest wall movements or non-respiratory chest movements). In this study, RSA was calculated using both respiration and IBI data. Respiration was calculated using one measurement for inspiration and one for expiration. The difference, measured in seconds, between the minimum IBI during inspiration and the maximum IBI during expiration was used to calculate RSA.

This procedure comprises 8 episodes, consisting of a series of separations and reunions, designed to activate the infant's attachment system (see Ainsworth et al., 1978 for a full description). During the first episode, the caregiver and child are introduced to a room they have never been in before. Episode 2 lasts for 3 minutes and starts when the experimenter leaves the room and the child plays with toys while the caregiver sits in a chair and watches. The caregiver may respond naturally but not initiate any play. During episode 3, a stranger comes into the room. The stranger sits in a chair for the first minute, begins talking with the caregiver at the start of the second minute, and then plays on the floor with the child at the start of the third minute. At the end of the third minute, the stranger signals to the caregiver that he/she can leave, and the fourth episode begins. This is the first separation episode, and lasts up to 3 minutes. The stranger attempts to soothe the child if the child needs soothing, but not to the extent that the child completely forgets that the caregiver has left. Episode 5 is the first reunion episode. The mother knocks on the door, calls for her child, and enters the room; pausing briefly so that the child may approach her. The stranger leaves inconspicuously, after the initial reunion has occurred. This episode lasts for approximately 3 minutes (up to 6 if the child needs more soothing). At the end of episode 5, the caregiver leaves the room, signaling the start of episode 6, the second separation episode. The infant is left alone in the room for up to 3 minutes. The stranger enters the room at the start of episode 7 and attempts to soothe the child if he/she is upset, but again, not to the extent that the child's attachment system is not activated. This episode also lasts up to 3 minutes. At the start of episode 8, the second reunion episode, the mother enters as she did in episode 5, and the stranger leaves after the initial reunion period. This episode lasts between 3-6 minutes, depending on the amount of soothing the child needs.

Episodes 5 and 8, the reunion episodes, are the most important for coding attachment behaviors. The tapes were coded by E. Carlson and L.A. Sroufe at the University of Minnesota. Toddlers were rated on the following scales: *Proximity seeking*, the extent to which the toddler moves toward the caregiver; *contact maintenance*, or the degree to which the toddler desires comfort/contact from the caregiver; *resistance*, or the extent to which the toddler rejects this comfort; and *avoidance*, or the degree to which the toddler ignores or fails to acknowledge the caregiver's presence. Of importance to the current study, 8% of infants were classified as avoidant, 67% secure, 5% resistant, and 20% were disorganized.

Social and emotional functioning at 17 months. The Brief-Infant Toddler Social and Emotional Assessment (BITSEA, Briggs-Gowan & Carter, 2001) is a 42-item measured designed to evaluate symptoms of social and emotional problems and competence in 1-3 year-old children. The BITSEA has demonstrated acceptable test-retest reliability (α's = .85-.87) and inter-rater (between parents) reliability (α = .61-.68; Briggs-Gowan, Carter, Irwin, Wachtel, & Cicchetti, 2004). The BITSEA consists of problem and competence scales, which have demonstrated reliability and validity, and a recent study has shown predictive validity in school-age children for the BITSEA problem scale (Briggs-Gowan & Carter, 2008). In these analyses, children's total problem scores on the BITSEA, completed by mothers when their child was approximately 17-months-old, was used in order to measure individual differences in toddler levels of social and emotional problems.

Analytic Plan

Data analysis proceeded in three steps, corresponding with the three major aims of the dissertation. First, the stepwise process outlined by Belsky et al. (2007) was used to determine whether infant baseline RSA was a susceptibility factor. A linear regression was computed to examine whether there was a significant cross-over interaction between maternal sensitivity and baseline RSA. Second, a bi-variate correlation was conducted to test if there was independence of baseline RSA and the environmental variables. Third, a chi-square test was used to examine the association between baseline RSA and the environmental variables. If the association was nonzero, there was no support for differential susceptibility. Fourth, the interaction plot was compared with the prototypical graphical displays found in Belsky et al. (2007). Finally, the specificity of the model was tested by examining whether baseline RSA remained a significant susceptibility factor in the presence of other environments (e.g. maternal sensitivity or attachment history).

Because the primary goal of Aim 2 was to describe the change in RSA during the SFP, latent variable growth curve modeling (LGM) was selected as the analytic framework of choice (Duncan, Duncan, & Strycker, 2006). LGM allows for a more flexible approach to studying change, as individual differences in intercepts and slopes can be modeled over time (Duncan et al., 2006). First, a baseline model was identified that best described the shape of the infant response to the still-face episode. The goal of this step was to find a model that adequately and parsimoniously characterized individual differences in growth of RSA. Multiple models were tested, including piecewise models, which allowed for the modeling of the growth curve in separate splines, or pieces, if the continuous linear or quadratic slopes did not fit the data well (Stoolmiller, 1995). In addition, models that included an autoregressive error structure, or ones that accounted for the effect of infant RSA at one time point on the subsequent time point that was not captured by the intercepts and slopes, was also tested. The final model was chosen based on the following fit indices: The Comparative Fit Index (CFI), which tests where a particular model fits relative to a baseline model; the root mean square error of approximation (RMSEA; Browne & Cudeck, 1993), which represents the error of approximation in the population; and the relative Chi-square, (χ^2 / df), which was used in lieu of the chi-square because it is less dependent on sample size. Once a final model was chosen, intercept and slope scores were exported into the SPSS platform, and tests of differential susceptibility were conducted[2]. Main effects of the intercept and slope scores, the environmental variables (quality of attachment, and maternal sensitivity) and the interaction between infant physiology and the environmental variables were examined as predictors of toddler behavior and competence at 17 months.

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[2] There is some debate in the literature about whether or not scores should be exported into a different statistical platform (such as SPSS; Nagin, 2005), or whether regression models should be run in Mplus (Muthén, 2004). The debate revolves around the idea of selecting a final model based on a good-fitting unconditional (e.g. no predictors or covariates) or conditional (including predictors and covariates) model. Muthén (2004) argues that the final model should be based upon all relevant data, including predictors and covariates. Nagin (2005) purports that a best-fitting unconditional model should be decided upon, and then predictors and covariates should be used to examine trajectories in a separate platform. Otherwise, the inclusion of covariates might lead to contamination of group membership by predictors. Because the goal of this dissertation was to examine group membership solely by infants' physiological profiles (and not, for example, maternal behavior), in order to understand infants' intrinsic response to stress, the unconditional model was first chosen, and then scores exported into SPSS, as recommended by Nagin (2005).

LGM assumes that the observed growth trajectories in a sample come from a single population, and that a single intercept and slope can adequately characterize the growth in the sample. It may be the case, however, that the sample is more heterogeneous and includes a mixture of sub-populations, each with its own unique starting point and growth trajectory. The goal of Aim 3 was to extend the sample-level Latent Growth Model to examine the core hypotheses using a person-centered (versus a variable-centered) approach. This approach models change by accounting for latent, or unobserved, heterogeneity in growth trajectories within the larger population. Using Growth Mixture Modeling (GMM; Muthén, 2004; Muthén & Muthén, 2007; Nagin, 2005) techniques, one can allow different groups of individuals to vary around different means, rather than assuming that all individuals in the population vary around single growth parameters (e.g. intercepts and slopes). Model parameters are freely estimated and allowed to differ across groups, rather than constrained to be equal, which allows for each group to have a unique developmental trajectory. This approach is more flexible, as it allows for identification of sample heterogeneity at both the initial level and shape of growth over time. In Aim 3, Growth Mixture Modeling was employed to test the hypothesis that there are distinct subgroups of infants with different RSA response trajectories to stress. The goal was to examine whether infants can be classified into distinct classes based on their RSA response to the still-face episode of the SFP.

In GMM, a categorical latent variable is used to represent the distinct trajectory groups. Individuals are assigned to a particular group based on their posterior probabilities. In other words, for each individual, coefficient estimates are used to determine the likelihood that the individual belongs to one group, versus another group. GMM will be implemented using Mplus (version 5.1; Muthén & Muthén, 2007), using maximum likelihood estimation procedures, which is iterative in nature. Maximum likelihood, using the EM algorithm, uses all available information, including information about the individual's intercept and slope score, as well as information about observed outcomes and covariates, in order to classify individuals into groups. This iteration should result in successful convergence of the global maximum solution. However, the EM algorithm cannot distinguish between a global maximum and a local maximum. With small sample sizes, a local maximum is more likely to be identified, resulting in the mis-identification of classes. In this dissertation, the use of several different sets of starting values were used, and increased to the recommended level of 1000 iterations (Muthén, 2004), to be certain that the global maximum was reached.

GMM analyses proceeded in a series of steps. First, the best-fitting growth model from Aim 2 was subjected to alternative tests of model fit using both an LCGA approach, where all the growth trajectories within a class are assumed to be homogenous and a GMM approach, which allows for heterogeneity in growth trajectories. One of the assumptions of Growth Mixture Modeling is that individuals within a class are more similar with respect to their starting values (intercepts), and growth over time (slopes), than individuals between classes. Additionally, one can test whether within-class variability in intercepts and slopes should be constrained to be equal, (Nagin, 2005), or whether one should allow for within-class variability (Muthén, 2007). Rather than decide a priori which technique should be employed, quantitative psychologists are suggesting that both approaches be modeled (Jung & Wickrama, 2008; Muthén, 2004). First, a constrained model, in which the variance and covariance estimates for the growth factors within each class are fixed at zero, was used. In other words, using this approach, all the growth trajectories within a class were assumed to be homogenous; all individuals within a class were thought to follow the exact same trajectory (Hipp & Bauer, 2006). This approach is termed Latent Class Growth Analysis, and it is recommended as the starting part for conducting GMM (Jung & Wickrama, 2008; Muthén, 2004). This approach is advantageous because it allows for a clearer identification of classes. Next, the LCGA models were compared to models run using Latent Growth Curve Mixture Modeling (GMM). GMM models that allowed for heterogeneity in growth trajectories using an unconstrained model that allows for variation in the growth parameters within each class (Muthén, 2007) were examined. The final model was chosen based on: (1) The Bayesian Information Criteria (BIC; Schwartz, 1978), with lower values reflecting better model fit; it is often used because it strives for parsimony and maximizing the likelihood of model fit; (2) Akaike's Information Criterion (AIC), which takes into account the number of parameters that must be estimated to achieve a good model fit; (3) Entropy (values closer to 1 indicate better classification quality; Duncan et al., 2006); (4) the Vuong, Lo, Mendell, and Rubin (Lo, Mendell, & Rubin, 2001) Likelihood Ratio Test, which compares a model with *k* classes to a model with *k* -1 classes, and indicates whether the model with more classes significantly improves the BIC; and the (5) Bootstrap Likelihood Ratio Tests (BLRT), which also compares a model with *k* classes to a model with k -1 classes. Models with the smallest BIC, AIC, higher Entropy values, and significant VLMR-LRT and BLRT tests are considered good-fitting models.

The best fitting model was chosen based on the model fit and classification quality statistics described above, as well as parsimony, relevance to one's research question, interpretability of groups, and theoretical justification (Jung & Wickrama, 2008). Once this model was selected, it was subjected to tests of differential susceptibility using linear regressions. Similar to Aim 2, main effects of class membership, the environmental variables (quality of attachment, and maternal sensitivity) and the interaction between class membership and the environmental variables were examined as predictors of toddler behavior and competence at 17 months.

CHAPTER IV

RESULTS

Preliminary Analyses

Prior to conducting main analyses, central variables were evaluated for demographic effects to determine whether covariates would be needed. The means and standard deviations of all variables tested are presented in Table 1. There were no significant associations between infant baseline RSA, infant physiology during the still-face paradigm, problem behavior, competence, attachment status, or maternal sensitivity, and demographic variables that comprised maternal age, household income, ethnicity, marital status, child age, and child gender (*ps* > .31). Demographic covariates, including gender and age, were therefore not needed.

Aim 1: Examination of Baseline RSA as a Susceptibility Factor

Relations between baseline RSA and maternal report of temperamental reactivity and engagement with the environment were examined using the IBQ in order to provide validity for the hypothesis that baseline RSA is an index of these behavioral traits. As seen in Table 2, baseline RSA was significantly and positively correlated with Duration of Orienting, Perceptual Sensitivity, and Vocal Reactivity, providing support for the hypothesis that infants with high baseline RSA exhibit traits that are associated with greater engagement with – and reactivity or sensitivity to – the environment.

Table 1

Descriptive Information of Variables of Interest for Sample

Variable	*M (%)*	*SD*
Maternal Age (years)	24.11	4.77
Maternal household income	3.30	1.52
Maternal Ethnicity		
European American	81(%)	
African American	2.9(%)	
Hispanic	5.8(%)	
American Indian	3.8(%)	
Asian	1(%)	
Another group	5.7(%)	
Maternal Marital Status		
Living with Partner	43.5(%)	
Married	37.6(%)	
T1 Age (weeks)	20.99	2.55
T2 Age (months)	17.6	1.76
Gender	$n = 42$	
Boys	$n = 53$	
Girls		
Infant Movement	.03	.018
Maternal Sensitivity	2.99	.95
Infant RSA		
Baseline	.0142	.0174
RSA 1	.0170	.0130
RSA 2	.0141	.0067
RSA 3	.0141	.0064
Toddler problem behavior	17.50	7.92
Toddler competence	15.98	2.71

Note. Maternal Household Income (3 = $10,000 – $20,000)
RSA = Respiratory Sinus Arrhythmia
RSA1 = RSA during the face-to-face play episode
RSA2 = RSA during the Still Face episode
RSA3 = RSA during the reunion episode
T1 = Time 1 (5 month session)
T2 = Time 2 (17 month session)
N = 86

Table 2

Correlations Between Baseline RSA and Temperament

IBQ Temperament dimension	*r* with baseline RSA
Activity Level	.023
Distress to Limitations	-.055
Fear	-.033
Duration of Orienting	.223*
High Pleasure	.158
Low Pleasure	.146
Soothability	-.010
Rate of Recovery from Distress	.063
Perceptual Sensitivity	.229*
Sadness	-.008
Approach	.144
Vocal Reactivity	.226*
Smiling and Laughter	.108
Cuddliness	.014

Note. N = 95

Model 1.1. Does baseline RSA, attachment classification (B vs D), and/or an interaction of the two predict problem behavior at 17 months?

A series of regressions were used to examine relations between baseline RSA at 5 months, attachment classification at 17 months, and problem behavior scores at 17 months as a preliminary test of differential susceptibility. First, the independence of baseline RSA and attachment classification was tested. If these two variables were significantly related, then the evidence would not have shown that the predictive power of quality of attachment is greater for infants with higher baseline RSA, it would instead suggest that infants with higher baseline RSA were more likely to have a secure (or disorganized) attachment relationship, or vice-versa. The first regression revealed that there were no significant differences in baseline RSA among infants raised in an environment that fostered security or disorganization, *b* = .10, *p* = .395. Next, the relations between infant baseline RSA and infant problem behavior were tested. A regression revealed no significant association between baseline RSA and problem behavior, *b* = .103, *p* = .348. Last, a regression revealed that there were no significant differences in problem behavior among infants raised in an environment that promoted security and disorganization, *b* = .087, *p* = .456.

Next, the relations between infant baseline RSA, attachment classification (secure vs disorganized), and/or an interaction of the two were tested as predictors of problem behavior. Infant baseline RSA and attachment classification (secure vs disorganized) were entered in step 1, and the interaction between infant baseline RSA (grand mean centered) and attachment classification in step 2 of a linear regression. Infant problem behavior served as the dependent variable. As seen in Table 3, there were no main effects of infant baseline RSA or attachment classification on problem behavior. However, there was a significant interaction between infant baseline RSA and attachment classification, *b* = .350, *p* = .013. The overall model was marginally significant ($F(3, 72) = 2.51$, $p = .066$), and adding the interaction term in step 2 significantly improved the amount of variance explained by the model (R^2 change = .086, *p* = .013).

Following procedures by Aiken and West (1991), this interaction was probed by examining baseline RSA scores at one standard deviation above and below the mean. Figure 2 is a graphical representation of the interaction using only the infants that fell one

Table 3

Hierarchical Regression Predicting Problem Behavior at 17 months: Attachment Classification (B vs D) and Baseline RSA as Predictors

Model	B	(SE)	B	*t*	*p*
Step 1 (*df* = 2, 70; R^2 = .012; adjusted R^2 = -.016)					
Infant attachment classification (B vs D)	1.65	2.22	.089	.745	.458
Baseline RSA (natural log transformed)	.948	1.98	.957	.478	.634
Step 2 (*df* = 1, 69; R^2 = .098; adjusted R^2 = .059)					
Infant attachment classification (B vs D)	.848	2.16	.046	.393	.695
Baseline RSA (natural log transformed)	-2.04	2.24	-.123	-.914	.364
Infant attachment classification x Baseline RSA	11.00	4.29	.350	2.56	.013

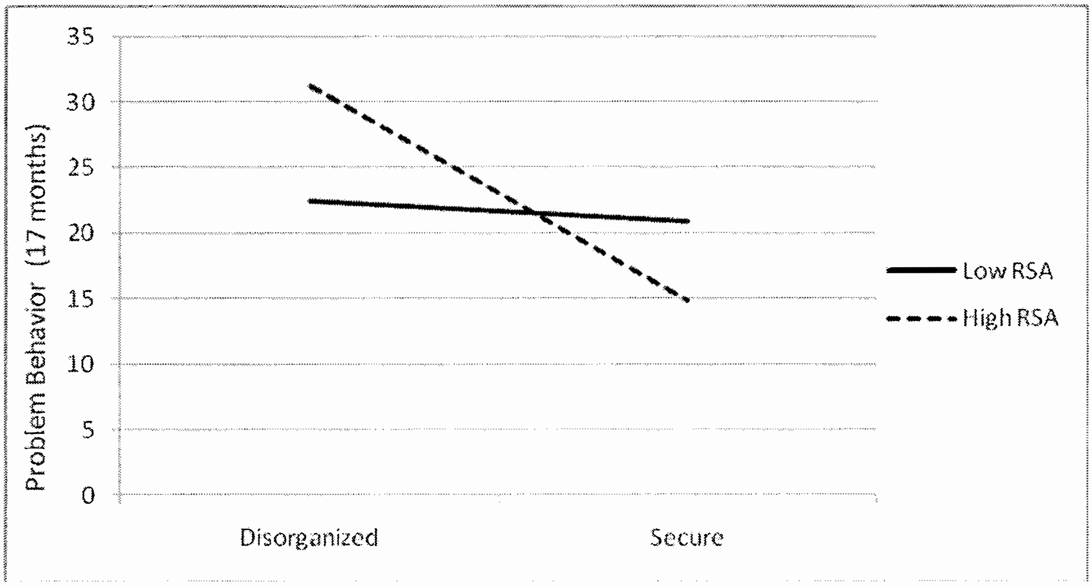
Note. N = 82

standard deviation above and below the mean of baseline RSA. Among infants with low baseline RSA, there was no significant difference in problem behavior among infants raised in an environment that fostered security and disorganization, $b = .234$, $p = .489$. However, among infants with High RSA, there was a significant increase in problem behavior, depending upon attachment classification, $b = .626$, $p = .053$. Among infants with high RSA only, those who were raised in an environment that promoted disorganization had significantly higher problem behavior scores than infants who were raised in an environment that fostered security.

In order to examine whether infants with high baseline RSA exhibited problem behavior scores that were significantly higher or lower than their low baseline peers, the groupings were used to examine whether: (1) infants raised in an environment that fostered disorganization with high RSA (n = 2) had significantly higher problem behavior scores than this same group of infants with low RSA (n = 3), and (2) infants raised in an

Figure 2

Baseline RSA by Attachment Classification (B vs D) Interaction Predicting Problem Behavior at 17 Months



environment that fostered security with high RSA (n = 6) had significantly lower problem behavior scores than secure infants with low RSA (n = 9). Although an independent samples *t test* revealed no significant differences in problem behavior among infants raised in an environment that promoted disorganization with high (M = 31.25, SD = 16.68) and low (M = 21.00, SD = 3.00) RSA, Cohen's d revealed a large effect at 0.86. An independent samples *t test* demonstrated, however, that, among infants with a secure relationship, infants with High RSA had significantly lower problem behavior scores (M

= 14.83, *SD* = 5.85) than infants with low RSA (*M* = 20.89, *SD* = 2.93), $t(13) = 2.68$, p = .019. Again Cohen's *d* revealed a large effect size, $d = 1.31$[3].

Model 1.2. Does baseline RSA, attachment classification (B vs D), and/or an interaction of the two predict competence at 17 months?

The same regressions were repeated using competence as the outcome measure. As seen in Table 4, none of the main effects or interactions were significant.

Table 4

Hierarchical Regression Predicting Competence at 17 Months: Attachment Classification (B vs D) and Baseline RSA as Predictors

Model	B	(SE)	B	*t*	*p*
Step 1 (df = 2, 72; R^2 = .004; adjusted R^2 = -.025)					
Infant attachment classification (B vs D)	-.081	.759	-.013	-.107	.915
Baseline RSA (natural log transformed)	-.334	.679	-.059	-.492	.624
Step 2 (df = 3, 72; R^2 = .014; adjusted R^2 = -.029)					
Infant attachment classification (B vs D)	-.176	.769	-.028	-.229	.820
Baseline RSA (natural log transformed)	-.686	.797	-.121	-.861	.392
Infant attachment classification x Baseline RSA	1.30	1.53	.121	.847	.400

Note. N = 82

Model 1.3. Does baseline RSA, maternal sensitivity, and/or an interaction of the two predict problem behavior at 17 months?

In order to test the specificity of a model of baseline RSA as a measure of susceptibility to environmental influences, a test of whether baseline RSA interacted with

[3] Other regression models were examined using different combinations of the attachment classification (B vs A +C; B vs A + C + D), with no significant main effects or interactions. In the interest of space, the results of these models will not be reported.

other environmental variables to predict problem behavior and socio-emotional competence was conducted. The degree to which baseline RSA and maternal sensitivity were related was first examined. A bivariate correlation revealed that baseline RSA and maternal sensitivity during reunion were not significantly correlated, $r = -.103, p = .325$. An examination of whether baseline RSA and the primary outcome measures, socio-emotional competence and problem behavior were independent was then conducted. A bivariate correlation revealed that baseline RSA was not significantly correlated with competence, $r = -.048, p = .658$, or problem behavior, $r = .124, p = .277$. There was, however, a significant correlation between maternal sensitivity and infant competence at 17 months, $r = .277, p = .011$, but not maternal sensitivity and problem behavior, $r = -.101, p = .361$. Greater levels of maternal sensitivity at 5 months were associated with greater infant competence at 17 months.

The main effect of baseline RSA, maternal sensitivity during reunion, and the interaction between baseline RSA and maternal sensitivity, in predicting problem behavior was then examined. As seen in Table 5, there were no significant main effects or interactions between maternal sensitivity and infant baseline RSA as predictors of problem behavior.

Model 1.4. Does baseline RSA, maternal sensitivity, and/or an interaction of the two predict competence at 17 months?

These same models were then run using toddler competence at 17 months as the criterion. As seen in Table 6, the overall model predicting toddler competence was

Table 5

Hierarchical Regression Predicting Problem Behavior at 17 Months: Maternal Sensitivity and Baseline RSA as Predictors

Model	B	(SE)	B	t	p
Step 1 (df = 2, 83; R^2 = .022; adjusted R^2 = -.002)					
Maternal sensitivity	-.676	.909	-.083	-.744	.459
Baseline RSA (natural log transformed)	1.81	1.81	.111	.999	.321
Step 2 (df = 3, 83; R^2 = .028; adjusted R^2 = -.009)					
Maternal sensitivity	-.664	.912	-.081	.727	.469
Baseline RSA (natural log transformed)	1.56	1.86	.096	.838	.404
Maternal sensitivity x Baseline RSA	-1.17	1.76	-.075	-.662	.510

Note. N = 82

Table 6

Hierarchical Regression Predicting Competence at 17 Months: Maternal Sensitivity and Baseline RSA as Predictors

Model	B	(SE)	B	t	p
Step 1 (df = 2, 83; R^2 = .077; adjusted R^2 = .054)					
Maternal sensitivity	.796	.310	.277	2.56	.012
Baseline RSA (natural log transformed)	.001	.619	.000	.002	.999
Step 2 (df = 3, 83; R^2 = .130; adjusted R^2 = .097)					
Maternal sensitivity	.782	.303	.273	2.58	.012
Baseline RSA (natural log transformed)	.281	.618	.049	.454	.651
Maternal sensitivity x Baseline RSA	1.29	.585	.236	2.21	.030

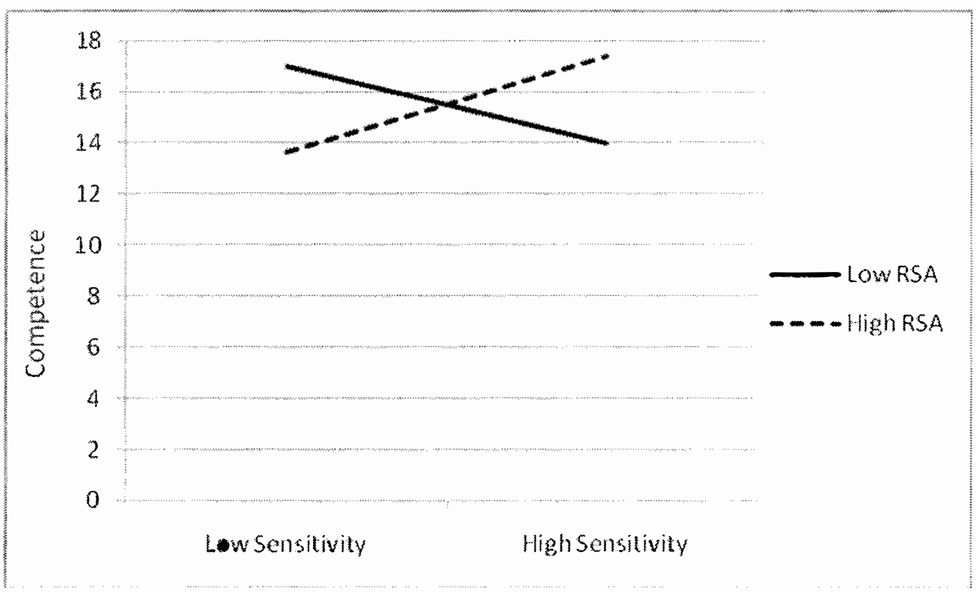
Note. N = 82

significant, $F(3, 83) = 3.98$, $p = .011$. There was a significant main effect of maternal sensitivity at 5 months as a predictor of socio-emotional competence at 17 months, $b = .273$, $p = .012$. The greater the maternal sensitivity at 5 months, the more socio-emotional competence the infants had at 17 months. As seen in Figure 3, this main effect was qualified by a significant interaction between baseline RSA and maternal sensitivity, which significantly improved the amount of variance explained by the model (R^2 change = .053, p = .030). Again, included in this figure are the infants who fell one standard deviation above and below the mean of baseline RSA.

An examination of the simple slopes at 1SD above and below the mean of baseline RSA and maternal sensitivity reveals support for differential susceptibility. Among the infants with low RSA, there were no significant differences in competence scores among infants of more and less sensitive mothers, b = -.284, p = .305. However, among infants with high RSA, competence scores increased along with maternal sensitivity, b = 2.33, p = .025.

Figure 3

Baseline RSA by Maternal Sensitivity Interaction Predicting Competence at 17 Months



An examination of whether there were significant differences in competence scores among infants of mothers who were less sensitive and who had low (n = 5, M = 17.0, SD = 2.83) and high (n = 6, M = 13.67, SD = 3.08) RSA was conducted. An independent samples *t-test* revealed no significant differences in competence, $t(9) = 1.40$, $p = .196$, although the effect size was large, Cohen's $d = 1.13$. An examination of whether infants of mothers who were more sensitive had significantly different competence scores, depending on their level of RSA revealed a trend toward significance between the low (n = 8, M = 14.0, SD = 4.97) and high (n = 6, M = 17.40, SD = 2.22) RSA groups, as per an independent samples *t-test*, $t(12) = -1.83$, $p = .092$, and the effect size was large (Cohen's $d = 0.88$). In the high sensitivity group, infants with lower RSA had moderately significantly lower competence scores than infants with higher levels of RSA.

Summary

The evidence suggests that infants with high basal RSA are more affected by their rearing environment than infants with low basal RSA. When examining the interaction between infant basal RSA and the infants' rearing environment, as indexed by their attachment relationship as well as maternal sensitivity, it appears as though higher basal RSA predisposes these infants to the positive and harmful effects of their environment. This relation was consistent across multiple indices of the environment – infants raised in an environment that fostered security and infants who had mothers who were more sensitive – and a harmful, possibly even threatening environment, as indexed by infants raised in environments that fostered disorganization, or had mothers who were less sensitive. Other possible covariates – including infant age and infant gender – were examined in relation to baseline RSA but no significant main effects or interactions emerged. Next, an examination of the growth trajectories of infant RSA was conducted in order to determine whether some infants responded to the stress of the still-face with greater reactivity than others.

Aim 2: Examination of Growth in Infant RSA as a Susceptibility Factor

Statistical Methodology

A series of linear and quadratic growth models were examined to determine: (1) whether there was significant variability in the level and growth of infant RSA over time, and (2) the best-fitting and most parsimonious model for describing individual differences in growth of RSA. Because the primary goal of Aim 2 was to describe the change in RSA over time, latent variable growth curve modeling (LGM) was selected as the analytic framework of choice (Duncan, Duncan, & Strycker, 2006). LGM allows for a more flexible approach to studying change, as individual differences in intercepts and slopes can be modeled over time (Duncan et al., 2006). Furthermore, LGM can be used even with small sample sizes, and when data are missing at random (Muthén & Muthén, 2002).

First, models were tested examining the level and shape of infants' RSA during the SFP. Individual, within-person variation in growth of RSA over time was modeled using a series of growth parameters (i.e. intercept, linear slope, and quadratic slope) that were allowed to randomly vary within the person (Muthén & Muthén, 1999). For each individual, the direction and degree of change in RSA during the still-face paradigm was modeled. This statistical technique was used to answer the question, "Are there individual differences in the level and shape of change in infant RSA during the still-face paradigm?" If there is indeed significant variability in the growth of infant RSA, this will allow for an explanation of factors that contribute to this heterogeneity in RSA trajectories, and whether or not we these trajectories can be characterized in terms of succinct patterns or, ideally, subgroups.

Determining Model Fit

First, the grand mean of infant RSA during the play, still-face, and recovery episodes were examined to determine if the still-face episode elicited the theoretical physiological response to acute stress (decrease in RSA from a baseline, or play episode). Pair *t-tests* revealed that the SFP generally produced the expected change in infants' RSA (physiological means presented in Table 7). Specifically, there was a significant increase in RSA from the baseline to the play episode, $t(89) = -2.83, p = .006$. Infants' RSA decreased significantly between the play and still face episodes, $t(89) = 3.27, p = .001$, which is consistent with parasympathetic withdrawal during distress. There was no significant difference in RSA between the still-face and recovery episodes.

Next, the data were examined to test the assumption of multivariate normality required for maximum likelihood estimation techniques, as outliers could distort model fit (Stoolmiller, 1995). Additionally, of relevance to Aim 3, Bauer and Curran (2003) caution that the existence of latent classes might be due to skewed data. Histograms and measures of skewness and kurtosis revealed that the RSA values were positively skewed (*M* skewness = 3.31, *M* kurtosis = 15.54). The natural log of the RSA value was

Table 7

Descriptive Statistics

Variable	*M*	SD	Skewness	Kurtosis
Baseline RSA	.0142	.0174	2.120	6.042
RSA T1	.0163	.0110	2.669	11.335
RSA T2	.0141	.0085	2.068	6.549
RSA T3	.0146	.0134	4.232	24.845
RSA T4	.0154	.0142	3.815	20.054
RSA T5	.0133	.0100	2.674	8.752
RSA T6	.0153	.0160	4.914	31.585
RSA T7	.0149	.0145	3.070	10.725
RSA T8	.0166	.0158	3.054	10.494
MOV T1	1.17	.5256	.444	.401
MOV T2	1.19	.5511	.072	-.097
MOV T3	1.26	.5478	-.179	-.127
MOV T4	1.26	.5822	.008	-.154
MOV T5	1.22	.5965	.076	-.231
MOV T6	1.23	.5588	.060	.241
MOV T7	1.24	.5660	-.144	-.091
MOV T8	1.16	.5871	.172	.030
RSA Play	.0170	.0130	2.181	7.98
RSA SF	.0141	.0067	1.62	4.54
RSA Recovery	.0141	.0064	1.61	5.80
Problem Behavior – 17 months	17.50	7.92	.593	1.30
Competence – 17 months	15.98	2.71	-.778	.854

Note. RSA = Respiratory Sinus Arrhythmia; MOV = Movement. N = 82

computed, and a constant of 1 was added. The transformation resulted in a more normal distribution of RSA scores (*M* skewness = 1.29, *M* kurtosis = 2.31).

Then, a series of baseline models, including infant RSA over time, were run to determine the best-fitting model. The final model was determined by identifying the timing and shape of RSA response that best described the data. As the central aim was to characterize the infant's response to the stress of the still-face, including RSA reactivity and recovery to the still-face episode, models that included the still-face and recovery episode of the SFP were compared with models that only included the still-face episode in order to determine the best model fit.

Table 8 includes the CFI, RMSEA, and relative Chi-square test of model fit of the 4 models tested. The Comparative Fit Index (CFI; Bentler, 2000) ranges from 0.00-1.00; a CFI of .90 represents the lowest acceptable measure of fit. The root mean square error of approximation (RMSEA; Browne & Cudeck, 1993) represents the error of approximation in the population. Values less than .05 represent good fit, and values ranging up to .08 indicate reasonable errors of approximation in the population (Byrne & Crombie, 2003). The relative Chi-square, (χ^2 / df), also termed normed or normal chi-square, is used as a fit index as it is less dependent on sample size (Arbuckle, 2005; Byrne, 2008). The relative chi-square should be in the 2:1 or 3:1 range for an acceptable model, that is, a relative chi-square value of less than 2 reflects good fit. The best-fitting model was chosen based on all available fit indices. The model tested using the still face and recovery data and linear and quadratic terms did not converge because the linear and quadratic slopes were so highly correlated. Therefore, these model statistics are not reported.[4]

Goodness-of-fit statistics related to Model 2 revealed a reasonably good fitting model (CFI = .975, RMSEA = .054). This unconditional model is presented in Figure 4.

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[4] Piecewise models (Muthén & Muthén, 2007; Stoolmiller, 1995) were tested, as well as models that examined different intercepts (e.g. at the beginning of recovery and at the beginning of peak stress during the still-face episode), but these did not lead to adequate model fit.

Table 8

Fit for Unconditional Growth Models

Model	CFI	RMSEA, *p*	Relative Chi-square (Chi-square/df)
1. Linear slope during the still-face episode	0.941	.087, $p = .080$	1.67
2. Linear and quadratic slope during still-face episode	0.985	.045, $p = .516$	1.18
3. Linear and quadratic slope during the still-face episode with an autoregressive error structure	.907	.103, $p = .016$	1.93
4. Linear slope during still-face and recovery episodes	0.847	.109, $p < .001$	2.05

Indeed, the model-fit indices were the best for this model, as it had the highest CFI, a nonsignificant RMSEA, and the lowest relative chi-square. This model included both a linear and quadratic growth term during the still-face episode. As seen in Figure 5, infants' RSA first declined, and then began to increase at the end of the still-face episode. This shape supports the hypothesis that, on average, infant RSA decreased during the start of the stressful episode (reflecting a withdrawal of RSA), and then increased toward the end of the still-face episode, which represented the beginning of recovery.

Baseline Model

Baseline models describing the level and shape of infants' RSA during the still-face episode were first run to examine between-person variability in the RSA trajectories. Intercept terms represented the infants' RSA value at the start of the still-face episode.

Figure 4

Unconditional Growth Model

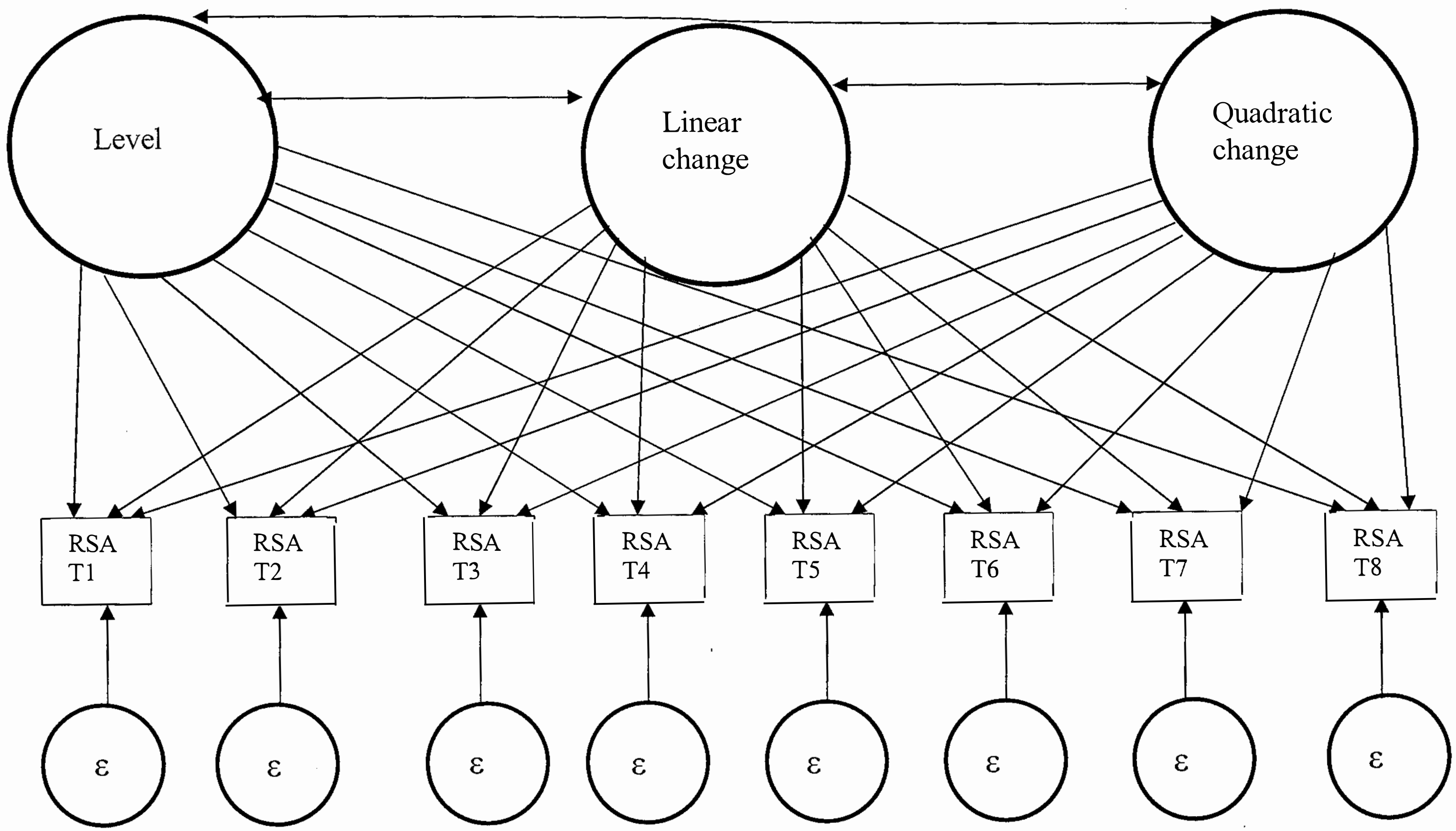
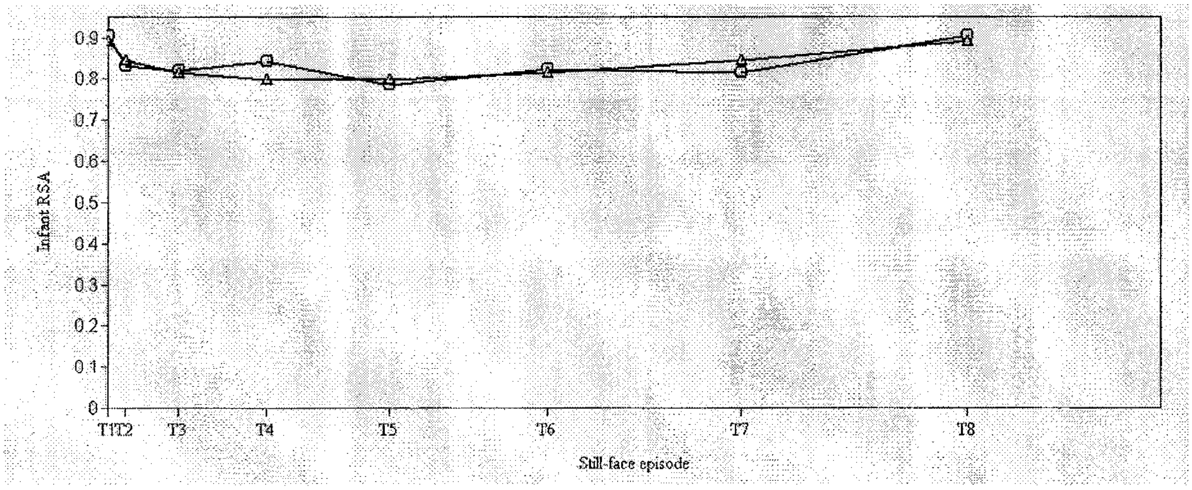


Figure 5

Level and Shape of Infant RSA Across the Still-Face Episode



Growth parameters (linear and quadratic) represented the shape of the infants' RSA response – the rate of change in RSA over time (Byrne & Crombie, 2003). The linear slope reflected the infant RSA increase or decrease over time and the quadratic slope reflected the curvature in the data.

The intercept, linear, and quadratic slopes were all allowed to randomly vary within the infant. The baseline model indicated that infants' RSA decreased significantly across the still-face episode from an intercept of .890, which is characteristic of a response to acute stress, b = -.053, p = .001. However, as seen in, Table 9, significant variability in these parameters indicated that this response varied across infants. On average, infants also exhibited a significant and positive quadratic slope, b = .008, p = .002, demonstrating that, as a group, infant RSA levels first decreased, and then increased toward the end of the still-face episode. Again, significant variability in this parameter suggested that there were individual differences with regard to this response pattern. Because a good-fitting model for RSA growth was found, and because there was significant variability in the level and shape of this growth, an exploration of whether growth in infant RSA was predictive relevant socio-emotional outcomes; specifically, problem behavior and competence at 17 months, was conducted.

Table 9

Parameter Estimates for the Latent Growth Model

	Estimate	SE	E/SE
Intercept			
Mean	.890	.034	26.37**
Variance	.069	.015	4.54**
Linear slope			
Mean	-.053	.017	-3.19**
Variance	.008	.004	1.91*
Quadratic slope			
Mean	.008	.002	3.06*
Variance	.000	.000	2.15*
Residual variance, T1	.054	.012	4.49**
Residual variance, T2	.019	.005	3.96**
Residual variance, T3	.058	.010	5.75**
Residual variance, T4	.053	.010	5.43**
Residual variance, T5	.033	.007	4.64**
Residual variance, T6	.066	.012	5.35**
Residual variance, T7	.095	.018	5.15**
Residual variance, T8	.039	.021	1.86

Note. N = 94, ** = $p < .001$, * = $p < .05$

Model 2.1. Does RSA level and growth, attachment classification, and/or an interaction of the two predict problem behavior at 17 months?

To examine the relative independence of the predictor variables and outcomes, bivariate correlations between the RSA measures and the two major outcomes of interest:

problem behavior and competence at 17 months were computed (see Table 10). There was a strong, negative correlation between the linear and quadratic slope, $r = -.879$, $p < .001$. Because this strong correlation raises concerns about collinearity, the linear and quadratic slopes were examined separately in all regression models. The correlations among the other predictors and outcomes were small and nonsignifcant ($M = -.049$, range = -.908 - .291), suggesting that collinearity is not an issue.

Next, the relation between RSA response to the still-face and quality of attachment as predictors of problem behavior at 17 months was examined. The intercept, slope, and quadratic slope factor scores was extracted using Mplus (Version 5; Muthén & Muthén, 2007) and exported into SPSS to examine these variables as predictors in a linear regression. Baseline RSA was entered as a covariate to account for variability in infant RSA that might be due to resting levels of RSA, rather than change in RSA from the start of the still-face episode. Baseline RSA, a dichotomous attachment variable (secure vs disorganized), and the intercept, slope, and quadratic factor scores (separately)

Table 10

Intercorrelations Among Predictors and Outcomes

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Baseline RSA	---									
2. RSA Intercept (start of still-face episode)	.151	---								
3. Linear slope of infant RSA	.145	.067	---							
4. Quadratic slope of infant RSA	-.054	-.035	-.879**	---						
5. Problem behavior	.131	.028	.022	.014	---					
6. Competence	-.043	-.048	.121	-.174	-.021	---				
7. Maternal sensitivity	-.103	-.185	-.045	-.013	.101	.277*	---			
8. Intercept of infant movement	-.137	-.021	-.121	.118	.040	-.077	-.192	---		
9. Linear slope of infant movement	.077	-.038	-.221*	.225*	.039	.074	-.012	.291*	---	
10. Quadratic slope of infant movement	-.048	-.047	.211*	-.248*	-.002	.001	-.029	-.402**	-.908**	---

Note. RSA and movement measures assessed during the still-face episode.
N = 87, ** = p<.001, * $p < .05$

were entered in step 1. As seen in Table 11, the interaction between infant attachment classification and RSA intercept, slope, and quadratic growth (separately) was entered in step 2.[5]

Table 11

Hierarchical Regression Predicting Problem Behavior at 17 Months: Attachment Classification (B vs D) and Level and Growth in RSA as Predictors

Model	B	(SE)	Β	*t*	*p*
Step 1 (df = 4, 65; R^2 = .032; adjusted R^2 = -.031)					
Infant attachment classification (B vs D)	2.57	2.45	.133	1.05	.298
Baseline RSA (natural log transformed)	3.16	3.80	.107	.830	.410
Intercept	.825	4.18	.025	.197	.844
Linear Slope	-5.61	18.81	-.039	-.298	.766
Step 2 (df = 6, 65; R^2 = .120; adjusted R^2 = .030)					
Infant attachment classification (B vs D)	2.25	2.39	.117	.942	.350
Baseline RSA (natural log transformed)	1.95	3.72	.066	.523	.603
Intercept	1.61	4.90	.049	.329	.744
Linear slope	-27.58	20.59	-.190	-1.34	.186
Intercept x attachment classification	-7.85	9.02	-.138	-.871	.388
Linear slope x attachment classification	106.75	44.17	.367	2.42	.019

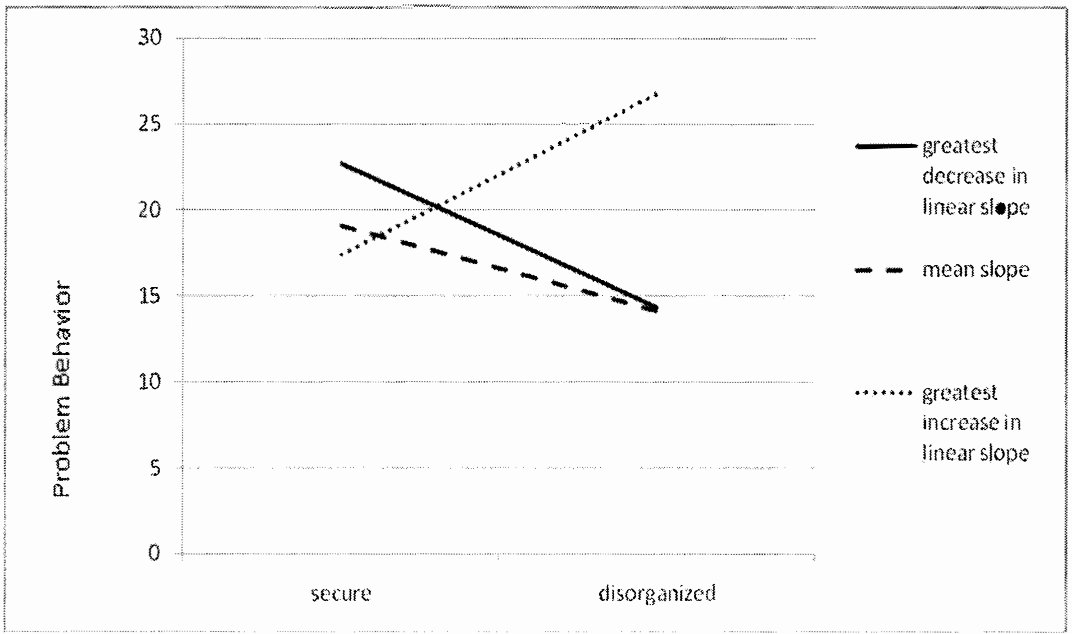
Note. N = 81

As seen in Figure 6, there was a significant interaction between infant linear slope and attachment classification, b = .367, p = .019, and a nonsignificant interaction between the quadratic slope and infant attachment, b = -.161, p = .386[6].

[5]Following recommendations by Bazhenova and colleagues (Bazhenova, Plonskaia, & Porges, 2001), in all the models described, infant movement was examined as a covariate because of its moderate (r = -.221) correlation with the linear slope of RSA and because movement could account for differences in RSA during the still-face episode. An examination of infant movement as: (1) a time-varying covariate, along with infant RSA in the growth models, and (2) including the intercept, linear, and quadratic slope of infant movement as a covariate in regression models was conducted. Infant movement did not substantially change the interpretation of these results, and was therefore not included in regression models.

Figure 6

Linear Slope x Attachment Classification (B vs D) Interaction



Infants were then divided into those with the greatest linear increase in RSA across the still-face episode (1 SD above the linear slope mean), those who were at the mean, and those who had the greatest linear decrease in RSA (1 SD below the linear slope mean) to clarify the nature of the interaction. The simple slope was significant among the infants with the greatest withdrawal of RSA, $b = -.692$, $p = .026$. In this group, infants with secure classifications (n = 7, $M = 22.71$, $SD = 3.95$) had significantly higher problem behavior scores than infants with disorganized classifications (n = 3, $M = 14.33$, $SD = 5.77$), resulting in a large effect size, Cohen's $d = 1.69$. Among the infants at

[6] These interactions were examined in the Mplus platform, but the interaction was not replicated, $b = 1.60$, $p = .109$.

the linear slope mean, there was no significant difference in problem behavior among infants with secure classifications (n = 16, *M* = 19.06, *SD* = 6.26) and those with disorganized classifications (n = 7, *M* = 14.14, *SD* = 5.33), $b = -.367$, $p = .085$. Among the infants who had the largest increase of RSA during the still-face, there simple slope of attachment quality on problem behavior was not significant, $b = .414$, $p = .268$.

Among the infants with disorganized classifications, those with the greatest increase in slope had marginally significantly higher problem behavior scores than those with the greatest decrease in slope, t (9) = -1.94, $p = .084$, Cohen's $d = 1.04$. There was no significant difference in problem behavior between children with secure attachment histories with higher increasing or lower decreasing RSA scores, $t(19) = .523$, $p = .607$.

Model 2.2. Does RSA level and growth, attachment classification, and/or an interaction of the two predict competence at 17 months?

The same analyses were repeated using infant competence at 17 months as criterion. None of the main effects or interactions were significant (see Table 12).[7]

Model 2.3. Does RSA level and growth, maternal sensitivity, and/or an interaction of the two predict problem behavior at 17 months?

Models were tested that examined infant baseline RSA, maternal sensitivity, the intercept of infant RSA at the start of the still-face episode, and the linear and quadratic growth (separately) of infant RSA at step 1. The interaction between intercept and linear and quadratic slope (separately) and maternal sensitivity were entered in step 2 as

[7] Other regression models were examined using different combinations of the attachment classification (B vs A +C); with no significant main effects or interactions. In the interest of space, the results of these models are not reported.

Table 12

Hierarchical Regression Predicting Competence at 17 Months: Attachment Classification (B vs D) and Level and Growth in RSA as Predictors

Model	B	(SE)	B	*t*	*p*
Step 1 (df = 4, 65; R^2 = .037; adjusted R^2 = -.026)					
Infant attachment classification (B vs D)	-.196	.817	-.030	-.239	.812
Baseline RSA (natural log transformed)	-.622	.717	-.111	-.868	.389
Intercept	-.806	1.40	-.073	-.578	.565
Linear Slope	8.16	6.27	.168	1.30	.198
Step 2 (df = 6, 65; R^2 = .090; adjusted R^2 = -.002)					
Infant attachment classification (B vs D)	-.065	.813	-.010	-.080	.937
Baseline RSA (natural log transformed)	-.606	.715	-.108	-.848	.400
Intercept	.930	1.67	.085	.558	.579
Linear slope	9.28	7.00	.191	1.33	.190
Intercept x attachment classification	-5.53	3.07	-.290	-1.80	.076
Linear slope x attachment classification	1.59	15.01	.016	.106	.916

Note. N = 81

predictors of problem behavior. As seen in Table 13, none of the main effects or interactions were significant.

Model 2.4. Does RSA level and growth, maternal sensitivity, and/or an interaction of the two predict competence at 17 months?

The same models were tested using competence as the outcome. As seen in Table 14, maternal sensitivity at 5 months significantly predicted toddler competence at 17 months, b = .266, p = .030. Mothers with greater levels of maternal sensitivity at 5 months had infants with greater competence at 17 months. None of the interactions were significant.

Table 13

Hierarchical Regression Predicting Problem Behavior at 17 Months: Maternal Sensitivity and Level and Growth in RSA as Predictors

Model	B	(SE)	B	*t*	*p*
Step 1 (*df* = 4, 73; R^2 = .017; adjusted R^2 = -.040)					
Maternal sensitivity	-.333	.930	-.044	-.358	.721
Baseline RSA (natural log transformed)	1.44	1.82	.097	.790	.432
Intercept	-.311	3.81	-.010	-.082	.935
Linear Slope	6.52	16.26	.049	.401	.690
Step 2 (*df* = 6, 73; R^2 = .034; adjusted R^2 = -.053)					
Maternal sensitivity	-.292	.940	-.039	-.311	.757
Baseline RSA (natural log transformed)	1.53	1.85	.104	.828	.410
Intercept	1.34	4.29	.043	.313	.755
Linear slope	7.51	16.80	.056	.447	.656
Intercept x maternal sensitivity	3.72	4.53	.115	.823	.414
Linear slope x maternal sensitivity	9.40	20.77	.058	.453	.652

Note. N = 81

Summary

Latent variable growth curve modeling was used to examine whether there was significant variability in infants' level and shape of RSA response to the still-safe episode. A good-fitting model was identified that included a linear and quadratic slope, during the still-face episode only. Tests were then conducted to examine whether infant RSA response, the attachment environment, and/or an interaction of the two were predictive of problem behavior and competence at 17 months. A significant interaction was found between the linear growth of infant RSA and the attachment environment as predictors of problem behavior. Specifically, among infants with the largest decreases in

RSA, infant problem behavior tended to decrease as the linear slope in RSA decreased, but only among infants raised in an environment that fostered disorganization. The implications of this finding will be addressed in the discussion.

Table 14

Hierarchical Regression Predicting Competence at 17 Months: Maternal Sensitivity and Level and Growth in RSA as Predictors

Model	B	(SE)	B	*t*	*p*
Step 1 (*df* = 4, 73; R^2 = .088; adjusted R^2 = .035)					
Maternal sensitivity	.733	.345	.254	2.13	.037
Baseline RSA (natural log transformed)	-.217	.675	-.038	-.321	.749
Intercept	-.205	1.41	-.017	-.145	.885
Linear Slope	7.48	6.02	.146	1.24	.219
Step 2 (*df* = 6, 73; R^2 = .116; adjusted R^2 = .037)					
Maternal sensitivity	.767	.346	.266	2.22	.030
Baseline RSA (natural log transformed)	-.215	.680	-.038	-.316	.753
Intercept	.341	1.58	.029	.216	.829
Linear slope	8.64	6.18	.169	1.40	.167
Intercept x maternal sensitivity	1.17	1.67	.094	.703	.484
Linear slope x maternal sensitivity	7.89	7.64	.127	1.03	.305

Note. N = 81

Aim 3: Examination of Heterogeneity in Infant RSA Trajectories

Conventional growth modeling assumes that individuals come from the same population, and that a single growth trajectory adequately describes developmental change in the population (Jung & Wickrama, 2008). However, we know from the physiological literature that some individuals respond to stress with a withdrawal of RSA, while others do not, with these profiles predicting different outcomes with respect to later problem behavior and psychopathology. Thus, the goal of this aim is to extend the sample-level Latent Growth Model to examine the core hypotheses using a person-centered (versus a variable-centered) approach. This approach models change by accounting for latent, or unobserved, heterogeneity in growth trajectories within the larger population. Using Growth Mixture Modeling techniques, one can allow different groups of individuals to vary around different means, rather than assuming that all individuals in the population vary around single growth parameters (e.g. intercepts and slopes). In this aim, Growth Mixture Modeling will be employed to test the hypothesis that there are distinct subgroups of infants with different RSA response trajectories to stress. The goal is to examine whether infants can be classified into distinct classes based on their RSA response to the still-face episode of the SFP.

Models were compared with respect to the following fit indices: The Bayesian Information Criteria (BIC) Akaike's Information Criterion (AIC), Entropy (values closer to 1 indicate better classification quality; Duncan et al., 2006), the Vuong, Lo, Mendell, and Rubin (2001) Likelihood Ratio Test, and the Bootstrap Likelihood Ratio Tests (BLRT). Models with the smallest BIC, AIC, higher Entropy values, and significant VLMR-LRT and BLRT tests are considered good-fitting models. The p values in the VLMR-LRT and BLRT report the probability that a model with one fewer classes is acceptable. A p – value greater than .05 indicates that the null hypothesis – that a reduced model is preferable – can't be rejected. Likewise, if a p value is less than .05, this suggests that the model is preferred over the reduced model – the model with one less class (Duncan et al., 2006). The model fitting statistics are reported in Table 15 below.

Mplus (version 5.1; Muthén & Muthén, 2007) was used with the Maximum Likelihood estimator as the statistical method for fitting the data. Because of the lower sample size in this study, the starts were increased to 1000 and the log likelihoods were checked to confirm that the same log likelihood was replicated at least five times. According to the model selection criteria described above, the two-class solution allowing for within-class heterogeneity in the growth parameters – specifically, one that constrained the variances of the intercepts and slopes as equal across all classes - provided the best fit. This model produced a BIC value almost 120 points lower than the 2-class, LCGA model. In one recent study, Monte Carlo simulations were run to evaluate which information-criteria (BIC, CAIC, AIC, and adjusted BIC) could correctly identify the number of classes; the BIC was the best indicator of model fit (Nylund, Asparouhov, & Muthén, 2007). Therefore, more weight was given to this model-fitting statistic. For none of the models was the VLMR-LRT significant. For this 2-class solution, however, the BLRT test was significant, indicating that a 2 – class model was a significantly better fit than a one-class solution. A 2-class solution with an auto-regressive structure was also tested, as RSA measures were sampled closely in time – only 15 seconds apart. This auto-regressive structure constrained the residual variances to be held equal, the residual covariances at adjacent time points to be held equal, and the residual covariances at time points once removed were held equal to the square of the residual covariances at adjacent time points (Muthén & Muthén, 2007). In other words, the effect of infant RSA at one time point on the subsequent time point that was not captured by the intercepts and

Table 15

Model-fitting Statistics for the Unconditional Growth Mixture Model

Model	Free parameters	AIC	BIC	Entropy	VLMR-LRT	BLRT, *p*
1. 2 class allowing setting the variances of the intercepts and slopes as equal across all classes – GMM	16	225.48	264.94	.966	-110.95, $p = .1951$	-110.95, $p < .001$
2. 2 class allowing separate estimates of within-class variances for each class – GMM	18	226.54	270.93	.766	-110.95, $p = .229$	-110.95, $p = .013$
3. 2 class with autoregressive error structure	10	245.73	270.39	.953	-126.46, $p > .05$	-126.46, $p < .001$
4. 3 class GMM	19	231.48	278.34	.394	-96.74, $p = .50$	-96.74, $p = 1.00$
5. 2 class LCGA	13	358.77	390.83	.948	-267.05, $p = .178$	-267.05, $p < .001$
6. 3 class LCGA	16	312.80	352.25	.835	-166.39, $p = .319$	-166.39, $p = 1.00$

slopes, was tested. However, there was not a significant improvement in model fit, as indexed by the higher AIC, BIC, and lower Entropy values.

In addition, the LCGA approach – constraining the variances in the intercept and slope growth parameters to be zero – was tested. This approach, advocated by Nagin (2005), is considered by some to be advantageous because the differences between groups are sharpened, although classifications of individuals within a group become diluted. Model fit statistics indicated a poorer model fit using this approach, as evidenced by higher AIC and BIC values. In addition, it was more difficult to interpret the groups. In the 2 class LCGA solution, there was a low stable class ($n = 72$) and a higher, stable class ($n = 15$). In the 2 class GMM solution, there was a clear low class whose RSA values decreased slightly across the still-face episode, and a high, increasing class. It was deemed theoretically more important to include the group of infants whose RSA scores were increasing, as opposed to decreasing, in order to test the hypothesis that infants who are more reactive (have RSA levels that decrease during stress) are more susceptible to their environment. The inclusion of the high, increasing class also allowed for a greater understanding of the construct of reactivity. Could it be this group of infants, for instance, who are most responsive, and perhaps most susceptible, to their environment?

Although the two-class GMM allowing separate estimates of within-class variances for each class (Model 2) produced the same trajectory classes as the Model 1 GMM, Model 2 had a poorer fit as evidenced by the lower entropy score. The two-class model was therefore chosen, in which the growth parameters were constrained to be equal within classes, as the best fitting, and theoretically most relevant model for the current sample.

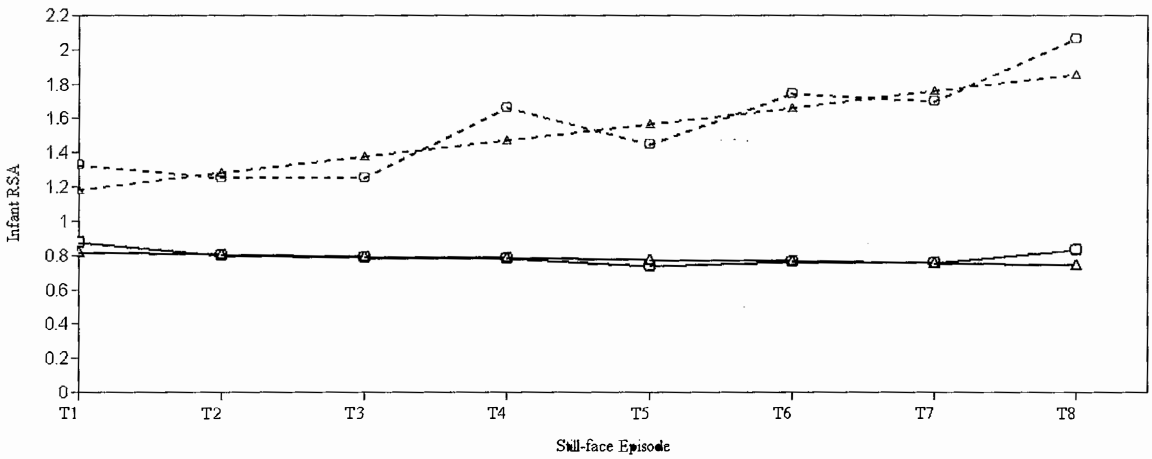
The RSA trajectories of the two-class solution are plotted in Figure 7. As seen in this figure, a low stable class and a high increasing class was identified using GMM. This figure includes the observed class means and class means obtained from the model estimation procedures. Parameter estimates are included in Table 16. Mplus syntax for the chosen unconditional model is included in Appendix A. Additional Mplus syntax employed to test alternative models are included in Appendix B.

Approximately 93.1% (n = 81) of infants were placed in the first, or "low stable" class. Consistent with a physiological response to an acute stressor, these infants had RSA values that decreased across the still-face episode, although this decrease was marginally significant. The second, "high increasing" class consisted of six infants (6.9% of the sample) whose RSA scores significantly increased during the still-face episode. These infants also had significantly higher RSA values at the start of the still-face episode than the "low stable" class (mean difference = -.3832), t (85) = -3.79, $p < .001$.

In order to describe the classes, differences in: (1) quality of attachment; (2) problem behavior scores; (3) competence scores; and (4) maternal sensitivity scores were examined between trajectory groups. Following the approach by Nagin (2005), the above predictors were examined separately in logistic regressions in SPSS. None of the predictors were significant (p's above .24). Differences between the classes were then examined using chi-square analyses in SPSS. First, the number of secure, insecure, and disorganized infants were in each class were calculated. In the "low stable" class, there

Figure 7

Infant RSA Trajectory Groups Identified in the 2-Class Unconditional Model



were 48 secure (82.8% of secure infants), 7 avoidant (100% of avoidant infants), 13 disorganized (72.2% of disorganized infants) and 3 resistant (75% of resistant infants) infants, while in the "high increasing" class there were 3 secure (5.2% of secure infants) and 3 disorganized infants (16.7% of disorganized infants). A chi-square test revealed that infant attachment status did not discriminate between latent trajectory classes, $\chi^2 = 2.47$, $p = .116$.

In an examination of the problem behavior scores, an independent samples *t* test revealed that infants in the high increasing class had marginally significantly higher problem behavior scores ($M = 20.33$, $SD = 2.73$) than the low stable group, ($M = 17.69$, $SD = 7.61$), $t\ (75) = -1.84$, $p = .088$, Cohens' $d = .46$. There were no significant differences between the classes with regard to competence or maternal sensitivity scores ($t\ (75) = .568$, $p = .323$ and $t(81) = 1.25$, $p = .216$, respectively).

Table 16

Parameter Estimates for the 2-Class Unconditional Model

	Estimate	SE	Estimate/SE
Class 1 (Low stable)			
Intercept mean	.809	.041	19.54**
Slope mean	-.011	.007	-1.65^{+}
Intercept variance	.055	.015	3.77**
Slope variance	.001	.000	1.57^{+}
Class 2 (High increasing)			
Intercept mean	1.08	.188	5.74**
Slope mean	.063	.048	1.31
Intercept variance	.149	.060	2.47*
Slope variance	.004	.003	1.37
Common Parameters			
Residual variance, T1	.072	.015	4.86**
Residual variance, T2	.017	.005	3.73**
Residual variance, T3	.060	.014	4.39**
Residual variance, T4	.055	.012	4.67**
Residual variance, T5	.040	.011	3.59**
Residual variance, T6	.059	.014	4.13**
Residual variance, T7	.095	.046	2.05*
Residual variance, T8	.085	.036	2.38*

Model 3.1. Does RSA trajectory group and secure vs disorganized attachment predict problem behavior at 17 months?

The last goal of this aim was to examine whether class membership interacted with attachment classification to predict socio-emotional outcomes; specifically, problem behavior and competence. Class membership information from the 2-class, unconstrained model was exported from Mplus into SPSS, and a series of linear regressions were modeled.

Main effects and interactions were tested between the different RSA trajectory classes and the attachment classification (B vs D) as predictors of problem behavior. The trajectory class and attachment classification was entered in step 1 of a hierarchical regression. The interaction between attachment classification and trajectory class was entered in step 2. As seen in Table 17, none of the main effects or interactions significantly predicted problem behavior.

Table 17

Hierarchical Regression Predicting Problem Behavior at 17 Months: Class Membership and Attachment Classification (B vs D) as Predictors

Model	B	(SE)	Β	t	p
Step 1 (df = 2, 65; R^2 = .014; adjusted R^2 = -.017)					
Attachment classification (B vs D)	1.21	2.29	.067	.527	.600
Class membership	2.26	3.34	.086	.675	.502
Step 2 (df = 3, 65; R^2 = .014; adjusted R^2 = -.033)					
Attachment classification (B vs D)	1.92	8.01	.107	.239	.812
Class membership	2.54	4.58	.097	.555	.581
Attachment classification x class membership	-.625	6.76	-.045	-.092	.927

Note. N = 81

Model 3.2. Does RSA trajectory group and secure vs disorganized attachment predict competence at 17 months?

The same models were examined with competence at 17 months as the criterion. As seen in Table 18, none of the main effects or interactions were significant.

Model 3.3. Does RSA trajectory group and maternal sensitivity predict problem behavior at 17 months?

As one final test of the predictive power of these classes, regression models using maternal sensitivity as the environmental variable were examined. Trajectory class membership and maternal sensitivity were entered in step 1 of a hierarchical regression

Table 18

Hierarchical Regression Predicting Competence: Class Membership and Attachment Classification (B vs D) as Predictors

Model	B	(SE)	B	*t*	*p*
Step 1 ($df = 2, 65$; $R^2 = .019$; adjusted $R^2 = -.012$)					
Attachment classification (B vs D)	-.009	.823	-.001	-.011	.991
Class membership	-1.30	1.20	-.138	-1.08	.284
Step 2 ($df = 3, 65$; $R^2 = .038$; adjusted $R^2 = -.008$)					
Attachment classification (B vs D)	3.04	2.85	.471	1.07	.290
Class membership	-.062	1.63	-.007	-.038	.970
Attachment classification x class membership	-2.69	2.40	-.534	-1.12	.268

Note. N = 81

model, and the interaction of the two were entered in step 2. As seen in Table 19, there were no significant main effects or interactions of class membership and maternal sensitivity in predicting problem behavior.

Table 19

Hierarchical Regression Predicting Problem Behavior at 17 Months: Maternal Sensitivity and Class Membership as Predictors

Model	B	(SE)	B	*t*	*p*
Step 1 ($df = 2, 73$; $R^2 = .013$; adjusted $R^2 = -.015$)					
Maternal sensitivity	-.379	.893	-.050	-.424	.673
Class membership	2.59	3.18	.097	.813	.419
Step 2 ($df = 3, 73$; $R^2 = .013$; adjusted $R^2 = -.029$)					
Maternal sensitivity	-.532	3.38	-.071	-.158	.875
Class membership	2.65	3.48	.099	.762	.448
Maternal sensitivity x class membership	.139	2.95	.022	.047	.962

Note. N = 81

Model 3.4. Does RSA trajectory group and maternal sensitivity predict competence at 17 months?

The same models were tested using competence at 17 months as criterion. As seen in Table 20, significant main effects and interactions emerged to predict competence. Specifically, there was a significant main effect of maternal sensitivity; higher levels of maternal sensitivity predicted lower levels of competence, $b = -.979$, $p = .019$. This main effect was qualified by an interaction, however, between maternal sensitivity and class membership, $b = 1.30$, $p = .003$[8]. As seen in Figure 8, competence scores increased as maternal sensitivity increased, but only in the high increasing class. In fact, an examination of simple slopes one standard deviation above and below the mean of maternal sensitivity revealed that, as maternal sensitivity increased, competence increased in the high increasing class, $b = .850$, $p = .032$, but not in the low stable class, $b = .142$, $p = .247$.

There was insufficient power to detect significant differences in competence between infants of mothers who were more sensitive and were in the: (1) high increasing class (n = 1, $M = 20$) and (2) low stable class (n = 15, $M = 16$, $SD = 3.16$). Additionally, there were no significant differences in competence between infants of mothers who were less sensitive and were in the (1) high increasing class (n = 2, $M = 11.0$, $SD = 1.41$) and (2) low stable class (n = 10, $M = 14.4$, $SD = 2.76$), $t(10) = 1.65$, $p = .129$ although the effect size was large, Cohen's $d = 1.55$.

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[8] This interaction was replicated using Mplus, following procedures by Stoolmiller, Kim, & Capaldi (2005). Specifically, Model 1 was run in which all predictor-to-intercept and predictor-to-slopes effects were freely estimated. This model was compared with Model 2 that forced each effect to be equal across all the latent classes. If Model 1 fit better than Model 2, then the class x predictor interaction was supported. See Appendix B for syntax.

Table 20

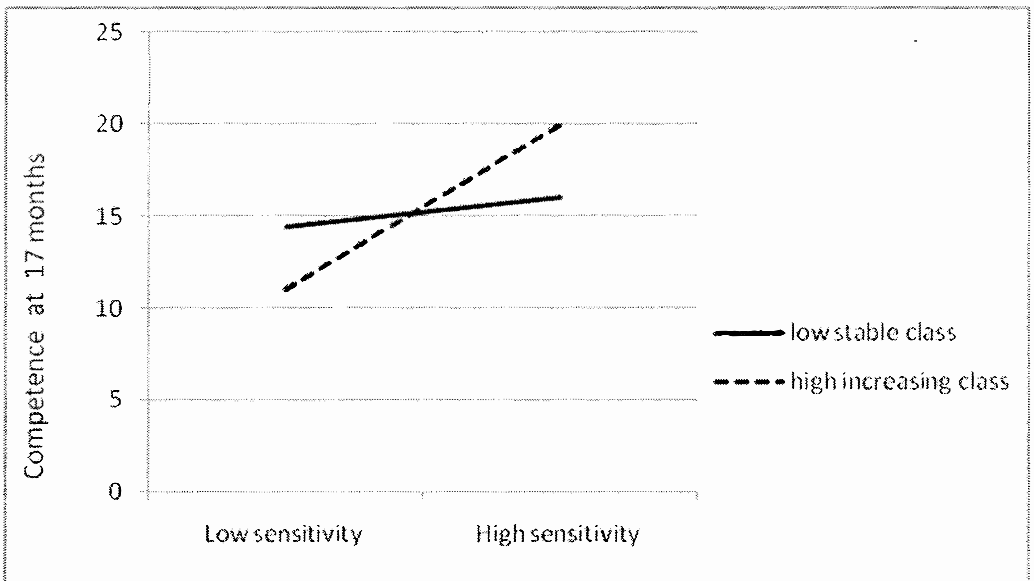
Hierarchical Regression Predicting Competence at 17 Months: Maternal Sensitivity and Class Membership as Predictors

Model	B	(SE)	B	*t*	*p*
Step 1 (df = 2, 73; R^2 = .074; adjusted R^2 = .048)					
Maternal sensitivity	.716	.333	.248	2.15	.035
Class membership	-.842	1.19	-.082	-.711	.480
Step 2 (df = 3, 73; R^2 = .186; adjusted R^2 = .151)					
Maternal sensitivity	-2.82	1.18	-.979	-2.39	.019
Class membership	.626	1.22	.061	.515	.608
Maternal sensitivity x class membership	3.21	1.03	1.30	3.11	.003

Note. N = 81

Figure 8

Maternal Sensitivity x Latent Class Interaction



Summary

Latent growth curve mixture modeling revealed two classes of infants with distinct trajectories of growth in RSA during a social stressor. The majority of infants exhibited RSA levels that were low, and decreased slightly across the still-face episode, which is consistent with an acute response to stress. A sub-set of infants exhibited RSA levels that were higher than the low, stable class. These infants' RSA also increased across the still-face episode. Tests of differential susceptibility revealed that this later class of infants appears to be more susceptible to their mothers' sensitive behaviors. Only among these infants did competence increase with greater levels of maternal sensitivity.

CHAPTER V

DISCUSSION AND CONCLUSIONS

In the past decade, developmental psychology has witnessed a burgeoning literature supporting the theory that some children manifest traits that place them at particular risk if placed in harmful environments, and that help them bloom in environments of support. The way in which an infant reacts and recovers physiologically to environmental conditions is prognostic of later adjustment. Theories of differential susceptibility and biological sensitivity to context are beginning to illuminate the underlying processes behind this effect but primarily among older children. No studies have examined physiological functioning as a susceptibility factor in infancy. It is important to determine whether, early in life, biological susceptibilities can be detected, as the way in which these susceptibilities intersect with the environment forecast long-term adaptation, including socio-emotional, academic, physical and psychological health.

The overarching goal of this dissertation was to examine infant parasympathetic functioning as an indicator of susceptibility. This dissertation also took advantage of newer statistical techniques that modeled growth in RSA, and person-centered growth in parasympathetic functioning over time, in order to test the hypothesis that infants who are more reactive are more susceptible to environmental influences.

Across all three aims, interactions emerged between physiological functioning and indices of both harmful and supportive environments in the prediction of problem behavior and competence. Physiological susceptibilities measured at five months significantly interacted with quality of attachment - a variable that represents environmental processes reflective of experiences during the infant's first 17 months of life – to predict 17 month outcomes. These interactions appeared unique to the secure vs disorganized attachment classifications, rather than secure vs insecure classifications. While all infants were reared in this risk condition, these results suggest that a disorganized attachment style might be particularly problematic in environments of considerable risk, where a disorganized status might be compounded by additional conditions of risk (e.g. low SES, parent history of psychopathology; Belsky & Fearon, 2002). Furthermore, this is the first study to test the differential susceptibility hypothesis in a risk sample. These results extend current theory by demonstrating that differential susceptibility processes are at work, even in environments where caregivers are presumably under a great deal of stress because of their poverty status.

Tests of Baseline RSA as a Susceptibility Factor

One of the most exciting findings to emerge from this dissertation was support for infant baseline RSA as a susceptibility factor in the context of both maternal sensitivity and the attachment environment. Previous empirical work suggests that higher baseline RSA is related to the infant's capacity to actively engage with the environment. In this dissertation, high baseline RSA was related to greater attention, sensitivity to environmental perturbations, and vocal reactivity, providing additional support for the hypothesis that high baseline RSA is reflective of greater alertness and awareness of the environment. Low baseline RSA, however, is associated with less attentiveness, decreased sociability, and a decreased ability to self-regulate in infancy (Porges et al., 1996). Infants with low baseline RSA have a diminished ability to suppress RSA during challenge, meaning they are less likely to sustain attention and cope during environmental challenge (Calkins & Dedmon, 2000). Thus, infants with low baseline RSA may be less aware of, and subsequently less susceptible to, environmental perturbations, compared with their high baseline RSA peers.

In this dissertation, baseline RSA interacted with the quality of the attachment relationship to predict problem behavior in toddlerhood. Infants with higher baseline RSA, and who were raised in environments that fostered security had significantly lower problem behavior scores than infants with low RSA *and* infants with high RSA who were raised in environments that fostered disorganization. It is remarkable that, already at five months, infants with high resting levels of RSA may be biologically able to reap the benefits of being raised in a particularly supportive environment – over and above even their low RSA peers.

From birth, infants rely heavily on their caregiver for homeostatic and behavioral regulation (Calkins & Hill, 2007; Feldman, 2007; Spangler & Grossman, 1993), as infants have not yet fully developed the bio-behavioral capacities needed for autonomous regulation (Sroufe, 2000). Infants with high baseline RSA are observed to be more attentive, but also more easily upset when exposed to novel objects or people, and thus, thought to be more sensitive to minor environmental changes. As these infants are thus more engaged with their surroundings, they presumably are also thought to be impacted by their caregiving environment-for better and for worse. It is possible that, when infants with high baseline RSA are reared in an environment in which they receive appropriate soothing from their caregiver, they are able to engage even more with the environment, all the while learning important self-regulatory skills (Bebee, 2006; Kopp, 1982). In this secure environment, the infant is thought to experience repeated warm, sensitive interactions in which the infant practices effective regulation, organized by the caregiver. These moments allow the infant to, "prolong his engagement in the world around him in the face of immaturity and physiological demands" (Brazelton et al., 1975, pg. 148). This is particularly important for the infants with high baseline RSA, who might be more engaged with the environment, and subsequently more reactive in the face of environmental perturbations. These caregiving strategies provide the foundation and support for the eventual development of the child's ability to regulate his/her own emotions (Kopp, 1982), and they lay the foundation for the development of more complex coping methods for dealing with stressors later in life (Schore, 2001).

It is possible that the infants who were more engaged in their surroundings, and who were raised in a secure environment, have been helped by their sensitive, responsive caregiver to regulate appropriately during their first 17 months of life. By the time they became toddlers, they learned how to effectively cope with their surroundings, resulting in significantly fewer problem behaviors. Infants with higher baseline RSA, an index of environmental engagement, or alertness and readiness to encounter environmental conditions, who were reared in an environment that lead to repeated practices of effective emotion regulation, were as toddlers better able to regulate and thus did not need to rely on more problematic ways of coping. Thus, having higher baseline RSA appears to be adaptive in the context of a supportive caregiving environment.

Infants with high baseline RSA, and who were raised in an environment that fostered disorganization, exhibited more problem behavior than infants with low RSA reared in this same environment, although this effect was not significant. The infants with high baseline RSA are presumably more attuned and aware of their environmental surroundings. Unfortunately, if these infants are reared in environments where their primary caregiver responds to their distress cues with insensitive and/or frightening behavior, they might not learn how to appropriately self-soothe, or they might learn inappropriate methods of self-soothing, such as aggression, leading to the expression of more problem behaviors.

Another fascinating finding is that there were no differences in problem behavior between infants with low baseline RSA raised in secure and disorganized environments. This group of infants did not appear susceptible to the different environments in which they were reared. Infants and children with low baseline RSA are presumably not as alert or aware of environmental changes or fluctuations; they might be less attuned to incoming signals coming from their environment – including caregiving behavior. This type of response (or lack thereof) to the environment appeared to be protective among the infants raised in an environment that fostered disorganization. On the other hand, the infants with low baseline RSA and who were raised in an environment that fostered security did not appear to reap the benefits of having a sensitive and responsive caregiver. The differential susceptibility hypothesis does little to describe individuals who are "less susceptible"; more attention is paid to susceptible individuals. Future research should examine these infants longitudinally to adequately characterize this group of infants.

The finding that baseline RSA acted as a susceptibility factor in interactions with the attachment environment as a predictor of problem behavior, but not with maternal sensitivity, is worthwhile noting. Research tells us that the attachment relationship comprises more than just sensitive interactions; indeed, van Ijzendoorn and others acknowledge that maternal sensitivity does not exclusively predict attachment security. Other mechanisms, including synchronous interactions, the sharing of positive affect, and mutual interactions, might be involved in the formation of these relationships (Coleman & Watson, 2000; De Wolff & van Ijzendoorn, 1997). The examination of quality of attachment as the environmental variable may be a more robust measure of the quality of the environment in infancy, as attachment is more of a global, molar construct and captures many positive interactions throughout the first 17 months of life, and not only the degree of maternal sensitivity at 5 months.

Another interesting outcome of this dissertation was that baseline RSA emerged as a susceptibility factor, but only when examined in specific environmental contexts and with regard to specific outcomes. For instance, the interaction between quality of attachment and infant baseline RSA did not predict competence, but when maternal sensitivity was used as the index of the environment, support for differential susceptibility was found. There may be something unique about maternal sensitivity in infancy as a predictor of social competence in toddlerhood that becomes obscured when looking at the more molar construct of attachment (which is comprised of multiple other factors).

Multiple studies have found significant predictive associations between maternal sensitivity, measured in infancy, and social competence in toddlerhood, suggesting that they way in which caregivers respond during play (Feldman & Masalha, 2010), or during distress (Leerkes, Blankson, & O'Brien, 2009), promotes positive socio-emotional development. There are several different explanations as to why greater levels of maternal sensitivity in infancy are supportive of toddler social competence. First, sensitive responses, particularly following times of distress, have been shown to help infants regulate physiologically and behaviorally (Conradt & Ablow, in press). It is possible that after repeated experiences of this sort, these infants develop a sense of self-efficacy in regulating the dyadic exchange (Tronick, 2007), and in their ability to self-regulate; in short, they develop a menu of strategies for self-regulation. Also as a result of these repeated interactions, the infant may begin to develop a positive internal working model of themselves and of others, as they learn that they can depend on their caregivers for appropriate soothing (Ainsworth et al., 1978). With time, these infants become more compliant, positive, and cooperative as toddlers, all important factors in the construct of social competence (Van Hecke et al., 2007).

These findings extend the theory of differential susceptibility by providing initial evidence for the specificity of baseline RSA as a susceptibility factor. Similar to this dissertation, Leerkes and colleagues (2009) examined infant reactive temperament as a susceptibility factor that might predispose infants to the harmful and beneficial effects of sensitive parenting, using social competence in toddlerhood as the outcome. In this dissertation, the same analyses were conducted, using baseline RSA as a susceptibility factor. Leerkes and colleagues (2009) found no support for infant reactive temperament as a susceptibility factor in this particular context, but in this dissertation, infant baseline RSA was identified as a susceptibility factor. Infant baseline RSA might be a more complete measure of susceptibility, as infant baseline RSA is related to not just negative emotionality and reactivity, but also greater attention, sociability, and sensitivity to the environment. It is also presumably a more objective measure of susceptibility, as it is not prone to bias of maternal report of temperament (though of course it is not void of measurement bias).

Belsky and Pluess (2009) advocate for a need to further the theory of differential susceptibility by examining multiple susceptibility factors in the same context and with similar outcomes, in order to further understand whether individuals who are more susceptible to environmental influences are susceptible at the macro-level, or whether they have more “domain –specific” traits. Person-centered analytic techniques can also be used to help elucidate whether the same individuals express multiple behavioral, physiological, and genetic susceptibility factors (Obradović et al., 2010). These results provide initial evidence for the idea that susceptibility factors might be domain-specific, as baseline RSA emerged as a susceptibility factor in the context of maternal sensitivity, and with regard to social competence as the outcome, while in a separate study, infant temperamental reactivity did not.

Test of Reactivity as a Susceptibility Factor: Variable - Centered and Person - Centered Approaches

Latent growth models were used to test the hypothesis that infants who exhibited the greatest withdrawal of RSA during the still-face episode, in short, the infants who were most "reactive", would be the infants who were most susceptible to their rearing environment. A normative response to acute stress is a decrease in RSA from a baseline; in this sample, infant RSA decreased significantly during the still-face episode. Boyce and Ellis (2005) theorize that individuals who are most reactive – meaning those with the greatest decreases in RSA, would be the individuals most susceptible to their environment. Although there was support for differential susceptibility in the sense that the infants who were most reactive appeared most susceptible to their environment, the results were not in the expected direction; greater decreases in RSA appeared to buffer disorganized infants from their environment. The infants who exhibited the greatest decreases in RSA (as opposed to infants whose RSA decreased slightly or whose RSA increased) and who were reared in an environment that fostered disorganization had significantly *lower* problem behavior scores than infants with the greatest decrease in RSA and who were reared in environments that fostered security.

There are several explanations for this surprising finding. First, a greater withdrawal of RSA among the infants reared in an environment that fosters disorganization could be protective in the short-term, in toddlerhood, as evidenced by the lower problem behavior scores in this group, but this protective effect could change with development. Perhaps 17 months is too young an age to observe the costs of this particular type of physiological stress response. For instance, greater withdrawal of RSA among 6-7 year-olds was related to greater internalizing symptoms (Boyce et al., 2001). Calkins and colleagues (Calkins, Graziano, & Keane, 2007) found that 5 year-old children with the greatest decreases in RSA exhibited more internalizing and externalizing symptoms, and Donzella and colleagues (Donzella, Gunnar, Krueger, & Alwin, 2000) found that 3-5 year-old children with the greatest decrease of RSA during a stressor exhibited the most anger. In infancy and toddlerhood, however, withdrawal of RSA is related to better regulation and more positive engagement with a stranger (Bazhenova et al., 2001); there is a lack of evidence describing relations between the extreme withdrawal of RSA and behavioral outcomes in infancy and toddlerhood. Perhaps developmentally, the effects of this more extreme withdrawal of RSA have not yet emerged.

If this is the case, however, then why did the infants who exhibited the greatest decreases in RSA and who were raised in an environment that fostered security exhibit greater problem behaviors; indeed, problem behaviors that were just above the clinical cut-off for this age group? It might be that these secure infants, who are physiologically more reactive, feel more comfortable expressing this distress to their caregivers. Secure infants openly express their need for connection, emit emotions more flexibly and are more adept at using their caregiver to self-regulate, as they have learned that their caregiver will appropriately and responsively meet their needs (Cassidy, 1994; Sroufe, 2000). Perhaps at 17 months, infants who are raised in a secure environment feel more comfortable expressing their discomfort or frustration with minor environmental perturbations by fussing or protesting, with their responsive caregiver picking up on these behaviors and as a result reporting elevated problem behaviors. Disorganized infants, however, might not feel as comfortable outwardly expressing this distress, as they view their caregiver as a source of threat (Lyons-Ruth, Repacholi, B, McLeod, & Silva, 1991). They might suppress these feelings of discomfort as they learned that they will not be soothed, or they will be soothed inappropriately. These infants might be able to cope in the short term by relying more heavily on intrinsic resources, but this over-reliance on physiological methods of coping might eventually come at a cost with development. In the future, it will be important to examine whether these infants exhibit greater problem behaviors as children.

Another explanation for the finding that infants with a disorganized attachment history, and who exhibited the greatest decrease in RSA also exhibited the fewest problem behaviors is that these results must be viewed in the appropriate context – that of an environment in which all caregivers exhibited psychopathology or were at risk for parenting problems. Issues of differential susceptibility might have to be re-examined depending on the nature of the sample. In no studies of biological sensitivity to context or differential susceptibility were the samples considered "high-risk". A secure attachment relationship might not be as protective in multiple risk environments. In fact, when reared in an environment with multiple risk factors, there are virtually no differences in the mean number of problem behaviors between secure and disorganized infants (Belsky & Fearon, 2002). In this dissertation, the infants with a secure attachment history and who exhibited greater withdrawal of RSA exhibited problem behaviors that were just above the clinical cut-off (*M* = 22.71, clinical cut-point at this age = 19 for girls and 21 for boys; Briggs-Gowan & Carter, 2001). These findings using a growth modeling approach should be replicated using lower risk samples to clarify the nature of this finding.

Although the slope of the infants with the greatest increase in RSA during the stress of the still-face was not significant, it is important to note the pattern of effect that emerged. Among these infants, those that were raised in an environment that fostered security exhibited lower problem behavior than infants raised in an environment that fostered disorganization, although this difference was not significant. An increase in RSA during what is putatively a social stressor is atypical (Moore, 2009), and may result in significant health costs in the long-term (Hill-Soderlund et al., 2007; McEwen & Wingfield, 2010). Although a small number of infants with secure and disorganized attachment histories exhibited this atypical physiological response, infants with secure attachment relationships expressed fewer problem behaviors. This might be because their supportive environment is acting as a protective factor, while the infants with disorganized attachment relationships are not experiencing the benefits of being reared in a higher quality environment. Instead, among these infants, this increase in RSA is coming at a cost, as evidenced by their higher problem behavior scores. Indeed, infants with disorganized attachment relationships who exhibited an increase in RSA, the atypical response, had marginally significantly higher problem behavior scores than infants with disorganized attachment histories whose RSA decreased during the stressor – the "healthier" response to stress (Porges et al., 1996). The group of infants with disorganized attachment histories who exhibited an increase in RSA might be the group most at risk for internalizing disorders in childhood. For instance, Hinnant and El-Sheikh (2009) found that children with higher baseline RSA *and* who exhibited increases in RSA in response to stress were most at risk for internalizing problems. The results from this dissertation suggest a premorbid pathway to psychopathology, as this group of infants exhibited the highest level of problem behavior, already at 17 months.

Why might an increase in RSA during times of stress be considered an unhealthy response? Research suggests that this type of response might be adaptive in the short-term, but this pattern results in long-term costs. According to the theory of allostatic load (McEwen & Wingfield, 2010), allostatis occurs when the body readies the organism to adapt to environmental challenges that frequently result in a stress response. Allostatic overload occurs when this readiness for stress persists, resulting in prolonged physiological and neuroendocrine activity that eventually results in "wear and tear" of the system, and ultimately, damage and sickness. In the short term, an increase RSA may be an adaptive means to cope with acute stress, particularly if these infants have learned that they will not receive support from their caregiver, or that they will receive inappropriate support. This method of coping, however, may lead to overuse of these systems, and subsequent wear and tear and/or a "burn-out" of the system, which increases the likelihood for disease and/or psychopathology (Conroy, Sandel, & Zuckerman, 2010; Hill-Soderlund et al., 2008). While no study has examined the relations between elevated sympathetic or parasympathetic responding in infancy and propensity for disease later in life, there are studies that find more indirect relations. Hill-Soderlund and colleagues

(2008) identified infants with avoidant attachment histories as the group of infants with elevated and sustained sympathetic responding to the Strange Situation Procedure. As avoidant infants also typically exhibit more externalizing behavior as children, this study provides initial evidence that sustained physiological arousal may lead to wear-and-tear of these systems, and subsequent "burn-out". Future research should examine the long-term impact of this type of stress response. These infants might be most at risk for developing regulatory problems that might lead to the expression of greater psychopathology.

Or, as evidenced by the results of Aim 3, these might be the children who are most susceptible to environmental influence. In this aim, Growth Mixture Modeling was used to identify distinct subgroups of infants who exhibited different RSA responses during the stress of the still-face episode. Two groups emerged: one group of infants who exhibited low, decreasing levels of RSA, (the expected response during acute stress) and a second, high increasing group of infants, who exhibited the more atypical pattern of increasing RSA during stress. Theoretically, it was deemed important to study this group of infants as they exhibited the more atypical response pattern – a pattern that is frequently mentioned in empirical articles, but rarely studied. Tests of differential susceptibility were conducted to examine whether one group of infants were more susceptible to their environment than the other group. The only significant interaction to emerge was with maternal sensitivity, not attachment history. Contrary to hypotheses, the group of infants with high RSA that increased across the still-face episode appeared more susceptible to their mother's level of sensitivity than the infants with lower, decreasing levels of RSA. Probes of the interaction between RSA group and maternal sensitivity revealed that infants who were in the high increasing class, and whose mothers were more sensitive, had higher levels of social competence than both infants in the low decreasing class and infants in the high increasing class but whose mothers exhibited less sensitivity. There were only six infants in the high increasing class, however, so these results should be interpreted with caution.

These results were surprising, as theory would dictate that the group of infants with increasing RSA should have poorer outcomes than the infants who show the typical, adaptive response to stress (only 13.8% of the sample - n = 12 infants - exhibited an increase in RSA during the still-face). Evidence to support this idea comes from studies that describe what an increase in RSA is *not* related to, such as greater emotion regulation and social competence, rather than what it is related to (Doussard-Roosevelt et al., 2003). These preliminary results change what theory would predict as the group that is more susceptible to environmental influences. According to the theory of Biological Sensitivity to Context (Boyce & Ellis, 2005), the group of infants with low, decreasing RSA scores should be most susceptible to the environment. However, these findings were the result of difference score analyses. This result needs to be replicated, but this finding provides preliminary evidence that an increase in RSA during stress, at least in infancy, might not be a problematic response to stress, at least not for the infants who are reared in more supportive environments.

Methodological Considerations

It is important to note the methodological implications of using the GMM approach with these physiological data. This is the first study to examine growth in RSA using a GMM approach. In addition, this is a relatively new technique, and while the accepted procedures for proceeding with GMM analyses are emerging, they are far from established. In this dissertation, the approach by Nagin (2005) was used to proceed with analyses once the baseline model was chosen. Specifically, the best fitting growth model using LGM was first chosen, and this model was subjected to further tests of model fit by first using an LCGA and then a GMM.

Of note for this dissertation were the difficulties in choosing the final person-centered model. While the GMM model fit better than the LCGA, the LCGA model was not a poor fit. Furthermore, the GMM model revealed two theoretically relevant classes: a low decreasing class and a high class that, while low in sample size, had RSA scores that increased across the still-face episode. In this study, maternal sensitivity was a significant predictor of the LCGA classes, suggesting that the groups were meaningfully different from each other. While sensitivity did not distinguish the two groups using a GMM approach, a significant sensitivity x class interaction emerged to predict social competence, also suggesting that the two groups in the GMM were meaningfully different. Thus, the GMM approach was used as it was the best fitting model, and was most relevant to existing theory and hypotheses. However, because of the low sample size in the high increasing class, these results need to be replicated to determine whether this is a class that is indeed more susceptible to environmental effects.

Beyond the difficulties that arose in selecting the most appropriate model, the person-centered approach is useful as it allowed for an examination of individual differences in growth in RSA, rather than examining reactivity with a difference score approach. The traditional approach to studying reactivity may obscure important information about *how* an infant responds to stress (see Figure 1). While the sample as a whole exhibited a significant decrease in RSA during the still-face episode, a distinct subgroup of infants was identified who exhibited increases in RSA during stress – it is possible that grand mean estimates would have washed out this group of infants. Thus, while the GMM approach has its limitations because it is a rather new and constantly evolving analytic technique, it allowed for the modeling of individual physiological stress response trajectories, rather than assuming all the infants in this study came from one, homogenous group.

Synthesis

In sum, this dissertation found mixed support for the differential susceptibility hypothesis, and the related biological sensitivity to context. Consistent with hypotheses, theory, and empirical evidence, baseline RSA emerged as a susceptibility factor, but in specific contexts and in relation to specific outcomes. Infant baseline RSA emerged as a susceptibility factor when examined using different measures of the environment and with regard to different outcomes, while RSA reactivity was not a consistent index of susceptibility. This might be because of the lack of specificity regarding what exactly RSA reactivity is reflective of in infancy. For instance, it is not clear at this point whether infants who exhibit increases in RSA in response to stress are more susceptible to the environment, or whether, like the childhood literature suggests, infants with decreases in RSA are the ones who are more reactive, and therefore more susceptible to the environment.

Infants with higher baseline RSA exhibited significantly lower problem behaviors when raised in a secure environment, and significantly greater competence when interacting with their more sensitive caregivers, above and beyond infants with low baseline RSA and infants with higher baseline RSA and who were raised in less adaptive environments. These exciting findings add specificity to what researchers conceive of as susceptibility factors, and contribute significantly to theories of differential susceptibility. When examining infant RSA reactivity using more dynamic models of change, the picture becomes murkier, perhaps owing to a general lack of research on the dynamic properties of RSA in infants. Infant RSA reactivity measured using growth models emerged as a buffer for infants raised in adverse environments. Infants exhibiting the greatest decreases in RSA and who were reared in environments that fostered disorganization exhibited lower problem behaviors than infants with decreases in RSA who were raised in environments that fostered security. When examining RSA reactivity using person-centered approaches, infants whose RSA increased across the stress of the still-face appeared most susceptible to their mothers' sensitive behaviors. This result leads one to question, what exactly is parasympathetic stress reactivity, particularly when examining the growth process of RSA? Could infants whose RSA levels increase during acute stress actually be more reactive? Perhaps these are the infants who are so perturbed by stress that they begin to regulate earlier than the infants who respond to stress with a withdrawal of RSA. Future studies should examine reactivity in similarly dynamic, person-focused contexts, so that we might better understand the complexities surrounding the stress reactivity process.

Central to the theory of Biological Sensitivity to context is the idea that the quality of the early social environment shapes individual physiological susceptibilities to stress (Boyce & Ellis, 2005). This dissertation provides initial support for this hypothesis, as it was found that infants with mothers who are more sensitive, or infants who come from environments that foster security and are more physiological susceptible to their environment, exhibit less problem behavior and more social competence. The organization of the parasympathetic nervous system occurs in utero, and parasympathetic activity can be monitored early in gestation (Groome, Loizou, Holland, Smith, & Hoff, 1999). Boyce and Ellis (2005) suggest that infant stress responses are programmed in utero, with the infant up-regulating stress-reactivity in beneficial environments in order to take advantage of the positive environment, and also up-regulating stress reactivity in harmful environments in order to maintain vigilance for safety purposes, though they are not specific as to how stress reactivity is up-regulated. While Boyce and Ellis (2005) hypothesize that it should be the more reactive infants who exhibit greater "biological sensitivity to context", this nascent theory would benefit from more studies conducted in infancy, while the stress response is forming.

Limitations and Areas for Future Research

While not always supportive of the differential susceptibility hypothesis or biological sensitivity to context, these results do lend themselves to interesting questions about the nature of the physiological response to stress in infancy; raising issues regarding the importance of understanding both the developmental stage of the individual under study, the type of stimuli used to invoke stress, and the analytic tools used to measure the stress response. The results of this dissertation have spawned many exciting avenues for future research, but it is first necessary to address its limitations.

Previous studies testing the theory of differential susceptibility or biological sensitivity to context have largely focused on environments of adversity, aggregating multiple measures of the environment (e.g., parental stress, socio-economic status, and parental conflict) in order to best capture the environment in which children are raised. In this study, there were two indices of the environment, one more specific and the other a more molar measure; both reflective of the environment during infancy. Critics might suggest that because the attachment environment and outcome variables were assessed at the same point in time -- 17 months -- outcomes may be more reflective of 17 month functioning than a history of the environment during the infants first 17 months of life, as attachment theory would imply. It will therefore be necessary to replicate these findings using additional measures of the environment assessed at 5 and 17 months of life.

In addition, as all the families in this sample were living at or below the poverty line, it will be important to replicate these findings using a more heterogeneous sample that includes families living in less economic stress. Importantly, the theory of differential susceptibility was validated in a higher risk sample. These results bolstered current theory by demonstrating that processes of differential susceptibility are at work even in higher risk environments. However, we know from the literature that the attachment relationship may be a stronger predictor of later outcomes in a higher risk sample, and therefore the attachment x physiology interactions might not be replicated in samples of lower risk, where caregivers are faced with less economic stress. These results should be replicated using the attachment environment as the environmental variable in samples of lower risk.

Another limitation of this study was the examination of only one index of reactivity – the parasympathetic response during the still-face episode of the SFP. Other measures of autonomic functioning should be examined, including Heart Rate, Pre-ejection Period, Skin Conductance Level and Response, as well as additional physiological systems – such as the neuroendocrine system. Additionally, reactivity is typically examined as part of a battery of stressors assessing reactivity related to social, cognitive, sensory, and emotional challenges (see Alkon et al., 2003). While this dissertation only examined reactivity related to a single stressor, the strength of this method is that the findings are interpreted in light of a specific stress response – a social stressor in infancy. Infants who were more physiologically aroused by this social stressor might have been the infants who typically depended on their parent as an external source of regulation. In the future, additional stressors should be measured, including ones that do not include this social component.

There is no minimum standard with regard to sample size in the use of GMM, but the sample size for this dissertation is considered low (Muthén, 2007). However, the appropriate corrections were conducted in order to be certain that the classes that emerged were not just an effect of the program converging at a local solution, but instead were indicative of the true, global maximum solution (see Hipp & Bauer, 2006, and results section for correction specifics). The fact that the class by sensitivity interaction was also replicated in Mplus also suggests that the classes that emerged were robust. In addition, the low number of toddlers who were classified as Disorganized made probing interactions difficult. Considering this important limitation, it is remarkable that multiple interactions emerged, particularly when comparing the secure and disorganized attachment groups. However, as this is the first study to examine physiological reactivity using a GMM approach, it is essential that these results be replicated in a larger sample.

The Differential Susceptibility Hypothesis and the related Biological Sensitivity to Context are nascent theories, and much more research needs to be conducted to fully validate these theories. In the future, individual differences in response to stress should be examined across multiple systems, including the endocrine, neurological, autonomic, and parasympathetic systems. Further research should be conducted that uses person-centered approaches, such as a latent class analysis, to examine multiple measures of reactivity in response to a variety of contexts (e.g. emotional, cognitive, and social). This will help us to determine whether reactive individuals are reactive across multiple contexts, or whether they express more domain-specific reactivity profiles.

In the future, it will also be important to examine whether reactive children remain reactive longitudinally, or whether this susceptibility changes across development. Do highly reactive infants, who are paired with sensitive, supportive caregivers, learn to eventually manage and cope with this reactivity to the extent that they express less physiological reactivity, or do these infants remain highly reactive as children? Research suggests that there is significant within-individual stability of baseline RSA (DiPietro, Bornstein, Hahn, Costigan, & Achy-Brou, 2007) from 20-36 weeks Gestational Age, and that baseline RSA is stable in children age 5-6 (Doussard-Roosevelt, Montgomery, & Porges, 2003), and from 2 months to 5 years (Bornstein & Suess, 2000). RSA reactivity to emotional stressors, however, was not stable in 5-6 year-olds (Doussard-Roosevelt et al., 2003), nor was RSA response to a cognitive stressor stable from 2 months to 5 years (Bornstein & Suess, 2000). Because RSA reactivity is not stable over time, this might indicate that infants who are more reactive but who are paired in an environment that better supports that reactivity, become less reactive over time.

Clinical Implications

Infants who are more susceptible to their rearing environment, and who receive the support they need to take advantage of that environment, are on a privileged pathway to success. Results of this dissertation support the idea that, when examining intervention effects, scientists should not look at the "average" effect across all groups, but instead examine whether some children, or caregivers, might be more susceptible to intervention effects than others. There is already evidence that infants with negative, reactive temperaments are more susceptible to interventions focused on increasing maternal sensitivity (Van den Boom, 1994; Velderman et al., 2006). This dissertation provides further evidence that infants with higher baseline RSA might also be more susceptible to interventions that promote sensitivity and security of attachment. These results this could inform and add specificity to interventions designed to enhance caregiver sensitivity.

There is initial evidence that baseline RSA is also susceptible to intervention. Bagner and colleagues (2009) studied a 23 month-old toddler referred to a clinic for externalizing problems. Upon completion of Parent-Child Interaction Therapy, this toddler's externalizing behavior decreased to normative levels, and remarkably, his parasympathetic functioning increased from pre-treatment levels. In addition, at pre-treatment, the toddler did not exhibit the expected withdrawal of RSA during stress, but at post-treatment he did. This finding suggests that physiological functioning – both baseline and baseline-to-task changes – is amenable to intervention effects, and provides evidence that monitoring an individual's physiology before, during, and after treatment may be a useful index of treatment response.

Should clinicians and intervention scientists only intervene with children who are most susceptible to their environment for intervention? The answer to this question is a resounding no. Far less is known about these less susceptible children. There is no evidence yet to suggest that some children are globally more susceptible to environmental influences while others exhibit no susceptibilities. In order to further current theory as well as intervention efforts, more research is needed to understand why these children are less susceptible to environmental influences, which will give us more information about how we can intervene with this population.

Interventions designed to prevent the development of psychopathology are hindered by the difficulties in identifying objective, reliable, and valid assessment of early symptoms that portend the development of later psychological dysfunction. This is particularly the case in toddlerhood, where it is difficult to determine when a behavior reaches clinical significance, because of rapid developmental changes that occur at this time, and the wide variability in the emergence of behavior. This study provides preliminary evidence for including physiological measures of functioning in intervention and clinical work, so that pre-post changes can be documented in physiology and behavior.

Differential susceptibility is an emerging area within developmental psychology and developmental psychopathology. These findings broaden our understanding of the individual susceptibility factors that promote adaptation and maladaptation, and how parenting may be used to help support optimal development among children of varying capacities for regulation.

APPENDIX A

MPLUS SYNTAX FOR FINAL 2-CLASS UNCONDITIONAL MODEL

```
TITLE: GMM 2-class model. Intercepts and slopes are set to be equal across classes.
Note:  Using Logged Scores
 DATA:  FILE IS C:\Documents and Settings\Elisabeth\My Documents\
    Dissertation\Results\Aim 3\RSA.dat;

 VARIABLE:
 NAMES ARE
    ID blRSA dis_sec problem comptnce sensreun RSA12 RSA13 RSA14 RSA15
      RSA16 RSA17 RSA18 RSA19 MOV12 MOV13 MOV14 MOV15 MOV16
      MOV17 MOV18 MOV19;
 MISSING ARE ALL (-999);

 CLASSES = c(2);

 USEVARIABLES ARE
     RSA12 RSA13 RSA14 RSA15 RSA16 RSA17 RSA18 RSA19;

 ANALYSIS:

           TYPE = MIXTURE;
           STARTS = 1000 50;
           ITERATIONS = 10000;
           CONVERGENCE = 0.00005;
           COVERAGE = 0.10;

MODEL:

 %overall%

 i3RSA s3RSA |
      rsa12@0 rsa13@1 rsa14@2 rsa15@3 rsa16@4 rsa17@5 rsa18@6 rsa19@7;

 PLOT:
 type is Plot3;
 series is rsa12 - rsa19 (s3RSA);
```

APPENDIX B

MPLUS SYNTAX FOR ALTERNATIVE MODELS

LCGA model

```
TITLE: LCGA 2-class model. No within-group heterogeneity (i.e. variance for growth
parameters set to zero).  Note:  Using Logged Scores
  DATA:  FILE IS C:\Documents and Settings\Elisabeth\My Documents\
     Dissertation\Results\Aim 3\RSA.dat;

 VARIABLE:
 NAMES ARE
    ID blRSA dis_sec problem comptnce sensreun RSA12 RSA13 RSA14 RSA15
       RSA16 RSA17 RSA18 RSA19 MOV12 MOV13 MOV14 MOV15 MOV16
       MOV17 MOV18 MOV19;
 MISSING ARE ALL (-999);

 CLASSES = c(2);

 USEVARIABLES ARE
     RSA12 RSA13 RSA14 RSA15 RSA16 RSA17 RSA18 RSA19;

 ANALYSIS:

            TYPE = MIXTURE;
            STARTS = 1000 50;
            ITERATIONS = 10000;
            CONVERGENCE = 0.00005;
            COVERAGE = 0.10;

MODEL:

 %overall%

 i3RSA s3RSA |
       rsa12@0 rsa13@1 rsa14@2 rsa15@3 rsa16@4 rsa17@5 rsa18@6 rsa19@7;
        i3RSA@0 s3RSA@0;

 PLOT:
 type is Plot3;
 series is rsa12 - rsa19 (s3RSA);
```

Alternative GMM model

```
TITLE: GMM 2-class model. Allowing separate estimates of within-class variances for
each class Note:  Using Logged Scores
  DATA:  FILE IS C:\Documents and Settings\Elisabeth\My Documents\
     Dissertation\Results\Aim 3\RSA.dat;

 VARIABLE:
 NAMES ARE
    ID blRSA dis_sec problem comptnce sensreun RSA12 RSA13 RSA14 RSA15
      RSA16 RSA17 RSA18 RSA19 MOV12 MOV13 MOV14 MOV15 MOV16
      MOV17 MOV18 MOV19;
 MISSING ARE ALL (-999);

 CLASSES = c(2);

 USEVARIABLES ARE
     RSA12 RSA13 RSA14 RSA15 RSA16 RSA17 RSA18 RSA19;

 ANALYSIS:

           TYPE = MIXTURE;
           STARTS = 1000 50;
           ITERATIONS = 10000;
           CONVERGENCE = 0.00005;
           COVERAGE = 0.10;

 MODEL:

 %overall%

 i3RSA s3RSA |
      rsa12@0 rsa13@1 rsa14@2 rsa15@3 rsa16@4 rsa17@5 rsa18@6 rsa19@7;

       %c#1%
       i3RSA s3RSA;

       %c#2%
       i3RSA s3RSA;

PLOT:
 type is Plot3;
 series is rsa12 - rsa19 (s3RSA);
```

Fully Constrained Conditional Model

```
TITLE: GMM 2-class model. Fully constrained conditional model. Note:  Using Logged
Scores
 DATA:  FILE IS C:\Documents and Settings\Elisabeth\My Documents\
    Dissertation\Results\Aim 3\RSA.dat;

 VARIABLE:
 NAMES ARE
    ID blRSA dis_sec problem comptnce sensreun RSA12 RSA13 RSA14 RSA15
       RSA16 RSA17 RSA18 RSA19 MOV12 MOV13 MOV14 MOV15 MOV16
       MOV17 MOV18 MOV19;
 MISSING ARE ALL (-999);

 CLASSES = c(2);

 USEVARIABLES ARE
     dis_sec problem comptnce sensreun RSA12 RSA13 RSA14 RSA15 RSA16 RSA17
       RSA18 RSA19;

 ANALYSIS:

           TYPE = MIXTURE;
           STARTS = 1000 50;
           ITERATIONS = 10000;
           CONVERGENCE = 0.00005;
           COVERAGE = 0.10;

MODEL:

 %overall%

 i3RSA s3RSA |
      rsa12@0 rsa13@1 rsa14@2 rsa15@3 rsa16@4 rsa17@5 rsa18@6 rsa19@7;
       c#1 ON dis_sec problem comptnce sensreun;

PLOT:
 type is Plot3;
 series is rsa12 - rsa19 (s3RSA);
```

Fully Unconstrained Conditional Model, Prediction of Within-group Variability

```
TITLE: GMM 2-class model. Fully unconstrained model, predicting within-group
variability. Note:  Using Logged Scores
 DATA:  FILE IS C:\Documents and Settings\Elisabeth\My Documents\
    Dissertation\Results\Aim 3\RSA.dat;

 VARIABLE:
 NAMES ARE
    ID blRSA dis_sec problem comptnce sensreun RSA12 RSA13 RSA14 RSA15
       RSA16 RSA17 RSA18 RSA19 MOV12 MOV13 MOV14 MOV15 MOV16
       MOV17 MOV18 MOV19;
 MISSING ARE ALL (-999);

 CLASSES = c(2);

 USEVARIABLES ARE
     dis_sec problem comptnce sensreun RSA12 RSA13 RSA14 RSA15 RSA16 RSA17
       RSA18 RSA19;

 ANALYSIS:

           TYPE = MIXTURE;
           STARTS = 1000 50;
           ITERATIONS = 10000;
           CONVERGENCE = 0.00005;
           COVERAGE = 0.10;

 MODEL:

 %overall%

 i3RSA s3RSA |
      rsa12@0 rsa13@1 rsa14@2 rsa15@3 rsa16@4 rsa17@5 rsa18@6 rsa19@7;
       c#1 ON dis_sec problem comptnce sensreun;

%c#1%
rsa12-rsa19;
i3RSA ON dis_sec problem comptnce sensreun;
s3RSA ON dis_sec problem comptnce sensreun;

%c#2%
rsa12-rsa19;
i3RSA ON dis_sec problem comptnce sensreun;
```

```
s3RSA ON dis_sec problem comptnce sensreun;

PLOT:
 type is Plot3;
 series is rsa12 - rsa19 (s3RSA);
```

For Class x sensitivity interaction

```
TITLE: Class x sensitivity interaction. Note:  Using Logged Scores
 DATA:  FILE IS C:\Documents and Settings\Elisabeth\My Documents\
    Dissertation\Results\Aim 3\RSA.dat;

 VARIABLE:
 NAMES ARE
    ID blRSA dis_sec problem comptnce sensreun RSA12 RSA13 RSA14 RSA15
       RSA16 RSA17 RSA18 RSA19 MOV12 MOV13 MOV14 MOV15 MOV16
       MOV17 MOV18 MOV19;
 MISSING ARE ALL (-999);

 CLASSES = c(2);

 USEVARIABLES ARE
     sensreun comptnce RSA12 RSA13 RSA14 RSA15 RSA16 RSA17 RSA18 RSA19;

 ANALYSIS:

            TYPE = MIXTURE;
            STARTS = 1000 50;
            ITERATIONS = 10000;
            CONVERGENCE = 0.00005;
            COVERAGE = 0.10;

MODEL:

 %overall%

 i3RSA s3RSA |
       rsa12@0 rsa13@1 rsa14@2 rsa15@3 rsa16@4 rsa17@5 rsa18@6 rsa19@7;
        ! comptnce on sensreun (comment is then removed to compare the two models)

        %c#1%
        rsa12-rsa19;
        comptnce on sensreun;

        %c#2%
        rsa12-rsa19;
        comptnce on sensreun;
 PLOT:
 type is Plot3;
 series is rsa12 - rsa19 (s3RSA);
```

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