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# Respiratory sinus arrhythmia and heart period in infancy as correlates of later oppositional defiant and callous-unemotional behaviors

**Nicholas J. Wagner**,
The University of North Carolina at Chapel Hill

**W. Roger Mills-Koonce**,
The University of North Carolina at Greensboro

**Michael T. Willoughby**,
Research Triangle Institute

**Cathi B. Propper**,
Center for Developmental Science

**Peter D. Rehder**, and
The University of North Carolina at Greensboro

**Noa Gueron-Sela**
Center for Developmental Science

## Abstract

Extant literature suggests that oppositional defiant (ODD) and callous-unemotional (CU) behaviors in childhood and adolescence are associated with distinct patterns of psychophysiological functioning and that individual differences in these patterns have implications for developmental pathways to disorder. Very little is known about the associations between psychophysiological functioning in infancy and later ODD and CU behaviors. This study examined associations between basal autonomic nervous system (ANS) functioning in infancy and ODD and CU behaviors in later childhood. Using longitudinal heart period (HP) and respiratory sinus arrhythmia (RSA) data from the Durham Child Health and Development Study (N = 206), the current study tested associations, within a structural equation modeling framework, between continuous measures of HP and RSA across the first two years of life and later ODD and CU behaviors at first grade. Results indicate that ODD and CU behaviors in childhood are associated with lower baseline RSA, but not HP, across infancy. The implications of these findings for developmental models of ODD and CU behaviors are discussed.

### Keywords

Oppositional Defiant Disorder; Callous-unemotional behaviors; Respiratory Sinus Arrhythmia; Heart Period

Evidence suggests that callous-unemotional (CU) behaviors, considered to be a downward extension of specific components of adult psychopathy, provide unique insight into disruptive behavior problems in childhood (Frick, Ray, Thornton, & Kahn, 2014a; Wagner, Mills-Koonce, Willoughby, Zvara, & Cox, 2015; Willoughby, Mills-Koonce, Gottfredson, & Wagner, 2014). Often exhibited in the presence of oppositional defiant (ODD) behaviors, CU behaviors describe non-normative emotional, affective, and cognitive deficits—such as a lack of guilt, empathy, and fear, as well as an over-focus on reward and insensitivity to punishment (Blair, Peschardt, Budhani, Mitchell, & Pine, 2006; Dadds, Fraser, Frost, & Hawes, 2005; Frick & White, 2008; Kotler & McMahon, 2005)—and typically denote greater risk for later antisocial behavior and psychopathy (Lynam, Caspi, Moffitt, Loeber, & Stouthamer-Loeber, 2007; Rowe, Costello, Angold, Copeland, & Maughan, 2010). Research with older children and adolescents suggests that CU behaviors are associated with distinct psychophysiological profiles characterized by reduced baseline functioning and blunted physiological responses to stressors (see Frick et al., 2014a for review). Although work investigating the early physiological correlates of later externalizing behavior problems is growing (Beauchaine, 2001; Patriquin, Lorenzi, Scarpa, Calkins, & Bell, 2015), little is known about the early physiological correlates of later CU behaviors. The current study examined associations between baseline respiratory sinus arrhythmia (RSA) and heart period (HP) during infancy and ODD and CU behaviors when children were in first grade.

Early autonomic functioning plays an important role in the emergence of children’s self-regulatory capacities (Calkins & Marcovitch, 2010). Theoretical work and extant research suggest that the ability to maintain homeostasis by shifting attention from internal processes to external demands, a process fundamental to emotional and behavioral adaptation (Calkins, Propper, & Mills-Koonce, 2013), relies heavily on autonomic nervous system (ANS) functioning (Porges, 2007). Heart rate (HR) or heart period (HP; inverse of heart rate) are considered broad measures of ANS functioning that reflect both parasympathetic and sympathetic functioning (Dietrich et al., 2007; Stevenson-Hinde & Marshall, 1999; Wagner, Propper, Gueron-Sela, & Mills-Koonce, 2015). There is some evidence that increased baseline HR in middle childhood, marking heightened autonomic functioning, is associated with higher levels of internalizing behavior problems (Dietrich et al., 2007; Monk et al., 2001), and low baseline HR is associated with externalizing problems (Dietrich et al., 2007; Ortiz & Raine, 2004). Although measures of HP may lack specificity given the combined PNS and SNS influences, they provide broad measures of psychophysiological functioning and therefore have some utility in research that investigates the relationship between autonomic activity and subsequent behavior.

Respiratory sinus arrhythmia (i.e., the variability in heart rate that occurs at the frequency of breathing) is commonly used to index parasympathetic influence on heart rate variability via the vagus nerve (Porges, 2007). High baseline RSA represents greater myelinated vagal control of the heart, which enables individuals to adapt in the face of a challenge (Calkins et al., 2013; Porges, 1992). Conversely, low baseline RSA indicates reduced myelinated vagal control that may interfere with the ability to regulate behavioral and emotional state (Porges, 2007). Baseline RSA is a correlate of physiological and behavioral adaptation (Porges, Doussard-Roosevelt, Portales, & Suess, 1994; El-Sheikh, 2005; Sulik, Eisenberg, Silva, Spinrad, & Kupfer, 2013) and high levels of baseline RSA are generally associated with positive psychosocial outcomes. For example, a recent prospective study found associations between high baseline RSA in infancy and attenuated stress response, more organized sleep, and better cognitive control at a ten year follow-up (Feldman, Rosenthal, & Eidelman, 2014). Additionally, high baseline RSA is related to efficient emotion regulation (Beauchaine, 2001; El-Sheikh, 2005; Scarpa, Haden, & Tanaka, 2010), greater cognitive abilities (Blair, 2003; Morgan, Aikins, Steffian, Coric, & Southwick, 2007; Watson, Baranek, Roberts, David, & Perryman, 2010), positive social interactions (Patriquin, Lorenzi, Scarpa, & Bell, 2014), and fewer internalizing problems (Neuhaus, Bernier, & Beauchaine, 2014). Low baseline RSA, on the other hand, has been linked to hostility, anxiety disorders, and aggression (see Beauchaine, 2001 for review).

Limited research on the associations between autonomic functioning and CU behaviors and ODD during later childhood and adolescence suggests that these behaviors are associated with low baseline psychophysiological functioning (Stadler et al., 2008), including low HR (Anastassiou-Hadjicharalambous & Warden, 2008; Dietrich et al., 2007; Raine, 2002; Frick, Ray, Thornton, & Kahn, 2014b), implying that children and adolescents demonstrating high levels of ODD and CU behaviors may exhibit autonomic under-arousal. Provocative etiological models for CU behaviors have drawn from the aforementioned research to posit that low fear and physiological under-arousal early in life may undermine parental socialization efforts (Frick & Morris, 2004) and disrupt processes through which arousal functions to inhibit deviant behavior (Frick et al., 2014b). Specific to parasympathetic functioning, a recent study on adolescents with disruptive behavior problems indicated that the sub-group of children with high CU behaviors had lower basal levels of RSA compared to children without behavior problems (De Wied, van Boxtel, Matthys, & Meeus, 2012), suggesting that these children may have a reduced capacity to organize physiological resources to deal with environmental challenge.

Research on the early psychophysiological correlates of later behavioral problems and CU behaviors is less well established. This is partly due to the fact that few studies have both prospective psychophysiological data from infancy and a sample of children large enough to include adequate numbers with clinically relevant levels of ODD and CU behaviors in later childhood. Important exceptions include recent work by Willoughby and colleagues (2011) and Mills-Koonce and colleagues (2015). Using independent samples, each of these studies of infants who later demonstrated clinically relevant levels of ODD and CU behaviors reported findings suggesting associations between CP and CU outcomes and low baseline RSA and HP. Using a clinically-informed grouping approach from the current sample, Willoughby and colleagues (2011) found that infants high on both ODD and CU behaviors at 36 months demonstrated heightened autonomic functioning (low HP) during baseline and an aversive social interaction at 3 and 6 months. Similarly, in a separate sample Mills-Koonce and colleagues (2015) found that 1$^{st}$ grade children showing high levels of conduct problems and CU behaviors had higher levels of autonomic functioning (low baseline HP) and lower parasympathetic functioning (low RSA) at 15 months of age compared to children with low levels of conduct problems and CU behaviors.

Both studies examined the associations between psychophysiological functioning in the first year of life and later ODD and CU behaviors using a clinically informed grouping strategy. Although informed by this work, the current study provides a novel extension of these findings by examining the extent to which RSA and HP functioning, measured across multiple time points in the first two years of life, predict continuous measures of later ODD and CU behaviors in a structural equation modeling framework. It is likely that subclinical levels of callous-unemotional behaviors overlap considerably with normative characteristics such as empathic responding, guilt, and conscience (Frick & White, 2008; Knafo, Zahn-Waxler, Van Hulle, Robinson, & Rhee, 2008; Kochanska, 1997). Because of this overlap, and because elevated but subclinical levels of CU behavior pose a risk for child development, much can be gained from studying predictors of variability in continuous measures of these outcomes in a community sample.

## Current Study

The current study assesses the associations between infants autonomic functioning, measured five times in the first two years of life, and continuous measures of ODD and CU behaviors in first grade. Very few studies have examined the associations between psychophysiological functioning in infancy and later ODD and CU behaviors, and no study has done so using multiple measures of psychophysiological functioning across infancy. As such, prior to addressing the primary research aims, the extent to which there is individual variability in growth of HP and RSA across the first two years of life was assessed using a latent curve modeling (LCM; Bollen & Curran, 2005) approach, which is subsumed within a broad structural equation modeling framework (SEM; Bollen, 1989) and allows us to examine associations between individual differences in change over time and later ODD and CU outcomes, if such individual variability in growth is evident. Next, the primary goal of this study was to examine the associations between baseline RSA and HP from 3 to 24 months of age and continuous measures of ODD and CU behaviors in first grade using an SEM approach. Given existing findings, we expected that baseline HP and RSA in early life would be negatively associated with ODD and CU behaviors in first grade.

## Methods

### Participants

The Durham Child Health and Development Study (DCHDS) is a longitudinal study consisting of 206 families whose children were recruited at 3 months of age. The study included only infants who were healthy, full-term, and born without significant complications. Participants were recruited from a primarily urban population living in North Carolina, such that there were equal numbers of African American and European American families, as well as both high- and low-income households. The sample was 57% African American and 43% European American, and approximately 53% of families were low income (below 200% of the poverty level). The current analyses examine physiological and questionnaire data from home visits that occurred when the infants were 3, 6, 12, 18, 24 months, and in first grade. The goals of the current study were addressed using the full sample.

### Measures

**ODD and CU Behaviors—**First grade measures of children's ODD behaviors were derived from the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach

& Rescorla, 2004), which was completed by maternal caregivers during a lab visit. The Inventory of Callous Unemotional (ICU; Essau, Sasagawa, & Frick, 2006) traits was used to assess CU behaviors at first grade, providing partial consistency in measurement with the work by Mills-Koonce and colleagues (2015). The ICU was completed by maternal primary caregivers who responded to 24 items on a 4-point Likert scale ranging from 0 (not at all true) to 3 (definitely true). The items that comprise the ICU were developed from other highly established clinical assessments (e.g. APSD, PCL-YV) and include questions about the extent to which the child uses emotions, expresses feelings, cares about getting in trouble, seems cold and uncaring, and hurts others' feelings. The factor structure and predictive utility of the ICU has been confirmed with samples ranging in age from 13 to 20 years of age (see Essau et al., 2006; Fanti, Frick, & Georgiou, 2009; Roose, Bijttebier, Claes, & Lilienfeld, 2011) and with samples as young as age 3 years (see Ezpeleta, de la Osa, Granero, Penelo, & Domènech, 2013).

**Heart Period and Respiratory Sinus Arrhythmia—**As previously mentioned, HP is a measure of the average interbeat interval (IBI; the length of time between heart beats) and is used as an index of broad ANS functioning, whereas RSA is measured as the variation in IBIs linked to respiration and is used as a specific index of parasympathetic functioning of the ANS. The Mini Logger 2000 was used to collect IBIs (Mini Logger 2000; Mini-Mitter Corp., Bend, OR). Researchers placed two electrodes cross diagonally (i.e., from upper right to lower left) on the child's chest at the beginning of the 3, 6, 12, 18, and 24 month visits for a 2–4 minute measure of baseline cardiac function while at rest. Electrodes were connected to a preamplifier, which transmitted IBIs to a monitor. Porges' (U.S. Patent No. 4,510,944, 1985) method of calculating RSA and HP, in which a moving polynomial filter is used to remove frequencies lying outside a normal physiological range (0.24±1.04 Hz), was used, and the estimate of RSA is reported in units of $\ln(ms)^2$. The data files were transferred to a computer and were edited by two reliable researchers using MXEdit software. The two researchers were trained to reliability in MXEdit software (Delta Biometrics, Bethesda, MD), with Porges's Lab at the University of Maryland and edited the files by visually scanning the data for outlier points relative to adjacent data and replacing those points by dividing them or summing them so that they would be consistent with surrounding data. Consistent with previous work (Willoughby et al., 2011), only participants who had full and sufficient data with less than 10% editing were included in the final dataset. RSA and HP were calculated every 15 seconds for the baseline period using Porges's (1985) method. Larger values of HP indicate lower heart rate and larger values of RSA suggest greater vagal tone.

**Additional Covariates—***Child's sex* and *race* were collected at the time of recruitment and were determined by the mother or primary caregiver. Infant race and sex was determined by the mother or primary caregiver. *Family income-to-needs ratio* was determined using the mother's or primary caregiver's report of the total family yearly income at the first grade visit, the size of the family, and the 2003 federal poverty guidelines.

### Analytic Strategy

Prior to addressing the primary research aims, the extent to which there is individual variability in growth of HP and RSA across the first two years of life was assessed using an LCM approach. If such heterogeneity of growth exists, the LCM approach allows for it to be incorporated into subsequent structural models. Next, the primary goals of this study were addressed using a structural equation modeling (SEM; Mplus 5.2, Muthén & Muthén, 2007) approach to examine whether baseline RSA and HP levels in early childhood predict later ODD and CU behaviors in 1$^{st}$ grade. Model covariates included child's gender, family income-to-needs ratio at 1$^{st}$ grade, and child's race. Missing data were handled using the full information maximum likelihood methods (Enders & Bandalos, 2001). Overall model fit was determined using root mean square error of approximation (RMSEA), standardized room mean square residual (SRMR), and comparative fit index (CFI). Good fit was defined as CFI values ≥ 0.95, RMSEA values ≤ 0.06, and SRMR values ≤ 0.08 (Hu & Bentler, 1999).

## Results

### Demographics and Growth Models

Means, standard deviations, and correlations among variables of interest and model covariates are presented in Table 1. Measures of baseline RSA were typically characterized by significant positive correlations ($r$ = .362 – .639, $p$ < .05) across time points except for the correlation between 12 and 24 months ($r$ = .095, $p$ = .54). Measures of baseline HP were characterized by positive correlations across time points that were significant or approached significance ($r$ = .226 – .499, $p$ < .10). Exceptions include the correlation between 3 and 6 months ($r$ = .131, $p$ = .25), the correlation between 3 and 24 months ($r$ = .137, $p$ = .27), and the correlation between 6 and 24 months ($r$ = −.057, $p$ = .72). Children's sex was not significantly correlated with ODD ($r$ = −.059, $p$ = .52) or CU behaviors ($r$ = .047, $p$ = .60), but children's race was correlated with income ($r$ = −.336, $p$ < .01).

Prior to estimating the full structural model, unconditional latent growth curves were separately estimated for baseline HP and RSA to determine if separate latent variables for HP and for RSA would sufficiently represent early autonomic functioning. Growth curve analyses indicated there was not significant individual variability in the rates of change of baseline RSA or HP over the three time points used in the study ($\eta$ = 0.021, $p$ = 0.496 and $\eta$ = 41.33, $p$ = 0.139, respectively). Further, there was a non-significant covariance between the intercept and the linear slope components of growth for both RSA and HP, indicating that variability in mean levels of ANS functioning at 3 months were not related to variability in the rate of change. As such, separate latent factors of baseline RSA and HP from 3, 6, 12, 18, and 24 months seem to provide sufficient estimates of the early ANS functioning and are preferred to other analytic approaches (see Bollen, 2002). Kaiser-Meyer-Olkin and Bartlett's test of sphericity supported the factorability of baseline RSA and HP. For the measures of baseline RSA, the Kaiser-Meyer-Olkin measure of sampling adequacy was .75, above the recommended value of .6, and Bartlett's test of sphericity was significant ($X^2$ (10) = 33.12, $p$ < .01). For the measures of baseline HP, the Kaiser-Meyer-Olkin measure of sampling adequacy was .62 and Bartlett's test of sphericity was significant ($X^2$ (10) = 25.43, $p$ < .01).

### Structural Equation Model

Continuous measures of ODD and CU behavior in first grade were regressed on a latent factor of infant baseline RSA (derived form 3–24 months of age). Lower baseline RSA levels in infancy predicted higher levels of ODD ($\beta = -0.277$; $p < 0.05$) and CU ($\beta = -0.251$; $p < 0.05$) behaviors in first grade, controlling for race, gender, and family income at first grade. The standardized factor loadings for baseline RSA ranged from .50 to .87 and the final model provided good fit to the data: $X^2(26) = 24.86$, $p = 0.52$; CFI = 0.99; RMSEA = 0.001; SRMR = 0.059. Finally, continuous measures of ODD and CU behavior in first grade were regressed on a latent factor of infant baseline HP (derived form 3–24 months of age). These associations were not significant. Standardized coefficients and standard errors for the associations between predictors and outcomes for each model are presented in Table 2.

## Discussion

The findings of the current longitudinal study suggest that the early psychophysiological profiles of children who demonstrate high levels of ODD and CU behaviors may be characterized by low baseline levels of RSA in infancy. Associations between baseline HP and ODD and CU behaviors were not observed, suggesting that, in our sample, parasympathetic functioning in the first two years of life may be more predictive of later ODD and CU behaviors than a broad measure of ANS functioning. This aligns with findings showing that adolescents high on disruptive and CU behaviors show lower levels of resting RSA, but not HP, than adolescents who demonstrate only disruptive behaviors or neither disruptive nor CU behaviors (De Wied et al., 2012). With regard to infancy, Mills-Koonce and colleagues (2015) observed larger effects for RSA than for HP, which, taken together with the current findings, suggests that specific measures of parasympathetic functioning may be more informative than more broad measures of autonomic functioning for the development of later CU behaviors. These results extend a broader literature on the associations between PNS functioning and the development of disruptive behavioral disorders (Calkins et al., 2013) and ODD and CU behaviors, in particular (De Wied et al., 2012; Mills-Koonce et al., 2015), and advance the literature by demonstrating associations between baseline RSA measured multiple times in the first two years of life and continuous measures of later ODD and CU behaviors.

Findings from the current study speak to the importance of considering early baseline physiological functioning in the development of ODD and CU behaviors. Much of the work on the extent to which physiological functioning informs the development of emotion and behavioral regulation has focused on stress physiology (Blair & Raver, 2012) and stress reactivity (Quas et al., 2014). Although the investigation of physiological responses to stress undoubtedly informs etiological models of psychopathology, there is theoretical and empirical support for the utility of examining the associations between baseline physiological functioning and later behavioral problems. For example, it is likely that patterns of stress responses do not become integrated until after early developmental periods, suggesting that there is some benefit to restricting initial investigations to baseline measures (Quas et al., 2014). Further, investigations into baseline physiological functioning provide important insight into developmental processes because baseline levels are thought to constrain the magnitude of possible stress response (Cacioppo, Uchino, & Berntson, 1994) and the maintenance and development of baseline physiological functioning in early life is, itself, a dynamic process (Porges, 1992).

There is clear evidence that patterns of RSA inform key regulatory functions implicated in the development and maintenance of pathological behavior patterns (Beauchaine, 2001; Porges, 1996) and the current findings join a body of literature that suggests that the investigation of basal levels of parasympathetic functioning provides important insight into the development of ODD and CU in particular (De Wied, et al., 2012; Mills-Koonce et al., 2015; Willoughby et al., 2011). Vagal control of organs including the heart, larynx, and pharynx provides the parasympathetic branch of the ANS substantial control over socially-oriented behaviors such as facial gestures and vocalizations, and consequently contributes to the modulation of social and communicative behaviors (e.g., eye contact, vocal intonation, facial expression). Thus, whereas high vagal control (indicated by high RSA) facilitates sensitive, adaptive responses to social interactions, low vagal control (low RSA) may be associated with decreased sensitivity and responsivness to social cues that compromise spontaneous social behavior, social awareness, and affect expressivity (Porges 2001, 2003, 2007). Consequently, infants' parasympathetic functioning likely plays an important role in establishing mutually positive and responsive interactions with caregivers (Moore et al., 2009; Propper & Moore, 2006).

One possible interpretation of the current findings is that low parasymathetic functioning disrupts early social communciation and undermines normative socialization processes (Calkins & Keane, 2004; Calkins & Marcovitch, 2010; Mills-Koonce et al., 2015; Patriquin et al., 2015), setting the stage for the development of ODD and CU behaviors. Indeed, research findings with samples of older children have demonstrated associations between ODD and CU behaviors and behavioral phenotypes that may disrupt the caregiver–child relationship, including deficits in orienting towards caregivers (i.e., less eye contact and mutual orienting) and dysregulated responses to social stimuli (Blair, 1999; Colder, Mott, & Berman, 2002; Dadds, Jambrak, Pasalich, Hawes, & Brennan, 2011; Frick, Cornell, Bodin, Dane, Barry, & Loney, 2003; Frick & White, 2008; Loney, Lima, & Butler, 2006; Mills-Koonce et al., 2014; Willoughby et al., 2011). Early responsive and sensitive interactive behaviors in infancy and early childhood have implications for children's conscience development (e.g., Kochanska, 1997; Kochanska & Murray, 2000) and the development of moral emotion and empathy (Kochanska, Forman, Aksan, & Dunbar, 2005). Further, mutually responsive parent–child interactions have been shown to predict fewer behavior problems for youth high on CU behaviors (Kochanksa, Kim, Boldt, & Yoon, 2013). It is likely that future work that examines the associations between early caregiving experiences and autonomic functioning in the prediction of psychopathological outcomes, including ODD and CU behaviors, will be important, particularly considering research indicating that low levels of baseline RSA were associated with greater improvements in child disruptive behavior following a Parent–Child Interaction Therapy (PCIT) program (Bagner et al., 2012).

The strengths of the current study include a prospective longitudinal design, measures of RSA and HP collected at multiple times in early and late infancy, and measures of ODD and

CU behaviors collected in first grade. However, these findings should be considered in the context of several limitations. Given the available data, we were only able to investigate differences in baseline RSA and HP functioning. Studies that incorporate measures of both parasympathetic and sympathetic branches of the ANS and examine baseline, reactivity, and recovery of psychophysiological functioning are necessary to provide a more complete picture of how these systems interact to influence development (El-Sheikh, Keiley, Erath, & Dyer, 2013; Nederhof, Marceau, Shirtcliff, Hastings, & Oldehinkel, 2014). Additionally, although the use of a community sample may increase the generalizability of the findings, our ability examine differences in autonomic functioning between clinically relevant groups was hampered by low sample sizes. With those limitations in mind, the current study replicates a provocative finding regarding the early etiology of a complex and socially significant behavioral phenotype. Future research examining how these early psychophysiological profiles change over time, and how they interact with the caregiving environment (and intervention contexts), are important next steps in identifying the developmental processes underlying these behaviors, as well as informing prevention and treatment.

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**Table 1**

Bivariate Correlations Between Variables of Interest and Model Covariates

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Sex (0 = female) | – | | | | | | | | | | | | | | |
| 2. Race (0 = White) | −.082 | – | | | | | | | | | | | | | |
| 3. Household Income | .033 | −.336** | – | | | | | | | | | | | | |
| 4. Baseline Respiratory Sinus Arrhythmia 3m | .078 | −.017 | .010 | – | | | | | | | | | | | |
| 5. Baseline Respiratory Sinus Arrhythmia 6m | .019 | .134 | −.072 | .413** | – | | | | | | | | | | |
| 6. Baseline Respiratory Sinus Arrhythmia 12m | −.068 | .265** | −.278* | .362** | .639** | – | | | | | | | | | |
| 7. Baseline Respiratory Sinus Arrhythmia 18m | .001 | .283** | −.150 | .364** | .425** | .455** | – | | | | | | | | |
| 8. Baseline Respiratory Sinus Arrhythmia 24m | .126 | .267* | −.113 | .213^ | .365* | .095 | .452** | – | | | | | | | |
| 9. Baseline Heart Period 3m | .112 | −.119 | .243* | .609** | .265* | .125 | .106 | .153 | – | | | | | | |
| 10. Baseline Heart Period 6m | −.081 | .025 | .013 | .058 | .507** | .272^ | .019 | −.142 | .131 | – | | | | | |
| 11. Baseline Heart Period 12m | .025 | .208* | −.316* | .223* | .322* | .734** | .266* | .017 | .315** | .256^ | – | | | | |
| 12. Baseline Heart Period 18m | .148^ | .133 | −.024 | .193^ | .338** | .212^ | .404** | .311* | .294** | .226^ | .392** | – | | | |
| 13. Baseline Heart Period 24m | .174 | .229* | −.010 | .089 | .253 | .277^ | .321* | .382** | .137 | −.057 | .252^ | .499** | – | | |
| 14. Callous-Unemotional Behaviors | .047 | −.005 | −.147^ | −.158 | −.134 | −.120 | −.135 | −.114 | −.086 | .028 | −.109 | .037 | .150 | – | |
| 15. Oppositional Defiant Behaviors | −.059 | −.049 | −.130 | −.310** | −.035 | −.211^ | −.108 | −.055 | −.231* | .304* | −.092 | .111 | −.082 | .356** | – |
| Number | 206 | 206 | 122 | 169 | 96 | 102 | 122 | 79 | 169 | 96 | 102 | 122 | 79 | 122 | 122 |
| Mean | .51 | .57 | 5.06 | 3.41 | 3.66 | 3.70 | 4.56 | 4.82 | 420.1 | 445.5 | 450.4 | 474.2 | 491.3 | .70 | 1.7 |
| Standard Deviation | .50 | .49 | 3.54 | .98 | .88 | .99 | 1.61 | 1.58 | 35.02 | 51.05 | 36.33 | 35.36 | 43.52 | .32 | 2.1 |
| Minimum/Maximum | 0/1 | 0/1 | 0/21.1 | 1.1/6.3 | 1.6/5.7 | 1.6/6.5 | 1.6/9.4 | 1.8/9.6 | 335.8/520.9 | 367.5/751.1 | 373.1/565.5 | 395.3/568.7 | 361.4/580.5 | .08/1.6 | 0/9 |

Notes:

* $P < .05$,

** $P < .01$

## Table 2

Standardized Parameter Estimates for the Full Structural Equation model

| | β (B) | 95% CI |
|---|---|---|
| *Respiratory Sinus Arrhythmia Model* | | |
| Child Gender → Callous-Unemotional Behaviors | 0.07 (0.04) | −0.07 to 0.16 |
| Child Race → Callous-Unemotional Behaviors | 0.03 (0.02) | −0.11 to 0.16 |
| Income 1st Grade → Callous-Unemotional Behaviors | −0.18* (−0.02)* | −0.03 to 0.00 |
| Baseline Respiratory Sinus Arrhythmia → Callous-Unemotional Behaviors | −0.25* (−0.08)* | −0.14 to −0.01 |
| Child Gender → Oppositional Defiant Behaviors | −0.04 (−0.16) | −0.89 to 0.56 |
| Child Race → Oppositional Defiant Behaviors | 0.00 (−0.01) | −0.87 to 0.87 |
| Income 1st Grade → Oppositional Defiant Behaviors | −0.19* (−0.11)* | −0.22 to −0.01 |
| Baseline Respiratory Sinus Arrhythmia → Oppositional Defiant Behaviors | −0.28* (−0.53)* | −0.98 to −0.08 |
| *Heart Period Model* | | |
| Child Gender → Callous-Unemotional Behaviors | 0.06 (0.04) | −0.08 to 0.16 |
| Child Race → Callous-Unemotional Behaviors | −0.05 (−0.03) | −0.16 to 0.09 |
| Income 1st Grade → Callous-Unemotional Behaviors | −0.17 (−0.02) | −0.03 to 0.01 |
| Baseline Heart Period → Callous-Unemotional Behaviors | −0.04 (−0.01) | −0.09 to 0.06 |
| Child Gender → Oppositional Defiant Behaviors | −0.06 (−0.25) | −1.03 to 0.53 |
| Child Race → Oppositional Defiant Behaviors | −0.11 (−0.46) | −1.28 to 0.36 |
| Income 1st Grade → Oppositional Defiant Behaviors | −0.16 (−0.10) | −0.20 to 0.01 |
| Baseline Heart Period → Oppositional Defiant Behaviors | 0.01 (0.01) | −0.47 to 0.49 |

Notes:

* $p < .05$.