EFFECTS OF CHILD PROTECTIVE SERVICES INVOLVEMENT ON DEVELOPMENTAL TRAJECTORIES OF RESPIRATORY SINUS ARRHYTHMIA

by

Tabitha Sellers

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Tabitha Sellers

Approved: ____
Mary Dozier, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ____
Tania Roth, Ph.D.
Chair of the Department of Psychological and Brain Sciences

Approved: ____
John Pelesko, Ph.D.
Dean of the College of Arts and Sciences

Approved: ____
Louis F. Rossi, Ph.D.
Vice Provost for Graduate and Professional Education and
Dean of the Graduate College

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ABSTRACT

Respiratory sinus arrhythmia (RSA) is a widely used biomarker of physiological regulation, such that higher levels of resting RSA are positively associated with behavioral regulation and negatively associated with psychopathology. Resting RSA increases across early childhood and typically remains stable across middle childhood to late adolescence for typically developing children. However, it is unclear whether early adverse experiences, such as child maltreatment, are associated with atypical developmental trajectories of resting RSA. The present study examined experience of CPS involvement as a predictor of change in resting RSA from middle childhood to adolescence. Further, change in resting RSA was examined as a predictor of adolescent emotion reactivity and regulation. Data from a randomized clinical trial were utilized resulting in a sample of 183 children (118 of which had histories of early maltreatment risk) who had completed 9-, 13-, and 14-year follow-up assessments where resting RSA and self-reported emotional reactivity and emotion regulation were measured. Structural equation modeling was used to calculate change in RSA from ages 9 to 13 as a latent change variable. Results revealed that history of child maltreatment marginally predicted change in RSA from 9- to 13-years-old. Change in RSA predicted emotional reactivity at age 13 and RSA measured at age 9 predicted emotion regulation at age 14. Findings suggest that early adversity may play a role in the development of RSA and individual differences in developmental trajectories of RSA are predictive of adolescent emotional functioning.

Chapter 1

INTRODUCTION

The field of developmental psychology has turned to biological correlates of behavior as transdiagnostic factors of different psychopathologies. The shift in focus towards potential biological vulnerabilities related to the emergence of psychological disorders was largely driven by the developmental psychopathology framework established by Sroufe and Rutter (1984). The developmental framework proposed highlights the importance of considering individual differences, developmental period, biological systems, and the environment to understand links between early adaptation and later psychopathology (Sroufe & Rutter, 1984). Advances in psychophysiological research have led to the investigation of potential biological markers of emotional processes such as emotion regulation (Porges, 1995; Beauchaine, 2015a; Beauchaine & Thayer, 2015). Cardiac vagal tone has since emerged as a reliable psychophysiological marker of emotion regulation and adjustment. Individual differences in vagal tone have been found as early as infancy and have been linked with emotional (Calkins & Fox, 1992), behavioral (DiPietro & Porges, 1991), and stress reactivity (Gunnar et al., 1995). Links found between vagal tone and emotionality have led to the investigation of respiratory sinus arrhythmia (RSA), a form of vagal tone, as a biomarker of emotion regulation across development (for a review, see Beauchaine, 2015). However, little research has examined the longitudinal development of RSA and how individual differences in changes of RSA are linked to current and later functioning. Further, while developmental psychopathology research has extensively examined the effect of child maltreatment on psychophysiology, emotion reactivity, and regulation, few studies have examined the effect of early adversity on the change in psychophysiological development over time. Thus, the present study seeks to address these gaps in the literature by examining the effect of child maltreatment on the developmental trajectory of RSA from middle childhood to adolescence and links with emotion reactivity and regulation.

1.1 Autonomic Nervous System

Heart rate variability (HRV) is a physiological process by which heart rate across respiratory cycles is observed and has been linked with behavioral regulation, executive functioning, and social competence among children and adolescents. RSA is a component of HRV that occurs at the frequency of the ebb and flow of respiration. According to Porges' poly-vagal theory, RSA is considered a measure of PNS functioning and has associations with the central nervous system via input from the brain stem (Porges, 1995, 1996). The PNS is theorized to send signals via the vagus nerve and slows heart rate upon exhalation through inhibition and accelerates heart rate upon inhalation through withdrawal of the PNS (Shader et al., 2018). Through this process of PNS inhibition and withdrawal, the dynamic cardiac activity facilitates an individual's speed and flexibility by which they respond to changing environmental demands.

Given the associations between PNS functioning and its role in responding to environmental demands, RSA at rest is regularly implicated in emotion regulation (Beauchaine et al., 2007; Calkins et al., 2019). In general, high resting RSA has been found to be associated with better regulation due to the increased capacity to flexibly react to environmental demands (e.g., El-Sheikh & Erath, 2011; Porges, 2007, 2011). Conversely, low resting RSA has been found to be associated with internalizing and externalizing psychopathology (Beauchaine, 2015; Beauchaine & Thayer, 2015; Chambers & Allen, 2007).

1.2 Development of Respiratory Sinus Arrhythmia

Although resting RSA has emerged as a stable neurophysiological marker of emotion regulation, less research has examined the development of RSA. Developmental trajectories of resting RSA from infancy through early childhood (Alkon et al., 2011; Bar-Haim et al., 2000; Bornstein & Suess, 2000; Porges et al., 1994) have shown significant mean-level increases and relative stability over time. Relatively little research has examined changes over time in RSA for older children. A few studies have found support for significant increases in resting RSA as late as seven years of age (Alkon et al., 2003; Marshall & Stevenson-Hinde, 1998). However, other studies have reported opposite effects (e.g., significant mean decreases), or no change in RSA among children aged 8 and older (El-Sheikh, 2005; Salomon, 2005). Research with adolescents has suggested that while RSA may remain stable over time (El-Sheikh, 2005; Salomon, 2005). This stability later in childhood may suggest that individual differences in resting RSA are established early in life, lending support for the use of RSA as a stable psychophysiological marker (Dollar et al., 2020).

Taken together, the current literature suggests that the development of RSA may have periods of change and periods of stability. Periods of change are typically observed in infancy to early childhood as exhibited by significant mean increases in resting RSA. Whereas, among the few studies conducted, stability in resting RSA is typically observed in middle childhood to adolescence. The present study sought to contribute to the scarce literature on developmental trajectories of RSA by examining children at two time points from age 9 to 13.

1.3 Effect of Early Adversity

Early experiences of adversity pose a risk for disturbances in development across a wide spectrum of domains of functioning (Cicchetti, 1996). Child maltreatment, a form of early adversity, represents a disruption to the early relational environment that has implications for long-term negative impacts on biological and behavioral domains necessary for optimal functioning (Cicchetti, 1996). Experiences of adequate caregiving are critical for the development of effective emotion regulation as infants are born dependent on their parents for basic needs and emotional support. Harsh or inconsistent caregiving, as seen in cases of maltreatment, disrupt the process of co-regulation, and have been linked with suboptimal emotion and behavior regulation later in life (Eisenberg et al., 1999; Sroufe & Fleeson, 1986). Therefore, exposure to child maltreatment increases risk for the development of psychopathology in childhood (Cicchetti & Rogosh, 2001; Cicchetti, 1996) and into adulthood (Briere & Elliott, 2003; Springer et al., 2007) through the systems of emotion and behavior regulation.

These early experiences can “get under the skin” and influence biobehavioral processes, thus leading to increased risk for psychopathology through disruptions physiological regulation. However, investigations of the effect of early maltreatment on ANS functioning have resulted in mixed findings when compared with populations without exposure to adversity. Higher levels of RSA at rest have been associated with more behavior problems among infants with histories of adversity, whereas high resting RSA levels have been associated with fewer behavior problems for infants raised in supportive environments (Conradt et al., 2013). Further, high resting RSA has been linked with longer delay of gratification among children raised in middle-class families, but with shorter delay of gratification among children living in poverty (Sturge-Apple et al., 2016).

Thus, examining differences in experiences of child maltreatment on psychophysiological development may result in complex findings that greatly depend on individual differences. Therefore, examining both group- and individual-level differences in developmental trajectories of RSA on later psychological functioning may lead to a better understanding of how early adversity may affect early biological programming and later risk for psychopathology.

1.4 Current Study and Hypotheses

Therefore, the present study sought to investigate the effect of early experiences of maltreatment on physiological regulation using two samples of school-aged to adolescent children who varied in exposure to early maltreatment. Specifically, I tested the hypothesis that early CPS involvement (i.e., risk for maltreatment) would predict change in respiratory sinus arrhythmia (RSA) from middle childhood to adolescence. I also hypothesized that adolescent emotion reactivity and use of regulatory strategies would depend on individual changes in RSA.

Chapter 2

METHOD

2.1 Participants

The present study included 183 participants from an ongoing study funded by the National Institute of Mental Health (R01MH074374), assessing middle childhood and adolescent outcomes of a longitudinal randomized clinical trial (RCT) for children whose families received the Attachment and Biobehavioral Catch-up (ABC) intervention during infancy. Of the 183 participants, 118 families were recruited when children were infants by referral from Child Protective Services due to risk for abuse or neglect. Infants and their parents were then randomly assigned to ABC or a control intervention. Additionally, a no-treatment community sample of children without Child Protective Services involvement were recruited based on comparable demographics when children in the RCT were in middle childhood from local community centers (although race comparability was not preserved in the current sub-sample, as described below). Sixty-five participants from the low-risk comparison sample were included in the present study.

Children participated in assessments in middle childhood and adolescence. The present data were collected during laboratory visits when children were nine (M = 9.74, SD = 0.45), thirteen (M = 13.31, SD = 0.45), and fourteen years old (M = 14.31, SD = 0.34). Demographic characteristics are presented in Table 1. Parents reported on the race and ethnicity of their children. Most children were reported to be Black or African American (61.1%) with a smaller proportion White (15.9%). About 29% were Hispanic or Latino/a. There was a significantly greater proportion of White children in the comparison sample than in the CPS-referred sample (χ^2 (4, N = 182) = 13.97, p = .007, Φ = 0.28). The groups did not differ significantly by proportion of children identifying as Latino/a (χ^2 (1, N = 171) = 0.03, p = .862, Φ = 0.01), sex assigned at birth (χ^2 (1, N = 183) = 0.12, p = .734, Φ = 0.03), or age at which the follow-up visits were completed [9-year follow-up: (t (152) = -1.00, p = .158); 13-year follow-up: (t (149) = -1.39, p = .083); 14-year follow-up: (t (141) = 0.16, p = .436)].

2.2 Procedures

2.2.1 Physiological Data Collection at the 9-year Follow-up

Software and hardware from the James Long Company were used for data acquisition, cleaning, and processing (James Long Company, Caroga Lake, NY, USA). Three disposable electrodes were placed in a bipolar configuration to collect electrocardiogram (ECG) data. Software was used to process and clean ECG data by automatically identifying heartbeats and calculating inter-beat intervals (IBI) as the difference between beats by milliseconds. Heartbeats that were mis-identified by the software were manually corrected. ECG data were excluded from analyses if 10% or more of the heartbeats required manual correction. Respiration data were collected using a pneumatic bellows belt fastened around the mid-section. RSA was then calculated using the cleaned ECG and respiration data using the peak-to-valley method, which accounts for the difference in IBIs during respiratory inspiration and expiration. RSA levels were averaged across a three-minute rested baseline task where children were asked to watch a relaxing video with their caregiver.

2.2.2 Physiological Data Collection at the 13-year Follow-up

Software and hardware from MindWare Technologies were used for data acquisition, cleaning, and processing (MindWare Technologies LTD., Westerville, OH, USA). Three disposable electrodes were placed in a bipolar configuration to collect ECG data. Heart Rate Variability Analysis Software (version 3.2.9) was used to automatically identify heartbeats, calculate IBIs, and to manually correct mis-identified heartbeats as needed. Segments were excluded from analyses if they required estimation of greater than 10% of total beats. RSA was calculated using the cleaned ECG data as the natural log of the child’s average high-frequency heart rate variability in each segment based on the recommended frequency band for adolescents (i.e., 0.12 – 0.40; Shader et al., 2018). RSA levels were then averaged across a three-minute rested baseline task where adolescents were asked to watch a relaxing nature scene independently.

2.2.3 The Emotional Reactivity Scale (ERS)

Adolescents completed the ERS (Nock et al., 2008) at the 13-year assessment. The ERS is a 21-item self-report questionnaire designed to assess how individuals experience emotions. With three subscales, (emotion sensitivity (*M* = 13.86, *SD* = 9.76), emotion intensity (*M* = 11.32, *SD* = 7.17), and emotion persistence (*M* = 6.47, *SD* = 4.09)), the ERS has one overall score (*M* = 31.66, *SD* = 19.45). Items are rated on a five-point Likert scale (0 = “not at all like me” to 4 = “completely like me”). The internal consistency for this scale was excellent ($\alpha = 0.94$). Authors of the original validation study recommend use of the total score given the high intercorrelation of the three subscales (Nock et al., 2008). The total score provides a unidimensional construct of emotional reactivity. Therefore, a total averaged score was used for analyses where greater emotional reactivity is indicated by higher scores.

2.2.4 The Emotion Regulation Questionnaire for Children and Adolescents (ERQ-CA)

Adolescents completed the ERQ-CA (Gullone & Taffe, 2011), an adaptation of the Emotion Regulation Questionnaire for adult populations (Gross & John, 2003). The ERQ-CA is a ten-item, self-report measure designed to assess the use of two different emotion regulation strategies: cognitive reappraisal and expressive suppression. The cognitive reappraisal subscale is designed to measure the use of cognitive strategies to change the impact of emotional situations. Ideally, cognitive reappraisal strategies would foster positive interpretations of potentially stressful situations. Conversely, the expressive suppression subscale seeks to measure inhibition of emotion-expressive behavior. Consequently, repeated use of expressive suppression has been linked to less experience and expression of both positive and negative emotions.

Items are rated on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The ERQ-CA has shown good internal consistency, construct validity, and convergent validity (Gullone & Taffe, 2011). Scores on the cognitive reappraisal subscale range from 6 to 30 and from 4 to 20 on the expressive suppression subscale, with higher scores indicating greater use of the corresponding strategy. In the present study, the alpha reliability coefficients were 0.85 (for cognitive reappraisal; M = 21.13, SD = 4.69) and 0.76 (for expressive suppression; M = 12.51, SD = 3.48).

2.3 Missing Data

Children were included in the present study if at least one follow-up assessment (i.e., 9-, 13-, or 14-year follow-up) had been completed. Usable ANS data from the 9-year follow-up assessment were available for 135 children. Due to the COVID-19 pandemic, ANS data were only available for children who completed the 13-year follow-up visit prior to March 2020 and after COVID safety measures allowed for psychophysiological data collection to resume in August 2020. Therefore, ANS data were only available for 75 of the 152 participants who had completed a 13-year follow-up visit. ERS total data collected at the 13-year follow-up were available for 152 participants. Finally, 143 participants completed the ERQ-CA at the 14-year follow-up visit.

Little's MCAR test, used to examine whether predictor, indicator, and outcome data were missing at random, suggested data were missing completely at random (χ^2 = 71.67, p = .848).

2.4 Analytic Plan

Preliminary analyses were conducted to examine whether demographic factors of child race, ethnicity, sex, and age at time of each RSA collection were associated with primary outcome measures or differed by risk group status.

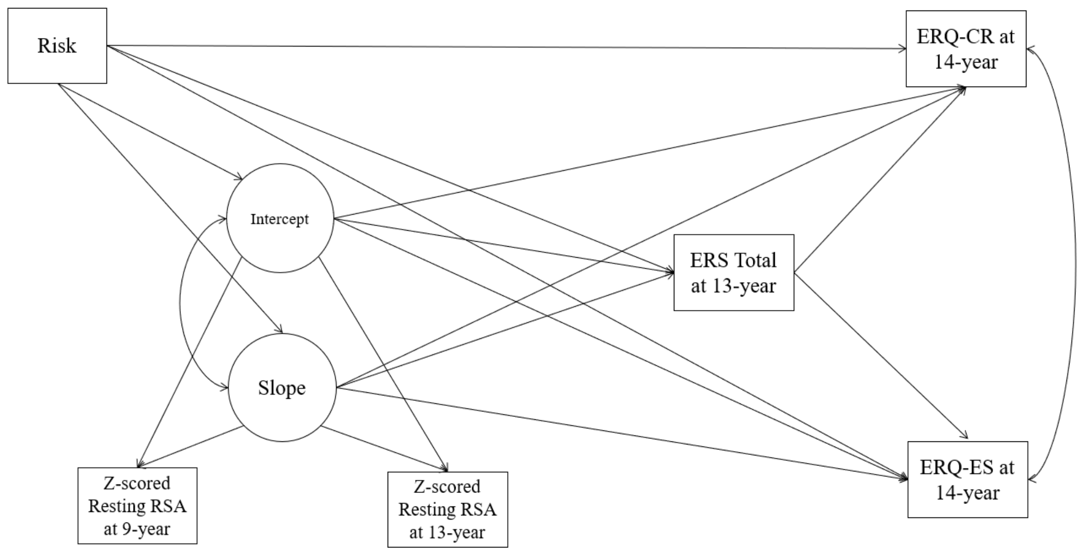
Primary analyses were conducted utilizing a latent change model using structural equation modeling with robust maximum likelihood estimation in Mplus 8.5 (Muthén & Muthén, 1998). Full information maximum likelihood was used to account for missing data. Figure 1 depicts the full model with change in RSA modeled as a latent difference variable using a latent change approach to model intraindividual change over time. In the present study, the indicators for the RSA latent factor were standardized to account for differences in each indicator's scale. Indicators were on different scales due to a change in psychophysiological data collection equipment from the middle childhood to adolescent studies and different methodology in the calculation of RSA (e.g., peak-to-valley vs. natural log change).

Intercept and slope were regressed on risk group status to examine CPS involvement as a predictor of RSA at age 9 and change in RSA over time as seen in Figure 1. ERS total and ERQ-CA variables were then regressed on intercept and slope to assess emotional reactivity and regulatory strategies as predictors of RSA at age 9 and change in RSA. Finally, ERQ-CA variables were regressed on ERS to examine emotional reactivity as a predictor of emotion regulatory strategies. Model fit was assessed using the root mean square error of approximation (RMSEA), the comparative fit index (CFI), and the Tucker-Lewis index (TLI).

Table 2-1. Child Demographics

	CPS Involved (*n* = 118)	**Non-involved** (*n* = 65)
Race [*n* (%)]		
Black/African American	79 (66.9)	31 (47.7)
White	10 (8.5)	18 (27.7)
Multiracial	19 (16.1)	10 (15.4)
Other	12 (8.5)	5 (7.7)
Missing	-	1 (1.5)
Ethnicity [*n* (%)]		
Hispanic or Latino/a	27 (22.9)	15 (23.1)
Not Hispanic or Latino/a	81 (68.6)	48 (73.8)
Missing	10 (8.5)	2 (3.1)
Sex [*n* (%)]		
Female	55 (46.6)	32 (49.2)
Male	63 (53.4)	33 (50.8)
Age [*M* (*SD*)]		
9-year follow-up	9.77 (0.50)	9.69 (0.37)
13-year follow-up	13.34 (0.35)	13.25 (0.35)
14-year follow-up	14.30 (0.35)	14.31 (0.33)

Figure 2-1. Conceptualized Path Model



Chapter 3

RESULTS

3.1 Preliminary Analyses - Descriptive Statistics

Bivariate correlations and descriptive statistics of study variables are presented in Table 2. CPS involvement was associated with race (there were significantly more White children present in the comparison group than in the CPS-referred group), and with ERS (children referred from CPS were more likely to report higher levels of emotional reactivity than the comparison group). Child sex assigned at birth and ethnicity (e.g., Hispanic or Latino/a) were also associated with ERS (girls reported greater emotional reactivity compared to boys and children of Hispanic or Latino/a origin reported greater reactivity compared to children who did not identify as Hispanic or Latino/a). The CPS-referred group and the comparison group did not differ in terms of resting RSA at 9- ($t(133) = -0.49$, $p = .311$) or 13-year ($t(73) = 0.79$, $p = .216$) follow-up visits, cognitive reappraisal ($t(141) = -1.23$, $p = .111$), or expressive suppression ($t(141) = -1.25$, $p = .107$).

3.2 Primary Analyses

As described earlier, the latent change model was set up to examine the change in resting RSA from 9- to 13-years-old and change in RSA as a predictor of adolescent emotion reactivity and regulation. Fit indices, intercepts, and residual variance values are presented in Table 3 and linear regression models are presented in Table 4.

There was a marginal effect of CPS involvement in early childhood on change in RSA (β = 0.45, *S.E.* = 0.27, p = .09). In other words, children in the low-risk group exhibited marginally greater increases in RSA from middle childhood to adolescence than children in the CPS-involved group. CPS involvement in early childhood did not, however, predict 9-year resting RSA [i.e., intercept; (β = -0.09, *S.E.* = 0.18, p = .62)], 13-year resting RSA (β = 0.36, *S.E.* = 0.24, p = .13), ERS (β = -0.13, *S.E.* = 0.10, p = .22), or ERQ-CA (cognitive reappraisal: β = -0.12, *S.E.* = 0.14, p = .38; expressive suppression: β = -0.12, *S.E.* = 0.15, p = .42).

Change in RSA over time significantly predicted ERS at age 13 (β = -0.29, *S.E.* = 0.12, p = .01). Children who showed greater increases in RSA over time reported less emotion reactivity in day-to-day situations than children who showed less change in RSA. Change in RSA did not predict either ERQ-CA subscale [cognitive reappraisal: (β = 0.04, *S.E.* = 0.12, p = .76); expressive suppression: (β = 0.07, *S.E.* = 0.12, p = .59)].

Resting RSA, measured when children were 9 years old, was significantly associated with change in RSA (i.e., slope; r = -0.56, p < .001). Children who exhibited lower levels of resting RSA at age 9 showed greater increases in RSA by age 13, compared to children with higher levels of resting RSA in middle childhood. Further, resting RSA measured at age 9 significantly predicted ERQ-CA ES only (β = - 0.22, *S.E.* = 0.10, p = .02). Children with lower resting RSA values at age 9 reported using expressive suppression as a regulatory strategy at age 14 more often than children with higher resting RSA at age 9. Resting RSA at age 9 did not predict ERS (β = -0.13, *S.E.* = 0.10, p = .22) or ERQ-CA cognitive reappraisal (β = 0.01, *S.E.* = 0.09, p = .90).

ERS at age 13 significantly predicted ERQ-CA expressive suppression at age 14 (β = 0.28, *S.E.* = 0.09, p = .001). Children who self-reported greater emotion reactivity at age 13 reported using more expressive suppression strategies at age 14 than children who reported less emotion reactivity. However, ERS did not predict ERQ-CA cognitive reappraisal (β = 0.12, *S.E.* = 0.08, p = .14).

Table 3-1. Descriptive Statistics and Bivariate Correlations between Standardized RSA, Emotion Reactivity and Regulation, and Demographic Variables

		1	2	3	4	5	6	7	8	9	10	11	12
1. Resting RSA at 9-year	*r*	-											
	N	-											
2. Resting RSA at 13-year	*r*	**0.34***	-										
	N	53	-										
3. RSA slope	*r*	**-0.56*****	**0.58*****	-									
	N	53	53	-									
4. ERS Total	*r*	0.01	**-0.25***	**-0.32***	-								
	N	110	74	53	-								
5. ERQ-ES	*r*	**-0.27****	-0.13	0.03	**0.28***	-							
	N	104	65	47	131	-							
6. ERQ-CR	*r*	-0.01	0.03	-0.18	0.14	**0.28*****	-						
	N	104	65	47	131	143	-						
7. Child age at 9-year visit	*r*	-0.09	-0.23	-0.09	0.04	-0.08	-0.04	-					
	N	134	66	53	128	123	123	-					
8. Child age at 13-year visit	*r*	0.13	-0.02	-0.07	0.06	0.04	0.01	**0.34*****	-				
	N	109	74	52	151	130	130	127	-				
9. Child age at 14-year visit	*r*	-0.08	-0.08	0.15	-0.03	0.11	-0.1	**0.30*****	**0.65*****	-			
	N	104	65	47	131	143	143	123	140	-			
10. Child sex assigned at birth	*r*	*-0.15*	-0.04	0.20	**0.20***	0.11	0.08	0.08	-0.05	0.01	-		
	N	135	75	53	153	143	143	154	151	143	-		
11. Child ethnicity	*r*	0.05	-0.11	0.01	**0.22****	0.14	-0.07	0.01	-0.01	0.05	0.03	-	
	N	130	74	53	147	137	137	149	146	137	171	-	
12. Child race	*r*	-0.10	-0.08	-0.05	0.07	-0.01	-0.12	0.10	-0.01	-0.03	-0.01	**0.43****	-
	N	134	75	53	152	142	142	153	150	142	182	170	-
Mean	-	0.00	0.00	0.03	1.51	3.14	3.55	9.73	13.31	14.31	0.52	0.25	2.64
Standard deviation	-	1.00	1.00	1.11	0.92	0.86	0.76	0.45	0.35	0.34	0.50	0.43	1.23
Min-Max	-	-1.81 - 3.06	-2.73 - 2.14	-2.15 - 3.06	0.00 - 3.95	1.25 - 5.00	1.00 - 5.00	9.00 - 12.08	12.00 - 14.33	13.92 - 15.33	0.00 - 1.00	0.00 - 1.00	1.00 - 5.00
N	-	135	75	53	153	143	143	156	151	143	183	171	182

Note. Standardized values of resting RSA used for correlations and simple difference scores of standardized RSA values [RSA at 13 - RSA at 9] were used to calculate RSA slope. Child sex: 0 (female), 1 (male); Child ethnicity: 0 (not Hispanic or Latino/a), 1 (Hispanic or Latino/a); Child race: 1 (Biracial), 2 (Black), 3 (More than one race), 4 (Other), 5 (White).

Table 3-2. Model Fit Indices, Intercepts, and Residual Variances

Fit Indices	Full latent change score model
χ^2 / *df*	0.00 / 0 (= 0.00)
CFI	1.00
RMSEA	0.00

Intercepts	*β*	*SE*	*Est./S.E.*	*p* value	95% CI Lower	95% CI Upper
Intercept	0.02	0.11	0.17	.866	-0.16	0.19
Slope	-0.12	0.15	-0.83	.407	-0.37	0.12
ERS Total	1.61	0.09	17.59	.000	1.46	1.76
ERQ-CA Expressive Suppression	2.76	0.16	17.15	.000	2.49	3.02
ERQ-CA Cognitive Reappraisal	3.41	0.11	22.47	.000	3.16	3.66

Residual Variances	*β*	*SE*	*Est./S.E.*	*p* value	95% CI Lower	95% CI Upper
Intercept	1.01	0.12	8.14	.000	0.80	1.21
Slope	1.12	0.23	4.98	.000	0.75	1.49
ERS Total	0.75	0.10	7.91	.000	0.60	0.91
ERQ-CA Expressive Suppression	0.61	0.08	8.01	.000	0.48	0.73
ERQ-CA Cognitive Reappraisal	0.55	0.07	8.14	.000	0.45	0.66

Table 3-3. Linear Regression Model Outputs with No CPS Involvement as Reference Group

Regression models with risk status as independent variable

Outcomes	*β*	*SE*	*Est./S.E.*	*p* value	95% CI Lower	95% CI Upper
Intercept	-0.09	0.18	-0.50	.620	-0.38	0.20
Slope	0.45	0.27	1.70	.090	0.01	0.89
Resting RSA at 13 years	0.36	0.24	1.50	.134	-0.04	0.76
ERS Total	-0.26	0.17	-1.60	.110	-0.54	0.01
ERQ-CA Expressive Suppression	-0.12	0.15	-0.81	.420	-0.37	0.13
ERQ-CA Cognitive Reappraisal	-0.12	0.14	-0.87	.382	-0.35	0.11

Regression models with change in RSA as independent variable

Outcomes	*β*	*SE*	*Est./S.E.*	*p* value	95% CI Lower	95% CI Upper
ERS Total	-0.29	0.12	-2.48	.013	-0.47	-0.06
ERQ-CA Expressive Suppression	0.07	0.12	0.54	.591	-0.13	0.26
ERQ-CA Cognitive Reappraisal	0.04	0.12	0.30	.761	-0.16	0.23

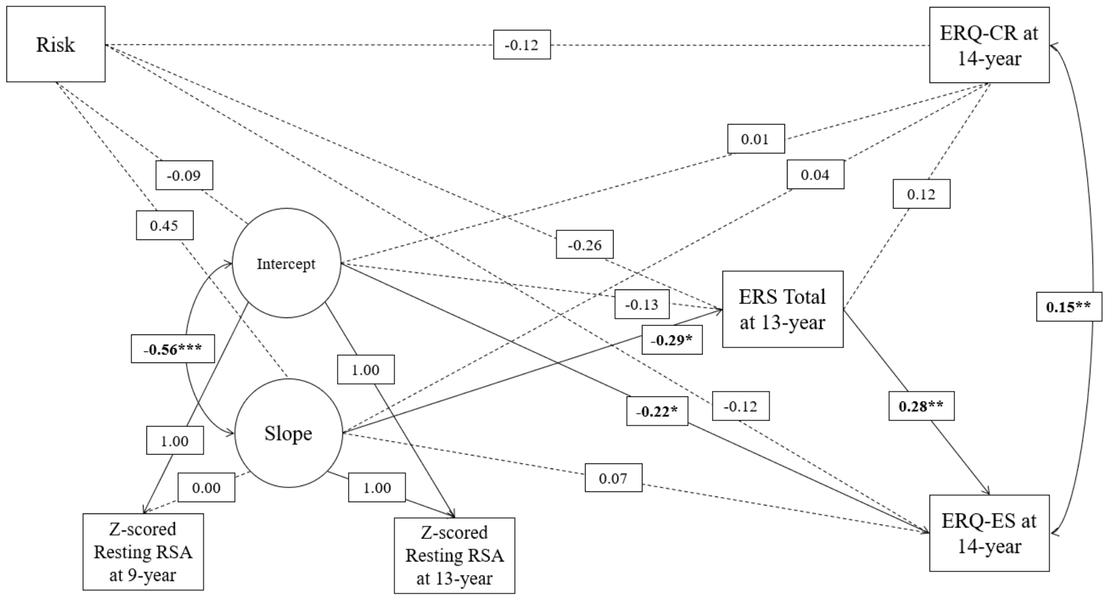
Regression models with resting RSA at age 9 as independent variable

Outcomes	*β*	*SE*	*Est./S.E.*	*p* value	95% CI Lower	95% CI Upper
ERS Total	-0.13	0.10	-1.23	.217	-0.29	0.04
ERQ-CA Expressive Suppression	-0.22	0.10	-2.29	.022	-0.38	-0.06
ERQ-CA Cognitive Reappraisal	0.01	0.09	0.13	.896	-0.14	0.16

Regression models with ERS Total as independent variable

Outcomes	*β*	*SE*	*Est./S.E.*	*p* value	95% CI Lower	95% CI Upper
ERQ-CA Expressive Suppression	0.28	0.09	3.20	.001	0.13	0.42
ERQ-CA Cognitive Reappraisal	0.12	0.08	1.47	.142	-0.01	0.25

Figure 3-1. Path Model with Standardized Parameters



Chapter 4

DISCUSSION

The present study examined the effect of early childhood maltreatment on developmental trajectories of children's physiological regulation in the form of RSA at rest, and associations with emotion reactivity and regulation in adolescence. We hypothesized that children with histories of CPS involvement would have lower levels of resting RSA and a more blunted slope from middle childhood to adolescent than children without CPS involvement. Further, we hypothesized that children with less change in RSA over time would demonstrate more emotional reactivity at age 13 and poorer emotion regulation at age 14 compared to those with greater change. Hypotheses were partially supported.

Individual differences in change in RSA from middle childhood to adolescence predicted emotional reactivity as measured by the ERS at age 13 in the hypothesized direction. Children who exhibited greater change in resting RSA reported less emotional reactivity in adolescence compared to children who exhibited less change (i.e., more blunted slope). The association between change in physiological regulation and self-reported emotional reactivity is particularly interesting as it suggests that children with suboptimal developmental trajectories of RSA may struggle more with prolonged emotionality, responding to day-to-day emotional stimuli, and strong emotional experiences and expressions. Emotional reactivity, defined as the initial response to an emotional situation, is considered the beginning of the emotional experience. This initial response may set the tone for how an individual regulates emotions after the situation unfolds (Becerra & Campitelli, 2013; Rottenberg & Johnson, 2007). Results from the present study suggest that increases in resting RSA over time may be associated with less emotional reactivity in adolescence.

The association between individual differences in resting RSA at age 9 and the use of expressive suppression as a regulatory strategy on the ERQ-CA furthers illustrates how deficits in physiological regulation may impact later flexible behavioral responding to the environment. As stated previously, expressive suppression is a regulatory strategy that has been linked with concurrent or later psychopathology. Individuals who rely on expressive suppression typically experience and express less emotionality broadly including positive emotions than those……. (John & Gross, 2004). Low resting RSA has been found to be associated with psychopathology and worse emotion regulation. This association may be due to the limited capacity an individual with low resting RSA has in their ability to flexibly change their RSA levels as they navigate through safe and stressful situations in day-to-day life. Children with lower resting RSA inherently have less flexibility in their ability to physiologically respond to everyday events than children with high resting RSA. Children with low resting RSA reach the "ceiling" of their RSA levels much sooner as a result. This may mean that children with low resting RSA may spend more time in a fight-or-flight (e.g., stress responses) system when confronted with typical emotional experiences than children with higher resting RSA. A potentially adaptive way of managing those strong emotions, in light of a suboptimal physiological response, may be to suppress feelings and thoughts to function in different environments. However, if this link holds true, it suggests that children are possibly blunted in both their physiological and behavioral responding to emotional stimuli, either negative or positive.

The potential link between low resting RSA in middle childhood and suboptimal emotion regulation in adolescence is further supported by the finding that emotion reactivity significantly predicted expressive suppression. Children who self-reported experiencing greater emotional reactivity at age 13 also reported using more suppression strategies at 14. Although change in RSA was not found to significantly predict expressive suppression, it is possible that the association between change in RSA and suppression may be mediated by emotion reactivity. It could be posited that children with less change in RSA from middle childhood to adolescence who report more emotional reactivity will also report using more expressive suppression at age 14.

The transitional period from middle childhood to adolescence is often fraught with intense emotions, hormonal changes, and increasing regulatory demands (Casey et al., 2010; Zeman et al., 2006). Further, the increased demand for autonomy, navigation of peer relationships, and heightened awareness of consequences associated with emotional expression often impact the ways in which children regulate and express their emotions (Fuchs & Thelen, 1988; Zeman & Shipman, 1997). Given the mounting demands on emotional systems during middle childhood and adolescence, suboptimal physiological development paired with increased reactivity and inefficient emotion regulation may confer risk for later psychopathology. Thus, it may be important to consider both the short- and long-term implications of suboptimal physiological regulation development on adjustment during later developmental transitions from child- to adulthood (e.g., starting high school, joining the workforce, navigating romantic relationships, parenting).

Unexpectedly, early experiences of child maltreatment did not predict resting RSA at age 9, change in RSA, emotion reactivity, or regulation. This was surprising given the extensive literature on the effects of early maltreatment on the development of biological and psychological systems that typically confers risk for later difficulties with emotional and physiological regulation (Cicchetti, 1996; Cook et al., 2012; Gruhn & Compas, 2020; Hibel et al., 2019; Rogosch et al., 1995; Skowron et al., 2014). However, given that there was significant unexplained variability in the present study's model, it is possible that individual differences in maltreatment may better explain the associations between early maltreatment and physiological development. For example, experiences of abuse and neglect may confer differential risk for developmental trajectories of resting RSA. Certainly, literature on the type and timing of adversity extensively supports a differential effect of abuse, compared to neglect, on other areas of functioning that are associated with later psychopathology (Lambert et al., 2016; Milojevich et al., 2020; Milojevich et al., 2019; Sheridan & McLaughlin, 2014). Additionally, prior work suggests that physiological systems, such as the PNS, are established in infancy and early childhood (De Rogalski Landrot et al., 2007; Patriquin et al., 2013; 2014). Thus, timing of the type of maltreatment may be necessary to include in future work to better examine the effect. It is possible that other early adversity, such as poverty, substance use exposure, and peripartum mental health, may play a more critical role on the development. For example, research examining fetal heart rate has potentially indicated that prenatal experiences in the first trimester, through the development of the central nervous system, may play a critical role on emerging PNS functioning (Cerritelli et al., 2021). Therefore, teasing apart the unique effect of type and timing of early adversity on physiological functioning, starting as early as in-utero exposures in the first trimester, may provide us with greater insight on how early experiences shape life-long physiological and behavioral regulation.

4.1 Strengths and Limitations

The present study benefits from several strengths. First, the literature on the developmental trajectories of RSA, and physiological regulation more broadly, is scarce. The present study uses a longitudinal study design to examine both developmental trajectories and the implications associated with resting RSA development. Second, group- and individual-level analyses were conducted to examine unique factors that may be related to both group- and individual-level differences in physiological and emotional functioning. Finally, findings from the current study have significant research and clinical implications. Participants from this study come from backgrounds that are historically under-researched. Thus, these findings may be of interest to scientists seeking to increase the inclusivity and generalizability of developmental psychobiological research.

Findings from the present study should also be interpreted with several limitations in mind. While the present study does include a large sample size, many participants had missing data from multiple time points, including participants who only had completed outcome measures and had no physiological data. While maximum likelihood estimation is the preferred method for estimating parameters in structural equation modeling when missing data is present (Allison, 2003), maximum likelihood estimates can be biased for smaller samples ($N<200$) (Jackson, 2001). Further, while previous research supports the use of estimation or imputation of missing physiological data (Moore et al., 2009; Sulik et al., 2015), these results should be interpreted in the context of parameter estimation of both self-report and physiological data. Additionally, the present study only examined the associations between change in RSA and self-reported outcomes of emotional reactivity and regulation. Self-report measures are limited given potential biases of the reporter which may lead to over- or under-reporting. Moreover, the ERQ-CA measures independent uses of cognitive reappraisal and expressive suppression as independent regulatory strategies when processes of emotion regulation are understood to be more dynamic. Research supports the flexible use of reappraisal and suppression as being more optimal as use of multiple regulatory strategies supports a context-dependent response (Aldao et al., 2015; Bonnano & Burton, 2013; Bonnano et al., 2004). For example, there may be stressful situations where suppression of emotion is more effective and appropriate than reappraising the event. Future research should consider using a more dynamic measure of emotion regulation strategy use to better understand how and when CR and ES are being used. Finally, behavioral measures of emotional reactivity and regulation may provide better insight into how adolescents react and regulate under stress. Behavioral measures may better indicate current functioning over self-reported data.

4.2 Conclusion

The present study adds to the developmental psychobiology literature by examining longitudinal changes in resting RSA during childhood and the effects on adolescent emotional reactivity and regulation. The present study found individual differences in the developmental trajectories of RSA from middle childhood to adolescence, regardless of child maltreatment history. These individual differences in RSA change were predictive of emotional reactivity at age 13 and resting RSA at age 9 was predictive of expressive suppression at age 14. History of child maltreatment was only marginally predictive of change in resting RSA. In summary, we found support for examining individual differences in physiological regulation development during a period of childhood marked by heightened emotionality and increased demands on regulatory systems. Future research should consider examining type and timing of early adversity and behavioral measures of emotion reactivity and regulation to better understand the development of resting RSA and later implications on functioning.

REFERENCES

Aldao, A., Sheppes, G., & Gross, J. J. (2015). Emotion Regulation Flexibility. *Cognitive Therapy and Research*, *39*(3), 263–278. https://doi.org/10.1007/s10608-014-9662-4

Alkon, A., Goldstein, L. H., Smider, N., Essex, M. J., Kupfer, D. J., & Boyce, W. T. (2003). Developmental and contextual influences on autonomic reactivity in young children. *Developmental Psychobiology*, *42*(1), 64–78. https://doi.org/10.1002/dev.10082

Allison, P. D. (2003). Missing data techniques for structural equation modeling. *Journal of Abnormal Psychology, 112*(4), 545–557. https://doi.org/10.1037/0021-843X.112.4.545

Bar-Haim, Y., Marshall, P. J., & Fox, N. A. (2000). Developmental changes in heart period and high-frequency heart period variability from 4 months to 4 years of age. *Developmental Psychobiology*, *37*(1), 44–56. https://doi.org/10.1002/1098-2302(200007)37:1<44::AID-DEV6>3.0.CO;2-7

Beauchaine, T. P. (2015a). Respiratory Sinus Arrhythmia: A Transdiagnostic Biomarker of Emotion Dysregulation and Psychopathology. *Current Opinion in Psychology*, *3*, 43–47. https://doi.org/10.1016/j.copsyc.2015.01.017

Beauchaine, T. P. (2015b). Future Directions in Emotion Dysregulation and Youth Psychopathology. *Journal of Clinical Child & Adolescent Psychology*, *44*(5), 875–896. https://doi.org/10.1080/15374416.2015.1038827

Beauchaine, T. P., Gatzke-Kopp, L., & Mead, H. K. (2007). Polyvagal Theory and developmental psychopathology: Emotion dysregulation and conduct problems from preschool to adolescence. *Biological Psychology*, *74*(2), 174–184. https://doi.org/10.1016/j.biopsycho.2005.08.008

Beauchaine, T. P., & Thayer, J. F. (2015). Heart rate variability as a transdiagnostic biomarker of psychopathology. *International Journal of Psychophysiology*, *98*(2, Part 2), 338–350. https://doi.org/10.1016/j.ijpsycho.2015.08.004

Becerra, R., & Campitelli, G. (n.d.). *Emotional Reactivity: Critical Analysis and Proposal of a New Scale*. 9.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993). Respiratory sinus arrhythmia: Autonomic origins, physiological mechanisms, and psychophysiological implications. *Psychophysiology*, *30*(2), 183–196. https://doi.org/10.1111/j.1469-8986.1993.tb01731.x

Bonanno, G. A., & Burton, C. L. (2013). Regulatory flexibility: An individual differences perspective on coping and emotion regulation. *Perspectives on Psychological Science*, *8*(6), 591–612. https://doi.org/10.1177/1745691613504116

Bonanno, G. A., Papa, A., Lalande, K., Westphal, M., & Coifman, K. (2004). The importance of being flexible: The ability to both enhance and suppress emotional expression predicts long-term adjustment. *Psychological Science, 15*(7), 482-487.

Bornstein, M. H., & Suess, P. E. (20000201). Child and mother cardiac vagal tone: Continuity, stability, and concordance across the first 5 years. *Developmental Psychology*, *36*(1), 54. https://doi.org/10.1037/0012-1649.36.1.54

Briere, J., & Elliott, D. M. (2003). Prevalence and psychological sequelae of self-reported childhood physical and sexual abuse in a general population sample of men and women. *Child Abuse & Neglect*, *27*(10), 1205–1222. https://doi.org/10.1016/j.chiabu.2003.09.008

Cacioppo, J. T., Uchino, B. N., & Berntson, G. G. (1994). Individual differences in the autonomic origins of heart rate reactivity: The psychometrics of respiratory sinus arrhythmia and preejection period. *Psychophysiology*, *31*(4), 412–419. https://doi.org/10.1111/j.1469-8986.1994.tb02449.x

Calkins, S. D., Dollar, J. M., & Wideman, L. (2019). Temperamental vulnerability to emotion dysregulation and risk for mental and physical health challenges. *Development and Psychopathology*, *31*(3), 957–970. https://doi.org/10.1017/S0954579419000415

Calkins, S. D., Graziano, P. A., & Keane, S. P. (2007). Cardiac vagal regulation differentiates among children at risk for behavior problems. *Biological Psychology*, *74*(2), 144–153. https://doi.org/10.1016/j.biopsycho.2006.09.005

Casey, B. J., Jones, R. M., Levita, L., Libby, V., Pattwell, S. S., Ruberry, E. J., Soliman, F., & Somerville, L. H. (2010). The storm and stress of adolescence: Insights from human imaging and mouse genetics. *Developmental Psychobiology*. https://doi.org/10.1002/dev.20447

Cerritelli, F., Frasch, M. G., Antonelli, M. C., Viglione, C., Vecchi, S., Chiera, M., & Manzotti, A. (2021). A review on the vagus nerve and autonomic nervous system during fetal development: Searching for critical windows. *Frontiers in Neuroscience*, *15*. https://www.frontiersin.org/articles/10.3389/fnins.2021.721605

Cicchetti, D. (1996). Child maltreatment: Implications for developmental theory and research. *Human Development*, *39*(1), 18–39. https://doi.org/10.1159/000278377

Cicchetti, D., & Rogosch, F. A. (2001). The impact of child maltreatment and psychopathology on neuroendocrine functioning. *Development and Psychopathology*, *13*(4), 783–804. https://doi.org/10.1017/S0954579401004035

Conradt, E., Measelle, J., & Ablow, J. C. (2013). Poverty, problem behavior, and promise: Differential susceptibility among infants reared in poverty. *Psychological Science*, *24*(3), 235–242. https://doi.org/10.1177/0956797612457381

Cook, E. C., Chaplin, T. M., Sinha, R., Tebes, J. K., & Mayes, L. C. (2012). The stress response and adolescents' adjustment: The impact of child maltreatment. *Journal of Youth and Adolescence*, *41*(8), 1067–1077. https://doi.org/10.1007/s10964-012-9746-y

De Rogalski Landrot, I., Roche, F., Pichot, V., Teyssier, G., Gaspoz, J.-M., Barthelemy, J.-C., & Patural, H. (2007). Autonomic nervous system activity in premature and full-term infants from theoretical term to 7 years. *Autonomic Neuroscience*, *136*(1–2), 105–109. https://doi.org/10.1016/j.autneu.2007.04.008

Dipietro, J. A., & Porges, S. W. (1991). Vagal responsiveness to gavage feeding as an index of preterm status. *Pediatric Research*, *29*(3), 231–236. https://doi.org/10.1203/00006450-199103000-00003

Dollar, J. M., Calkins, S. D., Berry, N. T., Perry, N. B., Keane, S. P., Shanahan, L., & Wideman, L. (20200130). Developmental patterns of respiratory sinus arrhythmia from toddlerhood to adolescence. *Developmental Psychology*, *56*(4), 783. https://doi.org/10.1037/dev0000894

Eisenberg, N., Fabes, R. A., Shepard, S. A., Guthrie, I. K., Murphy, B. C., & Reiser, M. (1999). Parental reactions to children's negative emotions: Longitudinal relations to quality of children's social functioning. *Child Development*, *70*(2), 513–534. https://doi.org/10.1111/1467-8624.00037

Elkind, D., & Bowen, R. (19790101). Imaginary audience behavior in children and adolescents. *Developmental Psychology*, *15*(1), 38. https://doi.org/10.1037/0012-1649.15.1.38

El-Sheikh, M. (2005). Stability of respiratory sinus arrhythmia in children and young adolescents: A longitudinal examination. *Developmental Psychobiology*, *46*(1), 66–74. https://doi.org/10.1002/dev.20036

El-Sheikh, M., & Erath, S. A. (2011). Family conflict, autonomic nervous system functioning, and child adaptation: State of the science and future directions. *Development and Psychopathology*, *23*(2), 703–721. https://doi.org/10.1017/S0954579411000034

Fuchs, D., & Thelen, M. H. (1988). Children's expected interpersonal consequences of communicating their affective state and reported likelihood of expression. *Child Development*, *59*(5), 1314–1322. https://doi.org/10.2307/1130494

Grossman, P., & Taylor, E. W. (2007). Toward understanding respiratory sinus arrhythmia: Relations to cardiac vagal tone, evolution and biobehavioral functions. *Biological Psychology*, *74*(2), 263–285. https://doi.org/10.1016/j.biopsycho.2005.11.014

Gruhn, M. A., & Compas, B. E. (2020). Effects of maltreatment on coping and emotion regulation in childhood and adolescence: A meta-analytic review. *Child Abuse & Neglect*, *103*, 104446. https://doi.org/10.1016/j.chiabu.2020.104446

Gullone, E., & Taffe, J. (2012). The emotion regulation questionnaire for children and adolescents (ERQ–CA): A psychometric evaluation. *Psychological Assessment*, *24*(2), 409–417. https://doi.org/10.1037/a0025777

Gunnar, M. R., Porter, F. L., Wolf, C. M., Rigatuso, J., & Larson, M. C. (1995). Neonatal stress reactivity: Predictions to later emotional temperament. *Child Development*, *66*(1), 1–13. https://doi.org/10.1111/j.1467-8624.1995.tb00851.x

Hibel, L. C., Mercado, E., & Valentino, K. (2019). Child maltreatment and mother–child transmission of stress physiology. *Child Maltreatment*, *24*(4), 340–352. https://doi.org/10.1177/1077559519826295

Jackson, D. L. (2001). Sample size and number of parameter estimates in maximum likelihood confirmatory factor analysis: A Monte Carlo investigation. *Structural Equation Modeling*, *8*, 205–223.

John, O. P., & Gross, J. J. (2004). Healthy and unhealthy emotion regulation: Personality processes, individual differences, and life span development. *Journal of Personality*, *72*(6), 1301–1334. https://doi.org/10.1111/j.1467-6494.2004.00298.x

Lambert, H. K., King, K. M., Monahan, K. C., & McLaughlin, K. A. (2017). Differential associations of threat and deprivation with emotion regulation and cognitive control in adolescence. *Development and Psychopathology*, *29*(3), 929–940. https://doi.org/10.1017/S0954579416000584

Marshall, P. J., & Stevenson-Hinde, J. (1998). Behavioral inhibition, heart period, and respiratory sinus arrhythmia in young children. *Developmental Psychobiology*, *33*(3), 283–292. https://doi.org/10.1002/(SICI)1098-2302(199811)33:3<283::AID-DEV8>3.0.CO;2-N

McLaughlin, K. A., Alves, S., & Sheridan, M. A. (2014). Vagal regulation and internalizing psychopathology among adolescents exposed to childhood adversity: Vagal regulation and stress vulnerability. *Developmental Psychobiology*, *56*(5), 1036–1051. https://doi.org/10.1002/dev.21187

Milojevich, H. M., Machlin, L., & Sheridan, M. A. (2020). Early adversity and children's emotion regulation: Differential roles of parent emotion regulation and adversity exposure. *Development and Psychopathology*, *32*(5), 1788–1798. https://doi.org/10.1017/S0954579420001273

Milojevich, H. M., Norwalk, K. E., & Sheridan, M. A. (2019). Deprivation and threat, emotion dysregulation, and psychopathology: Concurrent and longitudinal associations. *Development and Psychopathology*, *31*(3), 847–857. https://doi.org/10.1017/S0954579419000294

Moore, L., Hanley, J. A., Lavoie, A., & Turgeon, A. (2009). Evaluating the validity of multiple imputation for missing physiological data in the national trauma data bank. *Journal of Emergencies, Trauma and Shock*, *2*(2), 73–79. https://doi.org/10.4103/0974-2700.44774

Nock, M. K., Wedig, M. M., Holmberg, E. B., & Hooley, J. M. (2008). The emotion reactivity scale: Development, evaluation, and relation to self-injurious thoughts and behaviors. *Behavior Therapy*, *39*(2), 107–116. https://doi.org/10.1016/j.beth.2007.05.005

Patriquin, M. A., Lorenzi, J., Scarpa, A., & Bell, M. A. (2014). Developmental trajectories of respiratory sinus arrhythmia: Associations with social responsiveness. *Developmental Psychobiology*, *56*(3), 317–326. https://doi.org/10.1002/dev.21100

Patriquin, M. A., Scarpa, A., Friedman, B. H., & Porges, S. W. (2013). Respiratory sinus arrhythmia: A marker for positive social functioning and receptive language skills in children with autism spectrum disorders. *Developmental Psychobiology*, *55*(2), 101–112. https://doi.org/10.1002/dev.21002

Porges, S. W., Doussard-Roosevelt, J. A., Lourdes Portales, A., & Suess, P. E. (1994). Cardiac vagal tone: Stability and relation to difficultness in infants and 3-year-Olds. *Developmental Psychobiology*, *27*(5), 289–300. https://doi.org/10.1002/dev.420270504

Porges, S. W. (1995). Cardiac vagal tone: A physiological index of stress. *Neuroscience & Biobehavioral Reviews*, *19*(2), 225–233. https://doi.org/10.1016/0149-7634(94)00066-A

Porges, S. W. (1996). Physiological regulation in high-risk infants: A model for assessment and potential intervention. *Development and Psychopathology, 8*(1), 43-58.

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology*, *74*(2), 116–143. https://doi.org/10.1016/j.biopsycho.2006.06.009

Porges, S. W. (2011). *The polyvagal theory: Neurophysiological foundations of emotions, attachment, communication, and self-regulation (Norton Series on Interpersonal Neurobiology)*. WW Norton & Company.

Rogosch, F. A., Cicchetti, D., & Aber, J. L. (1995). The role of child maltreatment in early deviations in cognitive and affective processing abilities and later peer relationship problems. *Development and Psychopathology*, *7*(4), 591–609. https://doi.org/10.1017/S0954579400006738

Salomon, K. (2005). Respiratory sinus arrhythmia during stress predicts resting respiratory sinus arrhythmia 3 years later in a pediatric sample. *Health Psychology*, *24*(1), 68. https://doi.org/10.1037/0278-6133.24.1.68

Shader, T. M., Gatzke-Kopp, L. M., Crowell, S. E., Jamila Reid, M., Thayer, J. F., Vasey, M. W., Webster-Stratton, C., Bell, Z., & Beauchaine, T. P. (2018). Quantifying respiratory sinus arrhythmia: Effects of misspecifying breathing frequencies across development. *Development and Psychopathology*, *30*(1), 351–366. https://doi.org/10.1017/S0954579417000669

Sheridan, M. A., & McLaughlin, K. A. (2014). Dimensions of early experience and neural development: Deprivation and threat. *Trends in Cognitive Sciences*, *18*(11), 580–585. https://doi.org/10.1016/j.tics.2014.09.001

Skowron, E. A., Cipriano-Essel, E., Gatzke-Kopp, L. M., Teti, D. M., & Ammerman, R. T. (2014). Early adversity, RSA, and inhibitory control: Evidence of children's neurobiological sensitivity to social context. *Developmental Psychobiology*, *56*(5), 964–978. https://doi.org/10.1002/dev.21175

Springer, K. W., Sheridan, J., Kuo, D., & Carnes, M. (2007). Long-term physical and mental health consequences of childhood physical abuse: Results from a large population-based sample of men and women. *Child Abuse & Neglect*, *31*(5), 517–530. https://doi.org/10.1016/j.chiabu.2007.01.003

Sroufe, L. A., & Rutter, M. (1984). The domain of developmental psychopathology. *Child Development*, *55*(1), 17–29. https://doi.org/10.2307/1129832

Sroufe, L. A., & Fleeson, J. (1986). Attachment and the construction of relationships. In W. W. Hartup & Z. Rubin (Eds.), *Relationships and Development*. (pp. 51-71). Hillsdale, NJ: Erlbaum.

Sturge-Apple, M. L., Suor, J. H., Davies, P. T., Cicchetti, D., Skibo, M. A., & Rogosch, F. A. (2016). Vagal tone and children's delay of gratification: Differential sensitivity in resource-poor and resource-rich environments.

Psychological Science, *27*(6), 885–893. https://doi.org/10.1177/0956797616640269

Sulik, M. J., Eisenberg, N., Spinrad, T. L., & Silva, K. M. (2015). Associations between respiratory sinus arrhythmia (RSA) reactivity and effortful control in preschool-age children. *Developmental Psychobiology*, *57*(5), 596–606. https://doi.org/10.1002/dev.21315

Thayer, J. F., Hansen, A. L., Saus-Rose, E., & Johnsen, B. H. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine*, *37*(2), 141–153. https://doi.org/10.1007/s12160-009-9101-z

Zeman, J., Cassano, M., Perry-Parrish, C., & Stegall, S. (2006). Emotion regulation in children and adolescents. *Journal of Developmental & Behavioral Pediatrics*, *27*(2), 155–168.

Zeman, J., & Shipman, K. (19980201). Social-contextual influences on expectancies for managing anger and sadness: The transition from middle childhood to adolescence. *Developmental Psychology*, *33*(6), 917. https://doi.org/10.1037/0012-1649.33.6.917

APPENDIX A

IRB/HUMAN SUBJECTS APPROVAL: MIDDLE CHILDHOOD FOLLOW-UP

UNIVERSITY OF DELAWARE

Institutional Review Board
210H Hullihen Hall
Newark, DE 19716
Phone: 302-831-2137
Fax: 302-831-2828

DATE:	February 10, 2023
TO:	Mary Dozier, PhD
FROM:	University of Delaware IRB
STUDY TITLE:	[547621-25] Intervening Early with Neglected Children: Key Middle Childhood Outcomes
SUBMISSION TYPE:	Continuing Review/Progress Report
ACTION:	Approved for Data Analysis Only
APPROVAL DATE:	February 10, 2023
EXPIRATION DATE:	February 14, 2024
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # *(8)*

Thank you for your Continuing Review/Progress Report submission to the University of Delaware Institutional Review Board (UD IRB). The UD IRB has reviewed and APPROVED the proposed research and submitted documents via Expedited Review in compliance with the pertinent federal regulations.

As the Principal Investigator for this study, you are responsible for and agree that:

- All research must be conducted in accordance with the protocol and all other study forms as approved in this submission. Any revisions to the approved study procedures or documents must be reviewed and approved by the IRB prior to their implementation. Please use the UD amendment form to request the review of any changes to approved study procedures or documents.
- Informed consent is a process that must allow prospective participants sufficient opportunity to discuss and consider whether to participate. IRB-approved and stamped consent documents must be used when enrolling participants and a written copy shall be given to the person signing the informed consent form.
- Unanticipated problems, serious adverse events involving risk to participants, and all non-compliance issues must be reported to this office in a timely fashion according with the UD requirements for reportable events. All sponsor reporting requirements must also be followed.

Oversight of this study by the UD IRB REQUIRES the submission of a CONTINUING REVIEW seeking the renewal of this IRB approval, which will expire on February 14, 2024. A continuing review/progress report form and up-to-date copies of the protocol form and all other approved study materials must be submitted to the UD IRB at least 45 days prior to the expiration date to allow for the required IRB review of that report.

If you have any questions, please contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu. Please include the study title and reference number in all correspondence with this office.

INSTITUTIONAL REVIEW BOARD

APPENDIX B

IRB/HUMAN SUBJECTS APPROVAL: ADOLESCENT FOLLOW-UP

UNIVERSITY OF DELAWARE

Institutional Review Board
210H Hullihen Hall
Newark, DE 19716
Phone: 302-831-2137
Fax: 302-831-2828

DATE:	April 26, 2021
TO:	Mary Dozier, PhD
FROM:	University of Delaware IRB
STUDY TITLE:	[1437200-12] Intervening Early: Key Behavioral and Neurobiological Outcomes in Adolescence
SUBMISSION TYPE:	Continuing Review/Progress Report
ACTION:	APPROVED
APPROVAL DATE:	April 26, 2021
EXPIRATION DATE:	May 14, 2022
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # *(9)*

Thank you for your Continuing Review/Progress Report submission to the University of Delaware Institutional Review Board (UD IRB). The UD IRB has reviewed and APPROVED the proposed research and submitted documents via Expedited Review in compliance with the pertinent federal regulations.

As the Principal Investigator for this study, you are responsible for and agree that:

- All research must be conducted in accordance with the protocol and all other study forms as approved in this submission. Any revisions to the approved study procedures or documents must be reviewed and approved by the IRB prior to their implementation. Please use the UD amendment form to request the review of any changes to approved study procedures or documents.
- Informed consent is a process that must allow prospective participants sufficient opportunity to discuss and consider whether to participate. IRB-approved and stamped consent documents must be used when enrolling participants and a written copy shall be given to the person signing the informed consent form.
- Unanticipated problems, serious adverse events involving risk to participants, and all non-compliance issues must be reported to this office in a timely fashion according with the UD requirements for reportable events. All sponsor reporting requirements must also be followed.

Oversight of this study by the UD IRB REQUIRES the submission of a CONTINUING REVIEW seeking the renewal of this IRB approval, which will expire on May 14, 2022. A continuing review/progress report form and up-to-date copies of the protocol form and all other approved study materials must be submitted to the UD IRB at least 45 days prior to the expiration date to allow for the required IRB review of that report.

If you have any questions, please contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu. Please include the study title and reference number in all correspondence with this office.