UNIVERSITY OF CALIFORNIA,
IRVINE

Maternal Expressions of Positive Emotion for Children Predicts Children's Respiratory Sinus Arrhythmia Surrounding Stress

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF ARTS

in Social Ecology

by

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2020

DEDICATION

To

This is work is dedicated to my children; Violet, Norah, Rose and Josiah. The experience of being their mother has shaped and refined my research endeavors in ways that will benefit my life and career indefinitely.

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ACKNOWLEDGMENTS

I would like to thank Dr. Jessica Borelli for guiding me in this work and for helping to foster the kind of academic environment that led to higher levels of excellence and discovery in my research. I would also like to thank Dr. Sarah Pressman. Dr. Pressman's influence and contributions have helped me become a more rigorous, focused, and adventurous scientist. Together, my advisors created a scaffolding that resulted in my development as a researcher and, as a result, the development of this meaningful research.

ABSTRACT OF THE THESIS

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Professor Sarah Pressman, Chair

Background: Emotional well-being and the quality of the parent-child bond are robust predictors of cardiovascular functionality and stress responses, and thus may have important implications for health outcomes. The aim of the current study is to assess whether positive emotional exchanges (i.e., emotion coregulation) within the mother-child dyad play a protective role in children's stress responses. Specifically, we test whether positive emotion coregulation among mothers and their preschool-aged children is associated with children's respiratory sinus arrhythmia (RSA; a marker of heart rate variability) at rest or over the course of a stressful experience. Method: One hundred mother-child dyads (Mchildage = 3.5 years) participated in a standardized laughing task in which positive emotional constructs were measured. Children also participated in a frustration task without the mother present while RSA was continuously monitored. Results: Hierarchical linear regressions revealed that greater mother positive emotional response to child was associated with child baseline and stress recovery RSA, but not with children's RSA during the frustrating task. Exploratory analyses reveal that this effect is partially due to mother, but not child, overall positivity. Findings held in serial analyses in which we controlled for children's overall positive affect (PA) and children's positive affect (PA) in response to mothers but not when we controlled for mother's overall PA.

Conclusion: Positive emotion coregulation is associated with children's resting RSA as well as RSA recovery from a frustrating task.

INTRODUCTION

Decades of research has established that positive social relationships are inextricably intertwined with well-being across the lifespan (e.g., House, Umberson & Landis, 1988; Ramsey & Gentzler, 2015; Uchino, 2009). Strong social ties promote and sustain the experience of positive affect (PA) (Ramsey & Gentzler, 2015); in turn, high levels of positive affect (PA; e.g., happiness, serenity) are linked to greater longevity, better immune function (Diener, Pressman, Hunter, & Delgadillo-Chase, 2017), and reduced risk of cardiovascular disease (Boehm & Kubzansky, 2012). The influence of these psychosocial constructs on long term health outcomes likely occurs incrementally within the context of repeated, momentary experiences beginning early in life. One way this may transpire is via daily social and emotional influences on the functioning of the autonomic nervous system (Levenson, 2014), especially in the context of stress (Pressman, Jenkins, Moskowitz, 2019). The current study assesses whether one specific and potentially important socioemotional construct is linked to autonomic function, either at rest or during stress: positive emotional exchanges within the mother-child dyad.

The Autonomic Stress Response in Children: A Focus on Respiratory Sinus Arrhythmia

Associations between autonomic function and psychosocial experiences are consistently observed in studies of children (Diamond, Fagundes, & Butterworth, 2012; Cui, Morris, Harrist, Larzelere, & Criss, 2015; McLaughlin et al., 2015), particularly preceding, during and in recovery from stress which may have long-term implications for future health and wellbeing (Boehm & Kubzansky, 2012). Better stress responses are marked by quick cardiovascular adaptation (autonomic flexibility) to the conditions of the environment (Kok & Fredrickson, 2010). The parasympathetic nervous system (PNS), commonly indexed via measurement of respiratory sinus arrhythmia (RSA) as well as other measures of heart rate variability, is the branch of the autonomic nervous system that may be particularly important for future health and wellbeing (Kristal-Boneh, Raifel, Froom & Ribak, 1995). High baseline RSA indicates that the vagus nerve is functioning effectively and is associated with better health while low baseline RSA is associated with detrimental health outcomes in adults, such as diabetes and hypertension (Masi, Hawkley, Rickett & Cacioppo, 2007). Low resting baseline RSA is also linked to stressful experiences (Grossman & Svebak, 1987) while high resting baseline RSA is associated with healthier emotional and social functioning (Geisler, Kubiak & Weber, 2013).

The majority of the above RSA work has been done in adults, however, there is reason to believe that RSA is associated with more adaptive functioning in children as well. For instance, a small but growing body of research now links higher RSA at rest to a wide range of beneficial psychosocial outcomes, including higher quality attachment relationships (Diamond, Fagundes, & Butterworth, 2012), parent-child relationship quality (Calkins, Graziano, Berdan, Keane & Degnan, 2008), regulatory behavior, less negative affect, and more positive affect (Calkins, 1997). Similarly, high RSA is positively associated with better socialization, high inhibitory control (Skowron, Cipriano-Essel, Gatzke-Kopp & Ammeran, 2014) and less controlling parenting practices (Hastings et al., 2008), indicating that even in childhood, these associations may be an important indicator of parasympathetic function. Beyond high resting baseline RSA, studies have also shown links between high RSA during challenging tasks and high empathic responsiveness and low levels of attachment insecurity (Diamond, Fagundes, & Butterworth, 2012). Similarly, low RSA during challenging tasks has been linked to higher internalizing problems (e.g., social withdrawal, fearfulness) (Boyce, Quas, Alkon, Smider, Essex & Kupfer, 2001) and to emotion and behavioral regulation problems (Calkins, Graziano & Keane, 2007).

Nevertheless, other literature reveals that low RSA during reactivity to a stressor may be more adaptive (e.g., see review by Graziano & Derefinko, 2013). For instance, research has shown that greater decreases in RSA during challenging tasks are linked to fewer internalizing and externalizing problems (El-Sheikh, Harger & Whitson, 2001) better coping skills, and better emotion regulation (Gentzler, Santucci, Kovacs & Fox, 2009). Indeed, lower RSA during challenge may allow the sympathetic nervous system to mobilize during times of stress and could be the most adaptive response within certain contexts. Alternatively, these findings may reflect the population of children assessed, the type of challenging task presented (Graziano & Derefinko, 2013) or the quality of the relationships in the social environment. Together, this literature may underscore the relevance of when high versus low RSA is more adaptive and how specific types of coregulatory behaviors between caregivers and children modulate children's RSA -- context, and in this case the relational context, may matter in terms of regulatory impacts.

Positive Affect, Social Connectedness and Physiological Stress Responses

Studies have repeatedly shown that for the child, high quality bonds with the primary caregiver are associated with a host of positive outcomes such as higher levels of self-regulation, better relationship quality in adulthood, and adaptive physiological responses to stress (Calkins & Leerkes, 2004; Dalton, Frick-Horbury, & Kitzmann, 2006; Gunnar, Brodersen, Nachmias, Buss, & Rigatuso, 1996). Broadly, it is clear that high-quality social relationships, particularly those experienced within the parent-child dyad, benefit both autonomic processes as well as psychological outcomes in children. However, the specific types of social behaviors and emotional exchanges that foster these benefits remain ill-defined. Based on literature that supports the stress-buffering effects of PA in social contexts (Pressman & Cohen, 2005), it may be the case that high levels of maternal displays of positive emotion (i.e., genuine joy, enjoyment, delight) in direct response to children is associated with children's superior physiological regulation during challenge.

Definitions of PA vary in the literature, however, PA generally includes an array of positive emotions such as contentment, calm, elation, alertness and happiness. PA can be measured as a state (i.e., momentary) or trait (i.e., dispositional) construct, (Watson & Clark, 1994; Russell, 1980) and is linked to a host of adaptive health indices (e.g., see reviews by Pressman & Cohen, 2005; Pressman, Jenkins & Moskowitz, 2019) such as cardiovascular function. For example, research indicates that trait PA and positive emotional expressivity is positively correlated with baseline RSA in college students (Wang, Lu, & Qin, 2013), however, PA also seems to play a protective role during and surrounding times of stress. The "Broaden and Build Theory", (Fredrickson, 2001) as well as the "Stress Buffering Hypothesis" of PA (Pressman & Cohen, 2005) suggests that PA may aid in better cardiovascular responses to stress. Indeed, an extensive review found that positive psychological constructs predict adaptive autonomic stress function (e.g., Boehm & Kubzansky, 2012).

Links between PA and autonomic function are not limited to individuals. Positive emotions derived from high-quality social relationships are also linked to better autonomic function across the lifespan. Indeed, past research has shown that PA is often cultivated within the context of positive social experiences with close others promoting an upward spiral, nurturing psychological wellbeing (e.g., Kok & Fredrickson, 2010). Indeed, a review of social connectedness and PA confirms unambiguous, repeated links between the two constructs throughout the lifespan (Ramsey & Gentzler, 2015; Lyubomirsky, King & Diener, 2005) and multiple studies link social bonds and PA to adaptive parasympathetic function. For example, increases in social connectedness and positive emotions predicted higher resting RSA in adults in a community-dwelling environment (Kok & Fredrickson, 2010). Another study showed that social support and high trait-compassion were linked to more adaptive autonomic stress profiles during stress, in this case measured by high frequency heart rate variability (Cosley et al., 2010) which is another indicator of parasympathetic function. Further, research has indicated that the stress-buffering effects of PA are not limited to reactivity but also seem to aid in the recovery from stress. The "Undoing Hypothesis" hypothesizes that PA helps to reverse the cardiovascular aftereffects of stress (Fredrickson et al., 2000). In line with this theory, higher recovery RSA in children was associated with higher parental expressions of positive emotion (Cui, Morris, Harrist, Larzelere, & Criss, 2015), less aggression, more prosocial behaviors and adaptive emotion regulation (Miller, Chocol, Nuselovici, Utendale, Simard & Hastings, 2013; Brooker & Buss, 2010; Cui, Morris, Harrist, Larzelere, Criss & Holtberg, 2015). Surprisingly, younger samples (e.g., preschool aged) are rarely studied in this context creating an important gap to fill to examine both how parental PA responses to children and PA-relevant interactions may play a role in parasympathetic functioning for children. This time period is particularly relevant since research has shown that preschool-aged children are in a crucial period in which self-regulation develops (Fonagey & Target, 1997; Zeman, Cassano, Perry-Parrish, & Stegall, 2006). Beyond that, it is generally valuable to study experimental physiological stress responses given their importance for future wellbeing (e.g., Piazza, Charles, Sliwinski, Mogle & Almeida, 2012; Chiang, Turiano, Mroczek & Miller, 2018).

While there is little research demonstrating links between parental PA and RSA among preschool-aged children, some studies have examined the quality of preschoolers' social relationships and their RSA. For example, important work revealed the detrimental hormonal and autonomic stress effects of institutional orphanage care on young children as compared to those in high quality foster care (McLaughlin et al., 2015). Further, studies have shown that children exposed to marital violence or confronted with high levels of adversity, showed lower resting RSA (Hessler & Katz, 2007; Porter et al., 2003). Other studies of children confirm these patterns with findings linking chronic stressors such as maternal depression, poverty, and early life adversity to blunted parasympathetic function (Propper, 2012). Clearly it is the case that across age groups, ethnicity, and socioeconomic status, early social relationships and contexts are associated with autonomic stress responses.

Together, these studies provide compelling evidence that PA is tied to better stress responses, PA is connected to higher quality social relationships, and critically, that early social contexts and connections matter for future development of the autonomic stress response. However, these associations have predominantly been studied in adults. What is needed then is work that ties these factors together and brings them into the context of the developing child. While the exact pathways of these connections are still being explored, it is likely that emotion regulating dyadic exchanges (i.e., emotion coregulation) may be one mechanism by which these psychophysiological constructs are linked.

Emotion Coregulation and Autonomic Regulation

Emotion coregulation refers to the process by which members of a dyad direct emotions and behaviors towards the other in order to construct a stable, optimal, shared affective state as the outcome (Butler & Randall, 2013; Guo, Garfin, Ly, & Goldberg, 2017). Early dyadic regulation is critical to our understanding of the development of temperament (Rothbart & Posner, 1985), socialization (Eisenberg & Fabes, 1992), attachment (Cassidy, 1994), self and inter-subjectivity (Trevarthen, 1993), and psychopathology (Cole, Michel, & Teti, 1994). Emotion coregulation is a multi-faceted, interconnected construct that includes both the *process* of coregulation, that is, one partner's attempt to alter the emotions and behaviors of the other and the intended *outcome* of this process, which is often a state of simultaneous or *shared* emotions within a dyad; the current study assesses the process of emotion coregulation or one person's unidirectional, explicit or implicit efforts to influence the emotional states of another person, without reference to the shared outcome (i.e., synchrony) of said regulatory efforts (Fonagey, Gergely, Jurist & Target, 2002; Gulsrud, Jahromi, & Kasari, 2010). Synchrony oriented literature on emotion coregulation provides a valuable scholarly backdrop for the current study, however, we focus on the process of coregulation because the capacity to self-regulate emotion regulation typically develops during the preschool years-- it is during this time that children transition from relying on the caregiver as an external regulator of emotion into an internal or self-regulation of emotion in which the child learns to govern his/her own emotional responses (Fonagy & Target, 1997; Kopp & Neufeld, 2003; Zeman, Cassano, Perry-Parrish, & Stegall, 2006). Since it is the repeated dynamic emotional exchanges with the caregiver that are thought to provide the basis for the development of self-regulation in the young child (Sroufe, 2000), here we investigate whether positive coregulatory exchanges between mothers and children during one task predicts child RSA at baseline, during reactivity, and in recovery from a frustrating task *without* the mother present.

Broadly, there is preliminary evidence that higher levels of both shared and unidirectional positive emotion coregulation are associated with more adaptive (i.e., higher) heart rate variability in the child, operationalized as RSA. For instance, one study assessed synchronized emotion coregulation and found that high levels of coordinated mother-infant emotion coregulation (coded using Fogel's global Regional Coding System; Fogel, 1994) was associated with greater heart rate variability in infants, including higher RSA, at baseline and during a play episode (Porter, 2003). Another study found that mothers who showed higher levels of coordinating (i.e., synchronizing or matching) behaviors and affective expressions in response to their infants had infants with higher RSA at baseline and lower RSA during distress compared to infants with mothers who coordinate less (Moore & Calkins, 2004); a pattern supporting research that suggests that healthy autonomic stress responses are marked by the maintenance of homeostasis at rest, rapid physiological mobilization during stress or challenges, and a quick return to resting baseline once the threat is attenuated (Thayer & Lane, 2000, 2009; Thayer & Sternberg, 2006).

Mother-child synchrony studies such as these may reflect the outcome of coregulatory efforts, thus, they provide an important theoretical foundation for the current study and studies assessing the process of emotion coregulation in the mother-child dyad, that is, the parent's unidirectional efforts to regulate the child. While many of the specific parental positive emotions and behaviors involved with an advantageous coregulatory process remain unclear, research has shown that certain parental behaviors play a regulatory role in children's psychophysiological stress responses. For example, infants of sensitive, responsive parents displayed greater autonomic regulation following a stress inducing task than those with less responsive parents (Haley & Stansbury, 2003). Similarly, infants of predominantly insensitive mothers showed less autonomic regulation as indexed by lower RSA and also had greater sympathetic activation during stress than those with more sensitive mothers indicating that maternal behaviors may shape autonomic functioning early in life (Enlow, King, Schreier, Howard, Rosenfield, Ritz & Wright, 2014).

Indeed, literature has repeatedly shown that both emotion coregulation and emotion co-dysregulation (a dyadic interaction that results in destabilization of emotion) have a significant association with autonomic function (Porter, 2003; Enlow, et al., 2014; Hastings et. al., 2008). In contrast to the benefits of emotion coregulation, caregivers may also respond to children in ways that dysregulate child emotion if the child's efforts to communicate or connect are not met with a sensitive response. For instance, in a short-term longitudinal study of preschool age children, mothers high in negative control (dictating the minutiae of a child's cognitions, behaviors, and feelings) had children with lower RSA in response to a socially challenging stressor (Hastings et. al., 2008). Additionally, in a study of school-aged children, results showed that mothers high in overcontrol had a dampened cardiovascular response while observing their child participate in a laboratory stressor, however, the children of these over-controlling mothers had lower RSA during the stressor (Borelli et al., 2017). Together these studies suggest that parental emotions and behaviors towards children may be the variables that compose the process of emotion coregulation as indexed by children's autonomic stress responses. In sum, existing literature on child RSA and parent-child coregulation most commonly investigates links between either, shared (i.e., synchronized) emotional experiences or the parent's explicit or implicit efforts to down-regulate the negative emotional states of the child, however, far less is known about the relation between the up-regulation of positive emotion and child RSA during stress.

The Current Study

This correlational study assessed 100 mother-child dyads (Mchildage = 3.5 years) drawn from one wave of a larger birth cohort study called Growing Up in Singapore Towards healthy Outcomes (GUSTO) (Soh, Gluckman, Godfrey, Rifkin-Graboi, Chan & Saw, 2013). To our knowledge, no study has assessed whether positive emotion coregulation as demonstrated by maternal PA expressions for children performs a physiologically protective function for children when coping with stress, and few studies have focused on the preschool-age range, a critical developmental period for the advancement of emotion regulation skills (Zeman, Cassano, Perry-

Parrish, & Stegall, 2006). To address these gaps in the literature, this correlational study will assess whether mothers' PA in direct *response* to children is associated with preschool aged children's RSA in response to a laboratory stressor without the mother present. Specifically, hypothesis 1 predicts that higher maternal PA responses to children will be positively associated with higher child RSA at baseline, hypothesis 2 predicts that higher maternal PA responses to children will be positively associated with higher child RSA during reactivity to a frustrating/stressful task and hypothesis 3 predicts that higher maternal PA responses to children will predict higher child RSA during recovery from the frustrating task.

Method

Participants

The current study consisted of 100 mother-child dyads (64% Chinese, 24% Malay and 12% Indian). The child sample was 46% female and 54% male and the mean age = 3.4 years and the mean age of mothers was approximately 34 years. This study was approved by Sing Health Centralized Institutional Review Board the National Healthcare Group Domain Specific Review Board.

In the larger GUSTO study (Soh, Gluckman, Godfrey, Rifkin-Graboi, Chan & Saw, 2013), 448 healthy pregnant women over the age of 18 years old were recruited in the woman's first trimester of pregnancy from two hospital maternity units (KK Women's and Children's Hospital and National University Hospital, June 2009-September 2010) during an ultrasound appointment. Chinese, Malay, or Indian, Singapore citizens with ethnically homogenous partners (birth father of the child) were asked to participate and mothers with type 1 diabetes, or those receiving chemotherapy or psychotropic drugs were excluded. Data specific to the study hypotheses (i.e., video data of coregulation at the correct points) was available for 185 mother-child dyads-- of these, 85 were missing usable data required for physiological analyses, or relevant covariate data such as income, age, or sex for the mother or the child.

Procedure

After obtaining written consent from participants, a researcher attached disposable electrodes to the subject at 3 points; between the lower right ribs, on the chest at the apex of the heart, and just under the right collar bone and data was continually recorded for RSA throughout the study session. First, baseline RSA data was collected for the child using electrocardiogram (ECG) equipment while the child colored with a research assistant for two minutes. Next, the child went through a solitary four minute frustration inducing task followed by a one minute solitary recovery period. For the frustration task, the child picked out a toy they liked which was then locked into a transparent box. The child was then given a set of keys; none of which work to open the lock. The research assistant then exited the room, leaving the child alone with the incorrect set of keys for four minutes. After the four minute solitary frustration period, the research assistant re-entered the room and said “It looks like I gave you the wrong key. Here is the correct one”, and then exited the room once again, which commenced the one minute solitary recovery period. The mother and child then reunited during a free play task for five minutes. After the reunion the research assistant entered the room and asked the mother to make her child laugh as she normally would for two minutes (i.e., the “Laughing Task”). In addition to the above tasks, children also participated in tasks unrelated to the current study for approximately 20 minutes.

Measures

Mother and child positive emotion and emotion coregulation. Our goal in designing this coding scheme was to capture parent-child positive emotion coregulation during a task designed to elicit positive emotion exchanges between parents and children. No such coding scheme exists in the literature. To develop this coding scheme, we reviewed the literature for theories of emotion and emotion coregulation, grounding the coding scheme in the Circumplex Model of Affect to rate PA and PA responsiveness for the mother and the child (Russell et. al, 1980). Prior to implementing the coding scheme, we consulted with experts in the field of parenting, emotion, and parent-child emotion coregulation, as well as with the developer of the Laughing Task (Bureau, Yurkowski, Schmiedel, Martin, Moss & Pallanca, 2014). We revised the coding system several times in response to their feedback before ultimately implementing it with our coding team.

To provide the greatest level of independence of the coded data, we trained two separate teams of coders, a mother coding team and a child coding team -- the mother coding team coded only mothers and the child coding team coded only children across all interaction tasks. All coders rated targets' (mothers or children, respectively) observed overall PA throughout the Laughing Task and, in a separate scale, rated targets' PA exhibited *only* directly in response to the other person in the Laughing Task. One coder rated each video and a second expert coder rated a portion (20%) of the video-recorded interaction tasks to determine inter-rater reliability of the coders. Cronbach's alphas suggested satisfactory levels of reliability for all coded data (mother's overall PA at minute one: $\alpha = .71$, minute two: $\alpha = .79$), in direct response to the child: $\alpha = .80$ (computed across the two minute task) and for the child's overall PA at minute one: $\alpha = .85$, minute two: $\alpha = .86$, and in direct response to the mother: $\alpha = .91$). For analyses, we computed a mean score of overall PA at minutes one and two for the mother and child; we also used measures of mothers' PA in direct response to the child and children's PA in direct response to the mother as variables. Coding both overall PA and PA responsiveness separately, was necessary to distinguish the effects of trait-like PA (a known health and physiology predictor) from the positive and interactive behavioral pattern of interest.

Observed overall PA. Observed overall PA occurring during the 2-minute Laughing Task includes PA in response to the other member of the dyad, however, it is also intended to capture PA in response to the environment (i.e., toys, their own reflection in the two-way glass mirror). This scale was designed to capture trait-like PA in order to account for participant's trait affect when assessing PA in direct response to the other as the outcome variable. Coders were asked to identify parent and child displays of one or more positive emotions during the Laughing Task, for example, happiness, contentment, alertness, etc. and behaviors such as laughing, smiles and playfulness. Raters considered both frequency and intensity of emotional cues and rated targets' behavior separately for each minute of the interaction task (minute one and minute two). Targets' behavior was coded on a 1 to 7 scale with 1 representing "*not at all positive*" and 7 representing "*very positive*" levels of positive emotion.

PA responsiveness. PA responsiveness exclusively measures expressions in direct response to the other member of the dyad. Coders were asked to rate PA expressions only in response to the mother or child respectively. PA responsiveness to the other was operationalized by a marked increase in displays of positive emotions, such as expressions of happiness, serenity, elation and calm. Behaviors included laughing, smiles and playfulness that occur as a direct result of interacting with the other. Additionally, both the mother and the child's positive emotional response to each other were coded on a 1 to 7 scale with 1 representing "*no increase*" and 7 representing a "*high increase*" in positive emotion.

Respiratory Sinus Arrhythmia. The Vrije Universiteit Ambulatory Monitoring System (VU-AMS, version 5fs, TD-FPP, Amsterdam, the Netherlands), was used to collect respiratory and heart rate data using electrocardiogram leads. Data was processed using the VU-DAMS software (version 2.2). Respiration was recorded using four impedance cardiograms (ICG) (Ernst, Litvack, Lozano, Cacioppo, & Berntson, 1999). ICG electrodes were placed at the suprasternal notch above the top of the sternum, at the xiphoid process; at the back, on the spine, at least three cm above the level of the suprasternal notch; and at the back on the spine, at least 1cm below the level of the xiphoid process. A peak-valley estimation method was used to compute RSA (Grossman, van Beek, & Wientjes, 1990; de Geus et al., 1995) at the 2.5 minute baseline period, during the four-minute frustration (i.e., reactivity period) and during a one-minute recovery play-time.

Age and sex. Case notes from the child's birth hospital were obtained to collect routinely recorded birth data including the date of birth and sex of the child. The age in days of the child on the day of the current study was calculated from the child's birth date. Sex of the child at birth was coded 1=male; 2= female.

Household income. Mother's self-reported monthly household income in Singaporean dollars on scale of 1- 5 with 1 representing "*0-999*" and 5 representing "*Above 6000*". Based on conversion rates in September, 2019, 1.38 Singaporean dollars equals 1 United States dollar (Exchange-Rates.org, 2019).

Data Analytic Plan

Age, sex, household income, and observed overall PA were accounted for in subsequent analyses as covariates. These covariates were chosen based on prior research suggesting differences in sex (Morales, Beekman, Blandon, Stifter, & Buss, 2015), household income (Egbuonu & Starfield, 1982) and age (Alkon, Goldstein, Smider, Essex, Kupfer, & Boyce, 2003) for physiological metrics as well as in children's emotional displays (Hastings et al, 2008).

Analyses were performed using version 25 of SPSS. If participants were missing data for any of the variables used in our analyses, their data were excluded. To test study hypotheses, we conducted hierarchical linear regressions using the mother's PA response to the child as the predictor variable while controlling for potential demographic confounds (household income, age, and sex) in an initial step of the regression for each model. In analyses in which we predicted RSA during and following the task (i.e., reactivity and recovery levels of RSA), we also controlled for child baseline RSA levels on the initial step of the regression for reactivity. When testing mothers' PA responses to children as a predictor of children's RSA during recovery, due to our interest in modeling change from reactivity to recovery, we controlled for their RSA during the final minute of the frustration task due to its proximity in relation to the recovery period, similar to the methodology employed in prior work exploring changes within stressor-levels of physiology or from stressor-levels of physiology to recovery (Borelli et al., 2015; Partington et al., 2018; Borelli, Burkhart, Rasmussen, Smiley & Helleman, 2018).

When findings were significant in the initial step of each model, we followed up and also controlled for the child's PA response in all A. models in order to assess whether these findings are explained by the child's PA response to the mother. We additionally controlled for overall child PA in all B. models to test whether findings were explained by child PA more generally. Finally, we controlled for mother's overall PA in all C. models in order to assess whether children's RSA levels are explained by the mother's overall trait PA versus PA responses to children. To avoid overly saturating the models with overlapping constructs, we conducted these regressions individually.

Results

Descriptive Statistics

Descriptive statistics for key variables, overall and by child sex are reported in Table 1. Independent samples *t*-tests revealed that there were no significant differences in mothers' positive emotional response based on the sex of the child ($p = 0.64$). Zero-order correlations among key study variables and demographic factors (presented in Table 2) revealed that mothers with higher positive emotional responses to the child had children with higher RSA at recovery. Higher positive emotional responses by the mother, positive emotional responses by the child, overall maternal PA and overall child PA were positively intercorrelated.

Hypothesis 1 (Model 1): Dependent Variable, RSA-Resting Baseline Period

After adjusting for age, household income and sex (age, household income and sex will now be referred to as *demographic covariates*) in this and all subsequent models (adjusted $R^2 = 0.02$, $p = 0.19$), mothers' positive emotional response to their children were significantly, positively associated with higher child baseline RSA, $\Delta R^2 = 0.051$, $b = 9.34$, $SE = 4.01$, $p = 0.02$ (see Table 3). In model 1A., when we adjusted for the child's PA response to the mother (adjusted $R^2 = 0.09$, $p = 0.01$), the mother's PA in response to the child was still positively associated with child's baseline RSA ($\Delta R^2 = 0.05$, $b = 9.59$, $SE = 4.09$, $p = 0.02$), but child positive emotional response to the parent was not in the overall model ($b = 0.46$, $p = 0.80$). The association between mother's PA response to the child and child baseline RSA also held in model 1B. after adjusting for overall child PA (adjusted R^2=.10, $p = 0.01$, ΔR^2=.06, $b = 10.05$, SE=4.06, p =.02), although overall child PA was not associated with baseline RSA in the overall model (b =-5.15, p = .10). Finally in model 1C., after adjusting for overall mother PA (adjusted R^2=.12, p =.01), mother's positive emotional response to the child was no longer significantly associated with child RSA at baseline in the overall model (ΔR^2=.028, b =9.50, SE=5.37, p=.80).

Hypothesis 2 (Model 2): Dependent Variable, RSA-Frustration Task

After adjusting for baseline RSA and demographic covariates in this model (adjusted R^2 = 0.57, $p < .001$), mothers' positive emotional responses to their children were not a significant predictor of child reactivity RSA, $\Delta R^2 < 0.001$, $b = -0.26$, $SE = 3.12$, $p = 0.93$. Thus, we did not conduct follow up analyses covarying the child's PA response, overall child PA or mother's overall PA.

Hypothesis 3 (Model 3): Dependent Variable, RSA-Recovery

After adjusting for minute 4 of reactivity and demographic covariates in this and all subsequent models (adjusted $R^2 = 0.36$, $p < 0.001$), mothers' positive emotional responses to their children were significantly, positively associated with higher child recovery RSA, $\Delta R^2 = 0.03$, $b = 7.86$, $SE = 3.94$, $p = 0.05$ (see Table 3)**.** In model 1A., when we adjusted for the child's PA response to the mother (adjusted $R^2 = 0.35$, $p < 0.001$), the mother's PA response to the child was not associated with child's recovery RSA ($\Delta R^2 = 0.03$, $b = 8.11$, $SE = 4.36$, $p = 0.07$), and the child's PA response to the parent was also not associated with child recovery in the overall model ($b = -.41$, $p = 0.84$). However, the association between mothers' positive emotional response and child recovery RSA held in model 1B. after adjusting for overall child PA during the Laughing Task (adjusted $R^2 =.39$, p < .001, $\Delta R^2 = 0.03$, $b = 8.61$, SE=4.22, $p < .05$), and overall child PA during the Laughing Task was negatively associated with recovery RSA in the overall model ($b = -7.54$, $p = .02$. Finally, in model 1C., after adjusting for observed overall mother PA during the Laughing Task (adjusted $R^2 = 0.40$, $p <. 001$), mother's positive emotional response to the child was no longer significantly associated with child RSA at recovery ($\Delta R^2 = 0.02$, $b =7.95$, SE= 5.76, $p =.17$).

Discussion

Broadly, the current study adds to existing literature linking high emotion coregulation and PA responsive parental behaviors to high RSA at resting baseline and in recovery from stress in children. Specifically, we found that mothers who showed more displays of enjoyment in response to the child during the Laughing Task had children with higher RSA overall (baseline) and high RSA during recovery from a frustrating laboratory task. However, when we controlled for mothers' observed overall PA the results were no longer significant. Further, associations between maternal PA responses to children and child RSA were not present during the frustrating task (reactivity) as we previously hypothesized. That is, the mother's expressions of joy towards her child did not seem to play a protective role with respect to children's RSA withdrawal during stress exposure. Research such as this may provide insight into whether positive parental responses to children might translate into internal psychophysiological resources that promote better autonomic function for children surrounding and during times of stress.

The positive association between maternal PA responses to children and resting baseline RSA supports literature linking high RSA overall to healthier emotional and social functioning (Geisler, Kubiak & Weber, 2013) and high levels of mother-child emotion coregulation to high baseline RSA in children (Porter, 2003). Indeed, past literature suggests that high quality parent-child relationships may equip children to achieve better autonomic functioning (Calkins, et al., 2008) hinting at networks of interdependent biopsychosocial systems. One possible explanation for the association between maternal PA responses to the child and child RSA at baseline in the current study is that baseline results may reflect a history of maternal PA responses to the child. That is, since the current study utilized brief "on-the-spot" laboratory tasks to measure the constructs of interest, these interaction tasks may have required that mothers draw upon past PA experiences with the child in order to fulfill the prompts given by research personnel. It could be quite difficult for mothers to make children laugh on demand, in front of cameras, strangers and in an unfamiliar place-- the ability to do so may underscore considerable resources within a dyad, such as a reservoir of interactive and play possibilities based on a pre-existing history. These suggestions are speculative and further research on the links between maternal PA responses and physiological processes in children is needed to understand whether causal pathways exist.

Interestingly, the associations between maternal PA responses to children and child RSA were not present during the frustrating tasks (reactivity). These null findings during reactivity compliments research that suggests that low RSA during times of challenge is sometimes the most adaptive autonomic response since RSA withdrawal allows engagement of the “fight or flight” response mobilizing the body for behavioral changes that could reduce pain, stress or threat (Porter, Porges, & Marshall, 1988; Porges & Lipsitt, 1993; Porter, Porges, & Marshall, 1988). High RSA at resting baseline and low RSA during frustration may be indicative of an autonomic response that adapts to the changing demands of the environment and the rapid return to high RSA during stress recovery supports this suggestion.

Our findings revealed a positive association between maternal PA responses to children and child RSA during recovery from the frustrating laboratory task. That is, maternal expressions of joy towards her child were associated with quicker autonomic recovery from the stressor. Research has suggested that, in the early years of development, children are largely dependent on the caregiver to serve as an external regulator for emotion regulation (Fonagy et al., 1997; Zeman, Cassano, Perry-Parrish, & Stegall, 2006) -- in infancy, children look to their caregivers as sources of information in the context of ambiguity (Campos, 1981) and enter a state of emotion dysregulation in the absence of responsiveness from caregivers (Tronick, 1989). In the preschool years, although children are more independent than during infancy, they are still in need of parental input to regulate emotion (Fonagey, et al., 2002). Thus, it should be unsurprising that our findings revealed an association between maternal PA response and children's RSA (during baseline and during recovery). We interpret these findings to support the notion that during this developmental period, parents' emotional responses are of tremendous importance in regulating children's physiological recovery from stressors. In this sense, our findings support the Undoing Hypothesis from a novel, dyadic reference point. While the Undoing Hypothesis suggests that one's own PA can help regulate negative emotions and undo the cardiovascular after-effects of stress (Fredrickson, Mancuso, Branigan & Tugade, 2000), the current study found that the mother's PA expressions for the child predicted quicker autonomic recovery from stress. A possible explanation for this association is that maternal PA responses to children could impart a self-regulatory resource that can be carried and utilized during stress with or without the mother's presence or in-the-moment co-regulatory behaviors. These findings may connect existing bodies of literature linking quicker RSA recovery to PA and to emotion coregulation in children, however, replication studies are needed to confirm associations between these constructs.

To further understand the positive associations between maternal PA responses and RSA at baseline and recovery, we probed deeper into these findings. We wanted to understand whether our findings were primarily driven by mothers' responses to children's positive emotions, as we had previously anticipated, or whether they were largely a result of mothers' trait-like positive affect, which we had attempted to address by controlling for mothers' overall PA in our models. Notably, when we controlled for mother's observed overall PA in the model while still including mothers' PA response, mothers' PA response was no longer significantly linked to child RSA at baseline, reactivity or recovery. In additional models in which we only included overall maternal PA as the predictor of child RSA at baseline, reactivity, and recovery while controlling for age, sex, and household income, we found that the relations between observed overall PA and child RSA at baseline, reactivity and recovery were also non-significant. One explanation for these null findings is that observed overall PA did not successfully capture mother's trait-like PA during the LT. By controlling for mother's overall observed PA (which included PA in response to the child) we may have effectively removed some of the predictive power of mother's PA response. That is, it is possible that the observed overall PA variable was simply a dampened version of the PA response to the child variable. Data regarding mothers' stable, trait PA were unavailable in the current study, which is why we attempted to capture trait-like PA during the LT by creating this observed overall PA scale that included PA responses to the child. While controlling for mothers' trait PA was our best way of assessing trait-like PA, it is unlikely that we captured a true measure of this during the LT since this was only a two-minute task in which mothers were asked to draw a particular affective response from children. That said, it is interesting and informative that this observed PA measure wiped out some of the observed effects. This hints at the possibility that dispositional levels of PA may influence how parents influence child emotional regulation and responses to stress and be a pathway connecting parental wellbeing to child wellbeing. Future researchers should collect trait PA measures using more established approaches such as self-reported affect checklists (e.g., Watson & Clark, 1994).

Further, our findings are in line with past work linking high baseline RSA in adults to positive emotional expressivity and trait positive affect (Wang, Lu & Qin, 2013). Similarly, our findings resonate with prior research on children that links high RSA during recovery from stress to higher parental expressions of positive emotion (Cui, Morris, Harrist, Larzelere, & Criss, 2015), less aggression, more prosocial behaviors and more adaptive emotion regulation (Miller, Chocol, Nuselovici, Utendale, Simard & Hastings, 2013; Brooker & Buss, 2010; Cui, Morris, Harrist, Larzelere, Criss & Holtberg, 2015). In addition to links with RSA, our findings support research that shows that low parental expressions of positive emotion and high expressions of negative emotion are associated with poor emotion regulation in children (Fosco & Grych, 2013; Jackson, Kuppens, Sheeber, & Allen, 2011; Kim, Pears, Capaldi, & Owen, 2009). Further, a study assessing the same sample as the current study reported that higher maternal sensitivity at 6 months of age predicted quicker habituation to a series of fear-inducing tasks at 42 months of age as indexed by attenuated startle responses (Tsotsi, Borelli, Abdulla, Tan, Sim, Sanmugam & Rifkin-Graboi, 2018). The findings of these studies are parallel in that they both reveal a pattern in which positive parenting practices (in one, sensitivity, in the other, positive emotion coregulation) is associated with recovery from stress.

Our findings complement and contribute to existing literature in theoretical ways as well. Research shows that emotion regulation forms in early childhood within the context of co-regulatory experiences with the primary caregiver (Butler & Randall, 2013; Dalton, Frick-Horbury, & Kitzmann, 2006) and co-regulatory positive emotional experiences with the primary caregiver are linked to high RSA (Smith, Woodhouse, Clark & Skowron, 2016). The current findings and this growing body of literature supports Kok & Fredrickson's (2010) suggestion that autonomic flexibility is marked by quick cardiovascular adaptation to the demands of the environment. Thus, our findings complement these past theories and findings and provide preliminary support that maternal PA responses to children may be one component of the "portable" protective resources provided by caregivers that shape psychophysiological function early in life. In adults, numerous studies link stress responses, social bonds and positive emotions to cardiovascular performance with adaptive responses predicting reduced risk of cardiovascular disease and optimal cardiovascular function (Boehm & Kubzansky, 2012; Gunnar et. al., 1996). If future research confirms links between maternal PA responses to children and children's RSA preceding and during recovering from challenging tasks, this could lead to the development of interventions designed to improve positive emotional exchanges in the mother-child dyad during the toddler years when emotion regulation strategies develop.

Limitations and Future Directions

It is important to contextualize the contributions of this study in terms of its constraints. The current study is limited by correlational design and by the demographic composition of the sample, therefore, we cannot generalize the results or determine causal pathways by which maternal PA responses and child RSA are linked. While we suspect that our findings may hint at a point in a child's development in which maternal PA response plays a physiologically protective role, we were unable to examine age effects due to the correlational design of the study and the limited age range of the child participants. Additionally, we only assessed variables of interest in the mother-child dyad due to an under-representation of fathers in the sample. Another limitation is that mothers were requested to make their children laugh at a moment's notice. We observed that many children were in a state of focused play when mothers were requested to do so; some of the children appeared annoyed at the interruption. Further, we observed that some mothers could not make their child laugh upon the request of the researcher but instead chose to increase low arousal positive emotions such as calm and serenity. Thus, the Laughing Task could be adapted to become a "Happy Task", where parents are directed to try to increase the child's happiness for two minutes which would allow parents to draw upon and impart a broader range of positive emotional resources other than humor alone and could also allow for parents to follow the child's cues with greater sensitivity. This may have unfairly advantaged dyads in which the preschoolers were already in a state of happy play at the outset of the task. Future studies should address the limitations of this study by examining maternal PA responses longitudinally in order to assess age effects, including both mothers and fathers, and adapting the Laughing Task to include both high and low arousal PA.

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Appendix

Table 1
Descriptive Statistics of Key Variables by Children's Sex.

Measures	Total $N = 100$ M (SD)	Boys $n = 54$ M (SD)	*Girls n = 46* *M (SD)*	*Sex differences* t
Age	3.47(.095)	3.46(.09)	3.48(.096)	-1.21
Household Income	4.00(.94)	4.12(.87)	3.87(1.00)	1.31
Overall Child PA	3.37(1.69)	3.50(1.79)	3.22(1.58)	0.89
Overall Parent PA	4.19(.75)	4.27(.75)	4.10(.75)	1.17
Child PA Response	3.52(2.03)	3.70(2.11)	3.33(1.96)	0.93
Maternal PA Response	3.25(.90)	3.31(.99)	3.18(.79)	0.79
RSA- Baseline[a]	68.74(33.60)	63.41(26.18)	74.38(39.49)	-1.67
RSA- Reactivity[b]	66.68(35.76)	65.55(30.81)	67.59(39.59)	-0.25
RSA- Recovery[c]	73.95(39.70)	72.61(39.43)	75.32(40.37)	-0.30

Note: no significant sex differences
[a]N at baseline = 100
[b] N at reactivity = 77
[c] N at recovery = 79

Table 2

Correlation Matrix for Key Variables.

Variables	1	2	3	4	5	6	7	8	9	10
1. Age	--									
2. Sex	0.01	--								
3. Household Income	0.07	-0.05	--							
4. Overall Child PA	-0.004	-0.08	0.01	--						
5. Overall Parent PA	-0.01	-0.09	0.14	0.37**	--					
6. Child PA Response	-0.04	-0.08	0.10	0.82**	0.39**	--				
7. Maternal PA Response	-0.15*	-0.04	0.04	0.37**	0.68**	0.39**	--			
8. RSA-Baseline	-0.004	0.06	-.14*	0.02	0.14	0.10	0.17	--		
9. RSA- Reactivity	0.03	0.01	-0.10	0.06	0.12	0.07	0.11	0.67**	--	
10. RSA- Recovery	-0.03	0.003	-0.12	-0.01	0.13	0.09	.22*	0.71**	0.70**	--

Note: Sex Coding: 1 = boys, 2 = girls;
* $p < .05$, ** $p < .01$, *** $p < .001$

Table 3

Hierarchical Regressions Examining Associations between Maternal PA Response, RSA-Baseline, RSA Reactivity and RSA-Recovery.

	Dependent Variable: RSA Baseline				Dependent Variable: RSA Frustration				Dependent Variable: RSA Recovery			
Step	*b*	*SE*	β	95% CI	*b*	*SE*	β	95% CI	*b*	*SE*	β	95% CI
Step 1 R^2	.02				.59***				.34***			
Constant	-19.90	129.46		[-276.88, 237.08]	-82.74	96.30			123.98	125.53		[-126.14, 374.10]
Age	.09	.10	.09	[-.12, .29]	.06	.08	.06	[-.09, .21]	-.06	.10	-.06	[-.26, .14]
Sex	3.64	7.20	.05	[-10.66, 17.93]	-1.21	5.44	-.02	[-12.05, 9.63]	-3.71	7.10	-.05	[-17.85, 10.44]
Income	-6.99	3.75	-.19	[-14.44, .44]	4.05	2.95	.11	[-1.83, 9.92]	-2.76	3.45	-.07	[-9.64, 4.12]
RSA Control[a]	---	---	---	---	.79***	.08	.78	[.63, .95]	.66	.10	.62	[.47, .86]
Step 2 ΔR^2	.05*				.00				.03*			
Maternal PA Response	9.34	4.01	.23	[1.39, 17.30]	-.26	3.12	-.01	[-6.5, 5.96]	7.86	3.94	.19	[.01, 15.71]

[a]In the regression in which the dependent variable is RSA during frustration, the RSA control is baseline RSA, whereas in the regression in which the dependent variable is RSA during recovery, the RSA control is frustration RSA

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