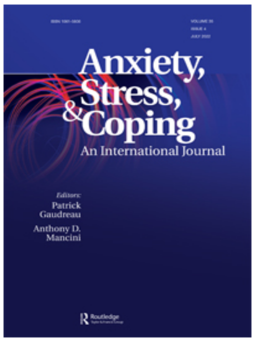

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Effects of adverse childhood experience on physiological regulation are moderated by evolved developmental niche history

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ABSTRACT
Childhood experiences of early life stress and adversity can lead to long-term detrimental outcomes across the lifespan. Recent evidence suggests avoiding stressors is not enough for species-typical development. Nurturing and responsive care are needed to both buffer adverse experiences as well as promote healthy development, but little is known regarding the interaction between species-typical environmental support in childhood, Evolved Developmental Niche history (EDN-history), and adversity on physiological regulation in adult women. To investigate the interaction between species-typical nurturing and adversity (ACEs, adverse childhood experiences), women ($N = 113$) were asked to report on EDN-history and ACEs. Physiological regulation was measured using respiratory sinus arrhythmia (RSA) across three conditions that included stress and relaxation. Applying latent basis coefficient modeling, EDN-history moderated vagal withdrawal from baseline to stress and supported vagal activation from stress to recovery, suggesting a link between EDN-history and vagal adaptability. EDN-history acted as a buffer against ACEs on physiological regulation supporting women's vagal adaptability across differing conditions. Physiological adaptability is a key component of physical and psychological wellbeing and resilience. Experiences of the EDN in childhood may not only buffer adversity but also support the physiological building blocks of health and resilience.

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Adverse childhood experiences; evolved developmental niche; vagal flexibility; vagal tone; wellbeing

Attention to early toxic stress and adverse childhood experiences (ACEs) has increased due to their correlations with health outcomes over the lifetime (Botros et al., 2019; Felitti & Anda, 2005), suggesting that avoiding adverse stressors in childhood may contribute to later wellbeing. Evidence is also accruing regarding the effects of *supportive* childhood experiences on later wellbeing (Bethell et al., 2019) because many physiological systems set their parameters and thresholds in the early years (Lanius et al., 2010). In this study, we investigated whether reported childhood experiences consistent with humanity's evolved developmental system moderated the effects of reported adverse childhood experiences on adult tonic and flexible parasympathetic activity, a signal of healthy development.

Humanity's evolved developmental niche

Like all animals, human beings evolved a developmental system for raising their young that matches the maturational schedule of the offspring (Gottlieb, 2002). Healthy biopsychosocial development is supported when a species' evolved developmental system is provided. Emerging initially from the

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social mammalian line 20–40 million years ago and identified worldwide among nomadic foragers (Konner, 2005), humanity's evolved developmental niche (EDN) for young children is communally-provisioned and includes soothing perinatal experiences, breastfeeding on request for several years, positive climate and community support, multiple responsive caregivers mitigating distress, and self-directed social play with multiple age mates in the natural world. Each component of the EDN fosters healthy psychosocial-neurobiological architecture according to converging evidence from neurobiology, anthropology, ethnography, and clinical and developmental psychology (e.g., Narvaez et al., 2013; Tarsha & Narvaez, 2019). For example, EDN components promote well-built neurobiological systems that bear on psychological functioning, such as secure attachment (Schore, 2019), a healthy autonomic system (both sympathetic and parasympathetic branches; Porges, 2011), a regulated hypothalamic–pituitary–adrenal axis (HPA, the stress response; McEwen, 2008), and well-functioning endocrine systems (e.g., oxytocin; Carter, 2019). As they develop, these major neurobiological systems are susceptible to environmental factors, in particular, the social environment and quality of caregiving (Loman & Gunnar, 2010; Schore, 2019). The influence of the social environment is heightened in early life when the brain and central nervous system are the most immature; for example, the brain doubles in size within the first year of life and does not finish developing until the third (sometimes fourth) decade of life (Kim et al., 2016).

In preliminary explorations of whether the EDN correlates with child and adult outcomes, several studies have shown promising relationships. In a recent study using a snap-shot metric of EDN provision (frequency of EDN components experienced by children in the last week as reported by parents) in samples from the United States, Switzerland and China, higher EDN experience predicted 3–5-year-old's social thriving in all samples (Narvaez, Woodbury, et al., 2019; Narvaez, Arrows, et al., 2019). In a study with adults (Narvaez et al., 2016; $N = 606$), EDN-consistent childhood experience (EDN-history) predicted social engagement orientation via a pathway through secure attachment, mental health and perspective taking, whereas two negative pathways emerged from low secure attachment and poor mental health, one leading to social oppositionalism through low perspective taking and the other pathway leading to social withdrawal through personal distress.

Adverse childhood experiences

Contrasting with the EDN, adverse childhood experiences (ACEs) demonstrably impair child and adult outcomes, leading to chronic illness, illbeing and early death (Felitti & Anda, 2005). The initial ACEs (Adverse Childhood Experience) study (Felitti et al., 1998) and the cascade of empirical studies that followed, provide evidence that adverse childhood experiences have lasting effects upon adult wellbeing. For example, in a sample of 13,494 adults, Felitti and Anda (2005) found a graded relationship ($p < .001$) between previous childhood abuse and familial dysfunction and adult health risk behaviors, including violent behavior and disease. ACEs studies demonstrate that as the number of adverse childhood experiences increases, there is a graded increase in the odds-ratio of developing poor outcomes: alcoholism, illicit drug use, injected drug use, smoking, sleep disturbances, severe obesity, multiple somatic symptoms, early intercourse, promiscuity, sexual dissatisfaction, high perceived stress, and aggressive behavior (e.g., Anda et al., 2006). Numerous follow-up studies with large samples have affirmed the initial findings from the ACEs study, providing converging evidence for the importance of early care experiences upon human flourishing (e.g., Anda et al., 2002; Botros et al., 2019; Danese et al., 2009; Dube et al., 2003; Edwards et al., 2003; Humphreys et al., 2020).

On the other hand, recent investigations now indicate that *positive* childhood experiences, such as nurturing relationships and community social embeddedness – fundamental components of the EDN–may reduce the odds of adult pathology even in the presence of ACEs. For example, Bethell et al. (2019) investigated both positive childhood experiences and ACEs in a sample of noninstitutionalized adults ($N = 6188$) that was weighted to represent the entire population of Wisconsin. Positive childhood experiences showed a dose–response association with adult depression and/or poor mental health and adult reported social and emotional support such that higher positive experiences related to lower negative adult outcomes. The researchers concluded that promotion of positive childhood experiences may not only reduce the risk for depression and poor mental health but may also promote adult relational health. Further, the research group highlighted that assessing both positive and negative childhood experiences is needed to better understand how to promote adult well-being. We take up their call for more research investigating both positive and negative childhood experiences on adult health, specifically autonomic functioning, a critical building block of wellbeing (Carter & Porges, 2013; Thayer et al., 2009).

Respiratory sinus arrhythmia

The autonomic nervous system (ANS) consists of two branches that innervate both internal organs and bodily systems, the parasympathetic systems (PNS) and the sympathetic system (SNS) (Beauchaine, 2001). Respiratory sinus arrhythmia (RSA) is a metric for assessing one aspect of autonomic activity, involving the parasympathetic system (PNS) regulation of cardiac pace-making function (Hayano & Yuda, 2019), which functions to soothe, restore and calm both psychological and physiological systems (Porges, 2011). A healthy autonomic system adaptively dampens sympathetic activation when an individual is in a perceived safe environment, facilitating growth and restorative processes (Porges, 2009). A well-regulated vagal system is associated with overall wellbeing, cognitive abilities and resilience (Hegarty-Craver et al., 2018; Pinna & Edwards, 2020; Souza et al., 2007). Its malfunctioning is involved in multiple disorders (e.g., post-traumatic stress disorder; attachment, neurological and eating disorders; obesity; migraines; depression; neuropsychiatric conditions; attention hyperactivity deficit disorder; and autism) and is considered a transdiagnostic biomarker for psychopathology and self-regulation (Beauchaine & Thayer, 2015).

The autonomic nervous system is susceptible to environmental and social influence in early life (Propper et al., 2008) due to high plasticity of developing neurobiological structures. Advances in developmental psychobiological research demonstrate that dynamic interactions in early life – the interplay between the child and the caregiving environment – shape children's biological process including the autonomic nervous system and vagal tone (Lomanowska et al., 2017). Consequently, the last two decades of developmental psychobiological research has focused on examining a wide range of environmental influences including the quality and nature of the caregiving environment (Calkins, 2011). For example, maternal sensitivity in the first months of life is predictive of long-term child vagal regulation (Kennedy et al., 2004; Perry, Calkins, & Bell, 2016; Perry et al., 2014). In addition, animal models demonstrate that negative experiences of adversity and stress in early life carry long-term changes to autonomic functioning into adulthood (McEwen, 2013), including parasympathetic functioning (McEwen, 2012).

The PNS is an important neurobiological component of stress and allostatic load because it slows the heart, influences anti-inflammatory effects and opposes the sympathetic (fight-or-flight) system (Thayer & Lane, 2000). As such, it plays a critical role in stress and allostatic load, the cumulative neurobiological effects of stress from both historical and current life events, which can cause dysregulated activity in the brain and body, such as not enough parasympathetic tone or too little/much cortisol, signals of pathophysiology (McEwen, 2017). Its important role in allostatic load and cumulative stress may be part of the reason that Winzeler et al. (2017) found a connection between ACEs and women's autonomic functioning. However, in their study, only baseline level of RSA was examined and flexible or phasic vagal regulation was not probed. Baseline (tonic) vagal tone refers to assessment of vagal activity during a non-stressful situation whereas flexible (phasic) vagal regulation captures vagal change from a baseline to a stress condition (or vice versa), indicating how the autonomic nervous system changes across situations, offering more ecologically valid information (Laborde et al., 2017). RSA changes depending upon context and situation, and consequently, studies that probe both baseline and flexible vagal activity are needed. Further, considering that both negative and positive experience are thought to be important factors in

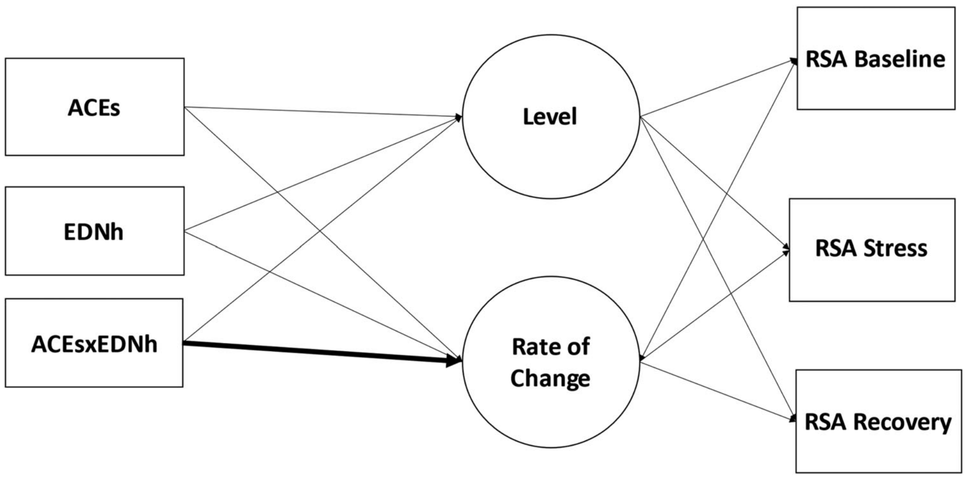

Figure 1. Latent Growth Curve Model with ACEs, EDNh and Interaction (Moderator) Predicting Women's Tonic RSA (Level) and Phasic RSA (Rate of Change).

shaping autonomic developing, there is a need to examine both components. In this study, the role of ACEs and EDN-history as predictors of autonomic activity is examined.

Current study

We were interested in finding out whether EDN-history was predictive of adult RSA and whether EDN-history might buffer the effects of ACEs. Given recent evidence regarding possible gender differences in vagal tone (Koenig & Thayer, 2016), we were interested in examining these variables in women alone. Thus, we investigated women's childhood history of both ACEs and the EDN in addition to assessing their vagal functioning and vagal flexibility across three conditions: baseline, a stress task and a recovery period. This allowed the investigation of both tonic and phasic vagal tone. We speculated that both tonic and flexible vagal activity would be influenced by the interaction between ACEs and EDN-history in childhood. We hypothesized that EDN-history would mitigate the detrimental effects of ACEs on parasympathetic regulation by supporting higher levels of RSA functioning across all conditions, that is, supporting higher vagal tone across baseline, stress and recovery. In addition, we hypothesized that EDN-history would relate to less change (vagal flexibility) from baseline to stress and a quicker recovery from the stress to recovery conditions. A moderate vagal withdrawal in response to a stressor has been associated with an optimal or adaptive engagement whereas excessive vagal withdrawal has been associated with emotional liability or less adaptiveness (Beauchaine, 2001). In this way, although a change from baseline to stress was anticipated, it was expected that more support in childhood, as measured through EDN-history, would lessen the amount of change indicating less stress during the stress-inducing condition (Figure 1).

Method

Participants

This investigation was part of a multi-year longitudinal study in which mothers and their children were followed prenatally to six years of age in order to study parenting practices, support and child outcomes. We used data from the mothers when the children were 12 months, four years and six years of age. At the first time point, 113 women reported their history of ACEs ($M_{motherage}$

= 28.75, $SD_{motherage}$ = 5.39; mean household income \$30,000–\$75,000 per year); at the second time point 89 women ($M_{motherage}$ = 31.75, $SD_{motherage}$ = 5.39; mean household income 50,000−50,000-75,000 per year) reported on their EDN-history; at the final time point ($M_{motherage}$ = 33.75, $SD_{motherage}$ = 5.39; mean household income \$50,000-\$75,000 per year) physiological data were collected. The RSA data from 74 women was usable due to movement artifacts (e.g., touching electrodes, electrodes falling off, a city-wide power outage).

Prior to data collection, each wave of the study was reviewed and approved by the university's institutional review board (IRB). At every time point, participants provided written informed consent.

Measures

Two kinds of data were collected, surveys of childhood experiences and biological data. Two questionnaires were used in these analyses.

Evolved Developmental Niche History: Childhood experience was assessed using Evolved Developmental Niche history (EDNh; Narvaez et al., 2016), a self-report checklist of adult recollections of childhood experiences (before 18) consistent with the Evolved Developmental Niche. Questions assessed *social embeddedness* (2 items; doing things together as a family inside/outside the home, respectively) on a 7-point scale (1 = less than yearly to 7 = every day, $r = .46$), and responsive social environment (3 items; happy, supportive, needs met) on a 5-point scale (1 = very slightly/not at all to 5 = very much, $\alpha = .90$). Positive (hugs and kisses) and negative (corporal punishment, reversed) *touch* were each assessed with a single item on a 5-point scale (1 = never to 5 = very often, $r = .35$) and then summed. Climate in the home was assessed by calculating the summed frequencies of six negative emotions (grief, humiliation, guilt, fear, anger, and numbness) yielding a sum negative home climate score (α = .90), and four positive emotions (joy, expansiveness, self-assurance, and serenity), yielding a sum positive home climate score ($\alpha = .87$). Responses followed a 6-point scale (1 = *don't recall* to 6 = *almost always*). A composite score of the checklist was used, adjusting and averaging the subscales to create an overall mean EDN-history score. Test-retest reliability was .87.

Adverse Childhood Experiences: Traumatic experiences in childhood were measured using a 9-item Adverse Childhood Experiences (ACEs) measure of childhood experience prior to the 18th birthday (Felitti & Anda, 2005). It functions as a summed checklist (yes/no; scores ranging 0–9). Traumas include personal experiences (physical abuse, verbal abuse, sexual abuse, physical neglect and emotional neglect) and family experiences (alcoholic parent, domestic violence, family member in jail, and family member diagnosed with mental illness). Test-retest samples show reliability from .67 (Zanotti et al., 2018) to .91 (Schauss et al., 2021).

Physiological Regulation: Respiratory Sinus Arrhythmia (RSA): In order to assess respiratory sinus arrhythmia (RSA) functioning, electrocardiogram (ECG) and respiration rate and volume were simultaneously measured. Together, ECG and respiration comprise an index of vagal tone functioning: the amplitude of heart rate rhythm associated with frequency of spontaneous breathing (Porges & Byrne, 1992). Instruments included BioPac hardware and AcqKnowledge software. In order to monitor ECG and respiration, three disposable Ag-AgCI electrodes were placed on the participant's chest in a lead II configuration (two under the clavicle and one on the lower left rib), connected to an ECG amplifier, and output to a Vagal Tone Monitor-II (Biopac Nomadix, Inc.). RSA has been identified as a stable and consistent metric across repeated measurements over time (Borges et al., 2017).

Biological Data Qualification: Bionomadix Wireless Respiration and ECG module pair (matched transmitter and receiver) detected the peak of the R-wave with 1-millisecond accuracy, timed sequential heart periods to the nearest millisecond (Riniolo & Porges, 1997) and stored the heart periods in files for off-line analyses of RSA and heart period. The data files of sequential heart periods (i.e., R–R intervals in ms.) were input into CardioEdit software (Brain–Body Center, University of Illinois at Chicago) in order to edit outlier data produced by movement and digitizing error. Editing consisted of integer addition or division of sequential values.

Heart period data were visually inspected and edited off-line using CardioEdit software. Editing consisted of integer arithmetic (i.e., dividing intervals when detections were missed or and adding intervals when spuriously invalid detections occurred). RSA was derived from the edited heart period via CardioBatch Plus Synchrony v1. (Brain–Body Center for Psychophysiology and Bioengineering, University of North Carolina, Chapel Hill, 2018), which employs the Porges (1985) method. The Porges method applies a time–frequency algorithm to quantify the amplitude of RSA with age-specific parameters, sensitive to the maturational shifts in the frequency of spontaneous breathing. CardioBatch Plus Synchrony additionally uses the same re-sampling rate (step b below), according to the fastest respiration rate for either member of dyad. For the current study, steps included: (a) R-R intervals were timed to the nearest millisecond to produce a time series of sequential heart periods; (b) sequential heart periods are resampled into 250-ms. intervals to produce time-based data; (c) the time-based series is detrended by a cubic moving polynomial filter MPF (41–point for adult) that is stepped through the data to create a smoothed template and the template is subtracted from the original time-based series to generate a detrended residual series; (d) the detrended time series is bandpassed to restrict the variance in the heart period pattern associated with spontaneous breathing and (e) the resulting bandpassed time series is divided into epochs (30 sec, in this case), the natural logarithm of the variance of each epoch is calculated as the measure of the amplitude of RSA and the epochs are averaged within each condition.

Procedure

Data collection took place at a university research center where mothers (and children) were observed and mothers completed a survey at each time point. Survey data from the first two time points were used. During the third timepoint visit, RSA data were collected by a trained experimenter. Participants received gift cards for each session. Only the mother's data were used for this study.

Following standard RSA methodology for experimental procedures (Laborde et al., 2017), there were three conditions equally spaced apart: (1) baseline (resting state) watching a non-stimulating video (butterflies) for 2 min; (2) stress task: five minutes in which the mother and child worked to finish difficult 3-dimensional picture puzzles while a timer ticked noisily beside them; (3) recovery watching a relaxing video (babies).[1] Data were collected after participants performed sedentary activities for approximately 15 min and were asked not to talk during the procedure in order to avoid influence on respiration cycles.

Results

The means, standard deviations and correlations for all variables are found in Table 1. Planned analyses were conducted according to the following design. An *a priori* power analysis was not conducted due to the unknown relationship of EDN-history and RSA. This is the first study to investigate EDN-history on RSA functioning.

Table 1. Descriptive statistics of minimum, maximum, mean and correlations for childhood history variables and RSA by condition.

Variable	*N*	Min	Max	Mean (SD)	1	2	3	4
1. EDN-history[a]	89	2.34	5.07	4.07 (.61)	1			
2. ACES[b]	113	1.00	8.00	2.34 (1.73)	−.52**	–		
3. RSA Baseline	74	3.42	9.05	6.05 (1.17)	−.05	−.19	–	
4. RSA Stress	74	2.38	10.01	5.56 (1,37)	−.01	−.34[t]	.74**	–
5. RSA Recovery	74	2.20	9.46	5.99 (1.25)	−.06	−.23	.81**	.81**

Notes: $^{t}p < .10$, $^{*}p < .05$, $^{**}p < .01$.
[a]Evolved Developmental Niche History.
[b]Adverse Childhood Experiences.

Prior to analyses, statistical testing of the effectiveness of the stress condition was assessed in order to evaluate if the stressor significantly influenced vagal tone. Paired sample t-tests demonstrated that the stress condition was significantly lower compared to both the baseline and recovery periods, $t_{\text{baseline \& stress}}(73) = 4.5$, $p < .001$ and $t_{\text{stress \& recovery}}(73) = -4.50$, $p < .001$. As expected, this provided information that the stress condition induced a reduction in vagal tone with an increase in vagal tone at both baseline and stress, a v-shape. The nonlinear shape of the RSA values across the three conditions (v-shape) indicated that a model that can accommodate nonlinear change patterns was needed to accurately account for the rapid fluctuations in vagal tone functioning. Thus, in order to accurately model the changing nature of RSA across different conditions, a latent basis coefficient model was used. Latent basis coefficient modeling is a type of latent growth curve model that takes into account nonlinear change patterns across time. The latent basis model is more flexible and allows for nonlinear change patterns because the basis coefficients at some time points are freely estimated (Grimm et al., 2011; McArdle & Epstein, 1987).

Both childhood history predictors and the interaction term were simultaneously added into the latent basis coefficient model. Latent growth curve models were conducted using Mplus (Muthén & Muthén, 2019). Goodness-of-fit was assessed using standardized root mean squared residual (SRMR) values below 0.08, comparative fit index (CFI) values greater than or equal to .95 and chi-square with *p* values greater than .05 (Hu & Bentler, 1999). In all models, missing data was handled using full-information-maximum-likelihood (FIML), which has been found to be appropriate for data that is missing completely at random (MCAR) and missing at random (MAR) (Enders & Bandalos, 2001). Missing data did not appear to be due to any identified variable ($ps > .33$ when comparing missing data based upon maternal age and income) and as such was determined to be MCAR.

Analytic plan

The first model investigating the relation of mother's childhood history experience to autonomic regulation included two latent variables and the manifest variables of EDN-history, ACEs and the interaction term. Different factor loadings for the level and trend (slope) latent variables were utilized. The first latent variable of level indicated mothers' RSA values for each condition and these factor loadings were all set to 1. The second latent variable of trend indicated mothers' RSA rate of change (or slope) across the conditions. Because the first line of investigation included analyzing change from the first to second condition, the factor loadings were 0 and 1 with the last factor loading being allowed to be freely estimated. Next, the predictors were included in the model to predict level and trend. None of the predictors were allowed to correlate with each other.

In the second model, the same factor loadings for level were utilized as in the previous model (all set to 1). The factor loadings for trend were different than the previous model because this model was focused on investigating the change from condition 2 to condition 3, stress to recovery. Because of this difference, the factor loadings for the latent variable of trend were 0 and 1 for the second and third condition with the first time point allowed to be freely estimated.

In the third model, the same factor loadings for level were utilized as in the previous model (all set to 1). The factor loadings for trend were different than the previous two models because this model was focused on investigating the level of recovery. Because of this difference, the factor loadings for the latent variable of trend were 1 and 0 for the second and third condition with the first time point allowed to be freely estimated.

Model results

Model 1 demonstrated a good fit ($\chi^2(3) = 6.94$, $p = .07$, $\text{CFI} = .96$, $\text{SRMR} = .038$). The correlation between RSA level and RSA trend was not significant, $r = .35$, $p = .11$. This indicated that the initial RSA level did not relate to rate of change from baseline to stress. Regarding the predictors, none of the variables significantly related to baseline level of RSA ($\hat{\beta}_{\text{ACEs}} = \text{-}.56$, $p = .58$, $\hat{\beta}_{\text{EDNh}} = \text{-}.28$, *p*

= .72, $\hat{\beta}_{ACEsxEDNh}$= .09, $p = .74$). All three predictors were significant in predicting RSA trend: ACEs ($\hat{\beta}_{ACEs} = 1.13$, $p = .01$), EDNh ($\hat{\beta}_{EDNh} = 1.03$, $p = .005$) in addition to the interaction term ($\hat{\beta}_{ACEsxEDNh}$ = -.37, $p = .004$). The influence of ACEs on vagal flexibility depended upon childhood history of the EDN such that as EDN experience increased, the influence of ACEs on vagal flexibility decreased. As expected, ACE scores were moderated by EDN experience such that it decreased the rate of change from baseline to stress; that is, individuals became less stressed.

Model 2 demonstrated a good fit ($\chi^2(3) = 6.94$, $p = .07$, CFI = .96, SRMR = .038). The correlation between RSA level and RSA trend was not significant ($r = .10$, $p = .95$), indicating that the stress RSA level did not significantly relate to rate of change from stress to recovery. Regarding the predictors, none of the variables significantly related to baseline level of RSA ($\hat{\beta}_{ACEs} = .57$, $p = .64$, $\hat{\beta}_{EDNh}$ = .75, $p = .43$, $\hat{\beta}_{ACEsxEDNh} = -.28$, $p = .42$). For trend, all three variables were significant, $\hat{\beta}_{ACEs} = -1.01$, $p = .015$, $\hat{\beta}_{EDNh} = -.92$, $p = .003$, $\hat{\beta}_{ACEsxEDNh} = .33$, $p = .004$. The influence of ACEs on vagal flexibility depended upon EDN-history such that as EDN increased, the influence of ACEs on vagal flexibility increased, suggesting that EDN-history facilitated vagal activation, an adaptive response, to the recovery period. Higher reporting of EDN experience buffered the effects of ACEs such that it increased vagal activation in response to a rest condition.

Model 3 demonstrated a good fit ($\chi^2(3) = 6.94$, $p = .07$, CFI = .96, SRMR = .039). Because this model was only investigating the level of recovery, the latent variable of trend is not interpreted and neither was the correlation between the latent variables of level and trend. For RSA level of recovery, none of the variables were significant, ($\hat{\beta}_{ACEs} = -.44$, $p = .67$, $\hat{\beta}_{EDNh} = -.17$, $p = .83$, $\hat{\beta}_{ACEsxEDNh} = .05$, $p = .86$).

Discussion

In this study, we were interested in examining effects of ACEs and EDN-history on parasympathetic regulation of cardiac pace-making, as measured by both tonic and phasic vagal tone, specifically whether the EDN-history mitigated the negative effects of ACEs in women. Testing female adults, we did indeed find a moderating effect for vagal flexibility but not for tonic vagal activity. EDN-history significantly moderated the relationship between ACEs and vagal flexibility but not vagal tone (level of RSA) at each condition. Further, this moderation facilitated cardiac parasympathetic activity in two ways. EDN-history facilitated vagal regulation when needed, during the baseline to stress condition (not becoming too stressed), and also facilitated vagal activation during the recovery period. In this way, EDN-history moderated adverse experiences in childhood by supporting vagal adaptability to contexts that included both restful and stressful conditions.

The lack of significance of ACEs on cardiac vagal tone (level) aligns with previous research on baseline RSA in women when examining history of adversity. Winzeler et al. (2017) found that ACE scores were associated with decreased sympathetic but not parasympathetic cardiac stress reactivity in a sample of women. Similarly in our data, ACEs were not related to women's parasympathetic level. The lack of association between ACEs and parasympathetic cardiac functioning in both studies may be because ACE scores were on the lower end of the spectrum in both samples. However, our findings add new information in that positive *supportive* experiences were also important predictors of women's autonomic regulation, that is, vagal flexibility, years later. EDN-history moderated cardiac vagal regulation, even in the presence of ACEs, and promoted vagal adaptability across changing conditions. In this way, EDN-history may have buffered against adverse experiences in childhood to facilitate cardiac vagal regulation. This finding was not true for tonic vagal tone, regardless of condition, suggesting that the way respondents changed across conditions, not cardiac parasympathetic functioning within conditions, was dependent upon EDN experience.

Apart from the Winzeler et al. (2017) study, there are few studies that have investigated ACEs, positive childhood experiences and RSA regulation in adults. To address this gap, this is the first study to examine both EDN-history *and* negative childhood experiences on female cardiac parasympathetic functioning and their interaction. These preliminary findings point to the possible moderating effect of positive experiences on autonomic development in women. As noted above, healthy autonomic regulation has implications for health and resilience.

The importance of positive childhood experience on female wellbeing is in line with decades years of research from the field of positive youth development (PYD) which has demonstrated that assets or positive experiences in childhood are critical building blocks of child and adult wellness, even in the presence of childhood adversity (Benson et al., 2011). The effect appears to be cumulative. That is, positive experiences in childhood exponentially increase positive outcomes such that as the number of positive childhood experiences increases, the likelihood of positive outcomes exponentially increases. Similarly, additive and interactive effects within and between EDN components may result in effects that are more than the sum of its measurable components. Though not tested here, the positive components of the EDN may also be cumulative.

The impact of PYD research has been vast: millions of people in the United States as well as more than 30 countries across the globe have implemented aspects of PYD to shape programs and community interventions (Syvertsen et al., 2019). However, what is lacking within this body of research and numerous programs is an evolutionary understanding of humanity's developmental system for its young. Our study helps fill this gap, suggesting that a wider lens that includes evolutionary history can assist in establishing the range and types of positive experience children may need to build resilience in the face of adversity. While trauma-informed best practice addresses and mitigates adverse experiences (Bethell et al., 2014), EDN provision offers a wellness-informed approach, aligning with PYD, that could equip children, particularly females, with neurobiological resilience, such as vagal adaptability.

There may also be cumulative interactive effects across development regarding positive experiences and vagal tone adaptability. For example, Kok and Fredrickson (2010) proposed that vagal flexibility may enable individuals to harness social and emotional opportunities which in turn brings about advantageous or positive experiences. Subsequently, the increase in positive experiences leads to increased vagal tone, a cycle that the authors identified as an upward spiral such that vagal flexibility and psychosocial well-being reciprocally enhance one another.

Limitations and future directions

There were several limitations in the study. The sample was moderately sized, was somewhat homogenous, and all participants were self-selected volunteers. The fact that all participants were women can be considered a limitation but also a strength, due to emerging gender differences in RSA analyses. A recent meta-analysis by Koenig and Thayer (2016) found 172 heart rate variability studies reporting gender differences, suggesting greater attention to this variable is needed. Future studies should consider examining possible gender differences, investigating EDN provision experiences on males as well as females.

Given the connection between the EDN and its effect on buffering adverse outcomes, future studies could probe the specific effects of each EDN component, examining which component is most influential, and when, in buffering the effects of ACEs on parasympathetic development. For example, having more free play experiences in early childhood may mitigate the harm of physical abuse later. Moreover, the interactions of the timing, intensity and duration of positive and stressful experiences over the course of development should be examined. Future research could investigate the buffering effect of particular EDN components on specific types of adversity. Of course, experiments of this nature could not be planned, being unethical, but retrospective analyses could be conducted.

Conclusion

At the heart of resilience resides the capacity to adapt, change and surmount difficult – sometimes traumatic – obstacles, at the biological and psychosocial levels. The findings here suggest that when the EDN is provided in childhood, cardiac autonomic regulation develops in a way that supports adaptive flexibility even in the presence of childhood adversity. Provision of the EDN in childhood may buffer against ACEs by promoting cardiac vagal activation when needed, enabling greater physiological adaptability, health and resilience in adulthood. The EDN offers a social ecological evolutionary framework that may be a useful addition to investigations of positive and adverse experiences in childhood.

Note

1. A study by Lewis et al. (2012) compared different indicators of vagal tone that included the Porges-Borhrer method, the same method used in our study, and found that the different indicators of vagal tone were highly correlated. The high correlations among these measurements have also been reiterated by Laborde et al. (2017). Other authors have pointed out the possible difficulties when examining correlations between metrics due to the lack of standard cut-offs or coefficients of determination. For example, Shaffer et al. (2020) describe the unresolved problem of evaluating and comparing two cardiac vagal tone metrics given the lack of standards or cut-offs for correlation or regression coefficients when comparing different methods. As such, more research is needed that examines the relationship among these metrics, providing researchers a better understanding of their similarity, correlation or unrelatedness.

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References

Anda, R. F., Felitti, V. J., Bremner, J. D., Walker, J. D., Whitfield, C., Perry, B. D., Dube, S. R., & Giles, W. H. (2006). The enduring effects of abuse and related adverse experiences in childhood. *European Archives of Psychiatry and Clinical Neuroscience*, *256*(3), 174–186. https://doi.org/10.1007/s00406-005-0624-4

Anda, R. F., Whitfield, C. L., Felitti, V. J., Chapman, D., Edwards, V. J., Dube, S. R., & Williamson, D. F. (2002). Adverse childhood experiences, alcoholic parents, and later risk of alcoholism and depression. *Psychiatric Services*, *53*(8), 1001–1009. https://doi.org/10.1176/appi.ps.53.8.1001

Beauchaine, T. (2001). Vagal tone, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. *Development and Psychopathology*, *13*(2), 183–214. https://doi.org/10.1017/S0954579401002012

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

Benson, P. L., Scales, P. C., & Syvertsen, A. K. (2011). The contribution of the developmental assets framework to positive youth development theory and practice. *Advances in Child Development and Behavior*, *41*, 197–230. https://doi.org/10.1016/B978-0-12-386492-5.00008-7

Bethell, C., Jones, J., Gombojav, N., Linkenbach, J., & Sege, R. (2019). Positive childhood experiences and adult mental and relational health in a statewide sample: Associations across adverse childhood experiences levels. *JAMA Pediatrics*, *173*(11), e193007–e193007. https://doi.org/10.1001/jamapediatrics.2019.3007

Bethell, C. D., Newacheck, P., Hawes, E., & Halfon, N. (2014). Adverse childhood experiences: Assessing the impact on health and school engagement and the mitigating role of resilience. *Health Affairs*, *33*(12), 2106–2115. https://doi.org/10.1377/hlthaff.2014.0914

Borges, C., Mathewson, K. J., & Schmidt, L. A. (2017). Short-term test-retest reliability of respiratory sinus arrhythmia (RSA) in young adults. *Journal of Psychophysiology*, *32*(3), 85–96. https://doi.org/10.1027/0269-8803/a000187

Botros, M., Hodgins, G., & Nemeroff, C. B. (2019). The long-lasting neurobiological scars of early-life stress: Implications for the neurobiology of depression. In J. Quevedo, A. F. Carvalho, & C. A. Zarate (Eds.), *Neurobiology of depression* (pp. 111–121). Elsevier. https://doi.org/10.1016/B978-0-12-813333-0.00011-1

Calkins, S. D. (2011). Caregiving as coregulation: Psychobiological processes and child functioning. In *Biosocial foundations of family processes* (pp. 49–59). New York, NY: Springer.

Carter, C. S. (2019). Love as embodied medicine. *International Body Psychotherapy Journal*, *18*(1), 19–25. https://doi.org/10.1111/j.1469-8986.1997.tb01748.x

Carter, C. S., & Porges, S. W. (2013). Neurobiology and the evolution of mammalian social behavior. In D. Narvaez, J. Panksepp, A. Schore, & T. Gleason (Eds.), *Evolution, early experience and human development: From research to practice and policy* (pp. 132–151). Oxford University Press.

Danese, A., Moffitt, T. E., Harrington, H., Milne, B. J., Polanczyk, G., Pariante, C. M., & Caspi, A. (2009). Adverse childhood experiences and adult risk factors for age-related disease: Depression, inflammation, and clustering of metabolic risk markers. *Archives of Pediatrics & Adolescent Medicine*, *163*(12), 1135–1143. https://doi.org/10.1001/archpediatrics.2009.214

Dube, S. R., Felitti, V. J., Dong, M., Chapman, D. P., Giles, W. H., & Anda, R. F. (2003). Childhood abuse, neglect, and household dysfunction and the risk of illicit drug use: The adverse childhood experiences study. *Pediatrics*, *111*(3), 564–572. https://doi.org/10.1542/peds.111.3.564

Edwards, V. J., Holden, G. W., Felitti, V. J., & Anda, R. F. (2003). Relationship between multiple forms of childhood maltreatment and adult mental health in community respondents: Results from the adverse childhood experiences study. *American Journal of Psychiatry*, *160*(8), 1453–1460. https://doi.org/10.1176/appi.ajp.160.8.1453

Enders, C. K., & Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling*, *8*(3), 430–457. https://doi.org/10.1207/S15328007SEM0803_5

Felitti, V. J., & Anda, R. F. (2005). *The adverse childhood experiences (ACE) study*. Centers for Disease Control and Kaiser Permanente.

Felitti, V. J., Anda, R. F., Nordenberg, D., Williamson, D. F., Spitz, A. M., Edwards, V., & Marks, J. S. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: The adverse childhood experiences (ACE) study. *American Journal of Preventive Medicine*, *14*(4), 245–258. https://doi.org/10.1016/S0749-3797(98)00017-8

Gottlieb, G. (2002). On the epigenetic evolution of species-specific perception: The developmental manifold concept. *Cognitive Development*, *17*(3-4), 1287–1300. https://doi.org/10.1016/S0885-2014(02)00120-X

Grimm, K. J., Ram, N., & Hamagami, F. (2011). Nonlinear growth curves in developmental research. *Child Development*, *82*(5), 1357–1371. https://doi.org/10.1111/j.1467-8624.2011.01630.x

Hayano, J., & Yuda, E. (2019). Pitfalls of assessment of autonomic function by heart rate variability. *Journal of Physiological Anthropology*, *38*(1), 1–8. https://doi.org/10.1186/s40101-019-0193-2

Hegarty-Craver, M., Gilchrist, K. H., Propper, C. B., Lewis, G. F., DeFilipp, S. J., Coffman, J. L., & Willoughby, M. T. (2018). Automated respiratory sinus arrhythmia measurement: Demonstration using executive function assessment. *Behavior Research Methods*, *50*(5), 1816–1823. https://doi.org/10.3758/s13428-017-0950-2

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Humphreys, K. L., LeMoult, J., Wear, J. G., Piersiak, H. A., Lee, A., & Gotlib, I. H. (2020). Child maltreatment and depression: A meta-analysis of studies using the childhood trauma questionnaire. *Child Abuse & Neglect*, *102*, 104361. https://doi.org/10.1016/j.chiabu.2020.104361

Kennedy, A. E., Rubin, K. H., Hastings, D., & Maisel, P. (2004). Longitudinal relations between child vagal tone and parenting behavior: 2 to 4 years. *Developmental Psychobiology*, *45*(1), 10–21.

Kim, J. C., Wang, L., Shen, D., & Lin, W. (2016). Biomechanical analysis of normal brain development during the first year of life using finite strain theory. *Scientific Reports*, *6*(1), 37666. https://doi.org/10.1038/srep37666

Koenig, J., & Thayer, J. F. (2016). Sex differences in healthy human heart rate variability: A meta-analysis. *Neuroscience & Biobehavioral Reviews*, *64*, 288–310. https://doi.org/10.1016/j.neubiorev.2016.03.007

Kok, B. E., & Fredrickson, B. L. (2010). Upward spirals of the heart: Autonomic flexibility, as indexed by vagal tone, reciprocally and prospectively predicts positive emotions and social connectedness. *Biological Psychology*, *85*(3), 432–436. https://doi.org/10.1016/j.biopsycho.2010.09.005

Konner, M. (2005). Hunter-gatherer infancy and childhood: The !Kung and others. In B. Hewlett & M. Lamb (Eds.), *Hunter-gatherer childhoods: Evolutionary, developmental and cultural perspectives* (pp. 19–64). Aldine Transaction. https://doi.org/10.4324/9780203789445-3

Laborde, S., Mosley, E., & Thayer, J. F. (2017). Heart rate variability and cardiac vagal tone in psychophysiological research-recommendations for experiment planning, data analysis, and data reporting. *Frontiers in Psychology*, *8*, 213. https://doi.org/10.3389/fpsyg.2017.00213

Lanius, R. A., Vermetten, E., & Pain, C. (2010). *The impact of early life trauma on health and disease: The hidden epidemic*. Cambridge University Press. https://doi.org/10.1017/CBO9780511777042

Lewis, G. F., Furman, S. A., McCool, M. F., & Porges, S. W. (2012). Statistical strategies to quantify respiratory sinus arrhythmia: Are commonly used metrics equivalent? *Biological Psychology*, *89*(2), 349–364. https://doi.org/10.1016/j.biopsycho.2011.11.009

Loman, M. M., & Gunnar, M. R. (2010). Early experience and the development of stress reactivity and regulation in children. *Neuroscience & Biobehavioral Reviews*, *34*(6), 867–876. https://doi.org/10.1016/j.neubiorev.2009.05.007

Lomanowska, A. M., Boivin, M., Hertzman, C, & Fleming, A. S. (2017). Parenting begets parenting: A neurobiological perspective on early adversity and the transmission of parenting styles across generations. *Neuroscience*, *342*, 120–139.

McArdle, J. J., & Epstein, D. (1987). Latent growth curves within developmental structural equation models. *Child Development*, *58*, 110–133. https://doi.org/10.2307/1130295

McEwen, B. S. (2008). Understanding the potency of stressful early life experiences on brain and body function. *Metabolism*, *57*(2), S11–S15. https://doi.org/10.1016/j.metabol.2008.07.006.

McEwen, B. S. (2012). Brain on stress: How the social environment gets under the skin. *Proceedings of the National Academy of Sciences*, *109*(Supplement_2), 17180–17185. https://doi.org/10.1073/pnas.1121254109

Mcewen, B. S. (2013). The brain on stress: Toward an integrative approach to brain, body, and behavior. *Perspectives on Psychological Science*, *8*(6), 673–675.

Mcewen, B. S. (2017). Allostasis and the epigenetics of brain and body health over the life course: The brain on stress. *JAMA Psychiatry*, *74*(6), 551–552.

Muthén, L. K., & Muthén, B. (2019). Mplus. *The comprehensive modelling program for applied researchers: User's guide*, Version 7.3.

Narvaez, D., Arrows, F., Halton, E., Collier, B., & Enderle, G. (Eds.). (2019). *Indigenous sustainable wisdom: First nation know-how for global flourishing*. Peter Lang. https://doi.org/10.3726/b14900

Narvaez, D., Panksepp, J., Schore, A., & Gleason, T. (2013). *Evolution, early experience and human development: From research to practice and policy*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199755059.001.0001

Narvaez, D., Wang, L., & Cheng, Y. (2016). The evolved developmental niche in childhood: Relation to adult psychopathology and morality. *Applied Developmental Science*, *20*(4), 294–309. https://doi.org/10.1080/10888691.2015.1128835

Narvaez, D., Woodbury, R., Cheng, Y., Wang, L., Kurth, A., Gleason, T., Deng, L., Gutzwiller-Helfenfinger, E., Christen, M., & Näpflin, C. (2019). Evolved developmental niche provision report: Moral socialization, social thriving, and social maladaptation in three countries. *SAGE Open*, *9*(2), 2158244019840123. https://doi.org/10.1177/2158244019840123

Perry, N. B., Calkins, S. D., & Bell, M. A. (2016). Indirect effects of maternal sensitivity on infant emotion regulation behaviors: The role of vagal withdrawal. *Infancy*, *21*(2), 128–153.

Perry, N. B., Mackler, J. S., Calkins, S. D., & Keane, S. P. (2014). A transactional analysis of the relation between maternal sensitivity and child vagal regulation. *Developmental Psychology*, *50*(3), 784.

Pinna, T., & Edwards, D. J. (2020). A systematic review of associations between interoception, vagal tone, and emotional regulation: Potential applications for mental health, wellbeing, psychological flexibility, and chronic conditions. *Frontiers in Psychology*, *11*, 1–15. https://doi.org/10.3389/fpsyg.2020.01792

Porges, S. W. (1985). Respiratory sinus arrhythmia: An index of vagal tone. In J. E. Orlebeke, G. Mulder, & L. J. P. Van Dornen (Eds.), *Psychophysiology of cardiovascular control: Models, methods, and data* (pp. 437–450). Plenum.

Porges, S. W. (2009). The polyvagal theory: New insights into adaptive reactions of the autonomic nervous system. *Cleveland Clinic Journal of Medicine*, *76*(Suppl. 2), S86. https://doi.org/10.3949/ccjm.76.s2.17

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

Porges, S. W., & Byrne, E. A. (1992). Research methods for measurement of heart rate and respiration. *Biological Psychology*, *34*(2–3), 93–130. https://doi.org/10.1016/0301-0511(92)90012-J

Propper, C., Moore, G. A., Mills-Koonce, W. R., Halpern, C. T., Hill-Soderlund, A. L., Calkins, S. D., Carbone, M. A., & Cox, M. (2008). Gene-environment contributions to the development of infant vagal reactivity: The interaction of dopamine and maternal sensitivity. *Child Development*, *79*(5), 1377–1394. https://doi.org/10.1111/j.1467-8624.2008.01194.x

Riniolo, T., & Porges, S. W. (1997). Inferential and descriptive influences on measures of respiratory sinus arrhythmia: Sampling rate, R-wave trigger accuracy, and variance estimates. *Psychophysiology*, *34*(5), 613–621.

Schauss, E., Zettler, H., Patel, M., Hawes, K., Dixon, P., Bartelli, D., Ellmo, F., Naik, S., Suchomelly, F., Cogdal, P., & West, S. (2021). Exploring the testretest differences of self-reported adverse childhood experiences among adolescents in residential treatment. *Journal of Family Trauma, Child Custody & Child Development*, 1–16.

Schore, A. N. (2019). *The development of the unconscious mind* (Norton series on interpersonal neurobiology). W.W. Norton & Company.

Shaffer, F., Meehan, Z. M., & Zerr, C. L. (2020). A critical review of ultra-short-term heart rate variability norms research. *Frontiers in Neuroscience*, *14*, 1–11. https://doi.org/10.3389/fnins.2020.594880

Souza, G. G. L., Mendonça-de-Souza, A. C. F., Barros, E. M., Coutinho, E. F. S., Oliveira, L., Mendlowicz, M. V., Figueira, I., & Volchan, E. (2007). Resilience and vagal tone predict cardiac recovery from acute social stress. *Stress*, *10*(4), 368–374. https://doi.org/10.1080/10253890701419886

Syvertsen, A. K., Scales, P. C., & Toomey, R. B. (2019). Developmental assets framework revisited: Confirmatory analysis and invariance testing to create a new generation of assets measures for applied research. *Applied Developmental Science*, 1–16. https://doi.org/10.1080/10888691.2019.1613155

Tarsha, M. S., & Narvaez, D. (2019). The evolved nest: A partnership system that fosters child and societal wellbeing. *Interdisciplinary Journal of Partnership Studies*, *6*(3), 1–33. https://doi.org/10.24926/ijps.v6i3.2244

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

Thayer, J. F., & Lane, R. D. (2000). A model of neurovisceral integration in emotion regulation and dysregulation. *Journal of Affective Disorders*, *61*(3), 201–216.

Winzeler, K., Voellmin, A., Hug, E., Kirmse, U., Helmig, S., Princip, M., Cajochen, C., Bader, K., & Wilhelm, F. H. (2017). Adverse childhood experiences and autonomic regulation in response to acute stress: The role of the sympathetic and parasympathetic nervous systems. *Anxiety, Stress, & Coping*, *30*(2), 145–154. https://doi.org/10.1080/10615806.2016.1238076

Zanotti, D. C., Kaier, E., Vanasse, R., Davis, J. L., Strunk, K. C., & Cromer, L. D. (2018). An examination of the test–retest reliability of the ACE-SQ in a sample of college athletes. *Psychological Trauma: Theory, Research, Practice, and Policy*, *10*(5), 559.