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Childhood Evolved Developmental Niche History and Autonomic Regulation in Women

Mary S. Tarsha | Darcia Narvaez

Department of Psychology and the Kroc Institute for International Peace Research, University of Notre Dame, Notre Dame, Indiana, USA

Correspondence: Mary S. Tarsha (mtarsha@nd.edu)

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ABSTRACT

Early life adversity has been studied widely, but still understudied is the impact of positive early life experiences. Emerging evidence suggests that humanity's millions-year-old evolved developmental niche (EDN) supports healthy biopsychosocial development. The EDN includes positive touch, responsive relationships, a welcoming social climate, social embeddedness, and self-directed free play. We examined the relation between EDN components and cardiac vagal regulation, the online biomarker for psychopathology, health, and a correlate of positive parenting behaviors.

Women ($N = 78$; 84% white/Euro-American) self-reported their childhood EDN history, and their respiratory sinus arrhythmia (RSA) was assessed across non-stimulating and stressful conditions, providing indexes of both cardiac vagal tone and cardiac vagal flexibility. Three latent growth curve models demonstrated that childhood history of social embeddedness and positive home climate outperformed the other EDN components. A higher positive home climate predicted higher cardiac vagal tone, whereas greater social embeddedness predicted vagal flexibility, buffering against stress and supporting faster rates of recovery from stress. EDN-consistent childhoods, specifically experiencing a positive home climate and social embeddedness, may promote overall cardiac vagal tone and vagal flexibility in women years later. Ecological contexts that support EDN provision may support physiological adaptations that protect against stress and promote stress resilience in adulthood.

1 | Introduction

Early life adversity is associated with numerous pathologies (McEwen 2009) and has the potential to impair parenting (Badovinac et al. 2023; San Cristobal et al. 2017). But what kinds of early life experiences have the opposite impact, supporting health? Each species has a developmental system that optimizes healthy physiological and psychological outcomes. For humans, this system is referred to as the evolved developmental niche (EDN) (Narvaez et al. 2013). We examined how childhood experience of the EDN influenced women's cardiac vagal regulation, an online biomarker for mental health resilience (Perna et al. 2020) that is associated with healthy parenting (Perlman et al. 2008).

The vagus nerve, the principal component of the parasympathetic nervous system, is a major neurobiological building block for both the maintenance of adult health and the avoidance of pathology (Kolacz et al. 2019). For example, the vagus nerve regulates the stress response system (hypothalamic–pituitary–adrenal axis) through the frontal-striatal network (Agorastos et al. 2019; Ohira et al. 2013). *Higher* vagal tone reflects more flexible top-down regulation yielding increased physiological and immune functioning (Ohira et al. 2013). Through afferent fibers, the vagus nerve also operates as the interface for the gut–brain axis, promoting gastrointestinal and microbiota health (Bonaz et al. 2018). When cardiac vagal functioning is dysregulated, the risk for psychopathology increases, such as depression, post-traumatic stress disorder (PTSD), and disorders involving the brain–gut axis and immunity (Breit et al. 2018).

Similar to other neurobiological systems, the vagus nerve is sensitive to experiences in early life (Porges 2011). Over the course of evolution, developmental systems (Oyama 1985) for raising the young became the source and range of both stability and variability of neurobiological development across species, including vagal regulation (Lickliter and Harshaw 2020). Importantly, cardiac vagal inflexibility is associated with negative parenting behaviors (Zhang et al. 2021). As such, understanding ways to support adult cardiac vagal functioning may have broad implications for the prevention of parent pathology and harmful parenting behaviors that influence an offspring's lifespan.

The human EDN is comprised of common characteristics identified worldwide among foraging small-band hunter-gatherer groups (Hewlett and Lamb 2005), the type of society in which the human genus spent 992010% of its existence (Lee and Daly 2005). Foragers are fiercely egalitarian and largely peaceful (Fry 2006, 2013) and raise children together (Hrdy 2009). Like every animal's nest, the EDN is a million-year-old developmental system that offers an evolutionary baseline for the kinds of experiences that promote species-normal healthy biopsychosocial development (Narvaez 2024; Narvaez et al. 2022). Childhood EDN includes experiences that biological, developmental, social, and neurosciences indicate are vital for well-being for example, positive touch (e.g., Champagne 2018; Field 1995), responsive relationships with mother and others (e.g., Hrdy 2009; Schore 2019), self-directed free play (e.g., Gleason et al. 2021), welcoming social climate, and social embeddedness (e.g., Carter 2005; Carter and Porges 2013; Worthman et al. 2010). (For more details on the psychological and physiological effects of each component of the EDN, please see Narvaez, Panksepp, et al. 2013b; Tarsha and Narvaez 2023).

When engaging with the social world, moderate changes to cardiac vagal functioning could be indicative of positive engagement and possible adaptive self-regulatory physiological functioning (Feldman 2012). On the other hand, large changes to maternal cardiac vagal are related to maternal psychopathology. For example, when confronted with stressful situations, cardiac vagal reactivity is associated with maternal psychopathology, but when engaged in a collaborative or positive task, cardiac vagal reactivity is associated with fewer psychopathological symptoms (Hale et al. 2024). Emerging research is beginning to disentangle the relationship between context, cardiac vagal reactivity, and the social world, but more research is needed to understand what factors influence, if at all, the relationships among these variables.

For example, a recent study demonstrated that childhood EDN experience may contribute to healthy autonomic regulation in adulthood. Adult women found that reported experiences consistent with the EDN in childhood buffered the effects of reported childhood adversity (Tarsha and Narvaez 2021). Greater EDN-consistent history was associated with cardiac vagal adaptability across baseline and stress conditions, suggesting enhanced autonomic flexibility, moderating the impairing effect of adverse childhood experiences. The results suggest that positive experiences in childhood may not only buffer the negative effects of trauma but also provide necessary support for healthy development. However, what is not known is which aspects of the EDN influence adult autonomic regulation. To address this gap, we utilized a stress protocol to examine the relation of EDN components to adult autonomic functioning.

1.1 | Current Project

Most studies examine and compare resting (baseline) cardiac vagal tone, whereas few studies have examined how cardiac vagal tone changes in challenging contexts (Scrimin et al. 2018). Cardiac vagal flexibility refers to the change of vagal activity from one context to another (Muhtadie et al. 2015). In this study, we examined baseline and flexibility aspects, specifically, whether the unique variance of each component of the EDN in childhood predicted adult cardiac autonomic regulation during (a) baseline and recovery (resting vagal activity), (b) stress, and (c) changes: *change or slope* across conditions from baseline to stress (vagal reactivity) and *change or slope* from stress to recovery (vagal recovery). We hypothesized that EDN experience would relate to *higher* (more relaxed, cardiac vagal augmentation) resting cardiac vagal tone, *higher* cardiac vagal tone during the stress conditions, and that experiences antithetical to the EDN would relate to *lower* (more stressed, cardiac vagal withdrawal) cardiac vagal tone levels across all conditions. In addition, we expected that a greater amount of EDN experiences would predict greater cardiac vagal flexibility (greater vagal reactivity and recovery) with the opposite pattern of cardiac vagal flexibility for experiences antithetical to the EDN.

2 | Materials and Methods

2.1 | Participants

Participants were from a multiyear longitudinal study of mother–child dyads recruited when mothers were pregnant through local community agencies and doctor's offices (67% White/Euro-American, 13% African-American). Maternal data (N = 78; 84% White/Euro-American, 8% African-American; 80% first-time mothers) from two timepoints were used. The first timepoint used was when the children were about age 4, and the second timepoint was when the children were about age six (Time 1: $M_{age} = 31.75$, $SD_{age} = 4.74$; Time 2: $M_{age} = 33.75$, $SD_{age} = 5.39$; at both times mean yearly household income was reported as $50,000–$75,000). Participants were observed at a university research center and given gift cards for each session.

2.2 | Measures

Two types of data were collected: survey responses (Time 1) and biological data (Time 2).

Survey. Women's childhood experience was assessed using EDN history (EDNh; Narvaez et al. 2016; test–retest $r = 0.87$; Tarsha and Narvaez 2021), a self-report measure of adult recollections of experiences consistent with the EDN. Although items can be added as a sum score, they do not load on one factor and can be treated individually, which was done here. Items assessed (a) touch with single items: positive (hugs and kisses) and negative (corporal punishment, reversed) (1 = *never* to 5 = *very often*) that were summed; (b) *responsive social environment* (3 items; 1 = *very slightly/not at all* to 5 = *very much*): happy, supportive, needs met; (c) *social embeddedness* (2 items; doing things together as a family inside/outside the home; 1 = *less than yearly* to 7 = *every day*); (d) two home climate sum scores (1 = *never* to 6 = *always/almost always*): experienced negative emotions (e.g., grief, guilt, fear, anger) and positive emotions (e.g., joy, expansiveness, serenity); (e) sum score of *self-directed free play* with other children inside and outside the home (2 items; 1 = *rarely* to 5 = *almost always*). The mean of each EDN subscale was used.

Biological Date. Respiratory Sinus Arrhythmia (RSA). Prior to data collection, participants were screened for medication use (e.g., stimulants that increase heart rate), including alcohol and caffeine. Women's electrocardiogram (ECG) and respiration rate and volume were simultaneously measured, comprising an index of vagal tone functioning: the amplitude of heart rate rhythm associated with frequency of spontaneous breathing (Porges and Byrne 1992; range of spontaneous respiration 0.12–0.4 Hz). Instruments included BioPac hardware and AcqKnowledge software. Three disposable Ag–AgCl electrodes were placed on the participant's chest in a lead II configuration, connected to an ECG amplifier, and output to a Bionomadix wireless RSP ECG transmitter (Biopac Nomadix, Inc.).

Biological Data Qualification. The Bionomadix Wireless Respiration and ECG module pair (matched transmitter and receiver) detected the peak of the *R*-wave with 1-ms accuracy, timed sequential heart periods to the nearest millisecond (Riniolo and Porges 1997) and stored the heart periods in files for offline 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) 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 offline using CardioEdit software. Editing of RSA data for anomalies and artifacts was done according to Porges' Laboratory method using CardioEdit (Abney et al. 2021; Brown et al. 2021). Editors received RSA editing training and reliability testing through the Porges lab. Editing consisted of integer arithmetic (i.e., dividing intervals when detections were missed 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, which are sensitive to the maturational shifts in the frequency of spontaneous breathing. CardioBatch Plus Synchrony additionally uses the same resampling rate (step b below), according to the fastest respiration rate for either member of the 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 were 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 adults and 21-point for children) (Porges and Bohrer 1990) 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 (i.e., Child: 0.24 –1.04 Hz and Adult: 0.12–0.4 Hz) specific to each member of the dyad; and (e) the resulting bandpassed time series is divided into epochs (30 s, in this case), the natural logarithm of the variance of each epoch is calculated as the measure of the amplitude of RSA (Riniolo and Porges 1997), and the epochs are averaged within each condition.

2.3 | Procedure

Women completed a survey at each time point, though only data from Time 1 was used; mothers' and children's RSA data were collected at Time 2 via three different conditions. Only the mother's RSA data were analyzed in this study. For the RSA experiment, all conditions were equally spaced apart and administered simultaneously. The three conditions were baseline (resting state), a stress task, and recovery. This design followed standard RSA methodology for experimental procedures (Laborde et al. 2017). The RSA data were collected only after the mother and child completed sedentary activities for approximately 15 min. The RSA conditions consisted of the following: during baseline and recovery conditions, participants sat on a comfortable couch and watched a non-stimulating video for 2 min. During the 5-min stressful condition, participants worked on two difficult 3-dimensional picture puzzles while a timer ticked. Two paired sample *t*-tests demonstrated the stress condition significantly reduced women's RSA values compared to the resting conditions, $ts\,(73) > 4.5$, $ps < 0.001$, demonstrating a v-shape data pattern. The stress condition was significantly lower than both the baseline and recovery conditions, providing evidence that both the stress and recovery conditions were effective.

2.4 | Analytic Plan

In order to accurately model the changing nature of RSA across different conditions, a latent basis coefficient (LBC) model was used. LBC modeling is a type of latent growth curve model that takes into account nonlinear (v-shape) change patterns across time (Grimm et al. 2011).

All predictors were simultaneously added to the LBC model and were treated as manifest variables (see Figure 1 for an overview of all three models). Latent growth curve models were conducted using Mplus (Muthén and Muthén 2023). Goodness of fit was assessed using root mean square error of approximation (RMSEA) values below 0.08, comparative fit index (CFI) values greater than or equal to 0.95, and chi-square with p values greater than 0.05 (Hu and Bentler 1999). Missing data were handled using full-information-maximum-likelihood, which has been found to be appropriate for data that are missing completely at random

TABLE 1 | Descriptives for all variables.

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Physiological variables					
Baseline RSA	74	3.42	9.05	6.12	1.17
Stress RSA	74	2.38	10.01	5.56	1.37
Recovery RSA	74	2.20	9.46	6.00	1.25
Evolved developmental niche history (EDNh)					
Touch	89	1.5	5.00	3.76	0.82
Responsive social environment	89	1.67	5.00	3.99	0.88
Social embeddedness	89	2.00	7.00	5.58	1.04
Negative home climate	89	1.00	5.00	2.62	0.84
Positive home climate	89	2.50	6.00	4.50	0.84
Self-directed play	89	2.00	6.00	4.82	1.01

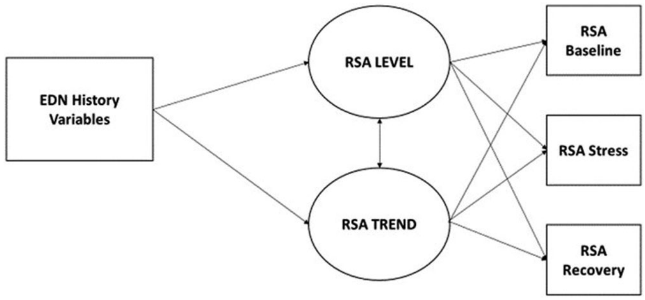

FIGURE 1 | Latent basis coefficient model: maternal evolved developmental niche history to maternal respiratory sinus arrhythmia.

and missing at random (Enders and Bandalos 2001). Descriptive statistics are found in supplemental material.

3 | Results

3.1 | Descriptives

Descriptives for all variables are found in Table 1. See Table 2 for correlations.

3.2 | Models

Three models were utilized to assess resting cardiac activity (baseline), cardiac vagal reactivity, and cardiac vagal recovery (flexibility). Different factor loadings for the *level* and *trend* (rate of change) latent variables were utilized. The first latent variable of the *level* indicated women's RSA values for each condition, and these factor loadings were all set to 1. The second latent variable of *trend* indicated women's RSA slope or vagal flexibility across the conditions and factor loadings depended upon the model. For Model 1 (baseline to stress), the *trend* factor loadings were 0 and 1, with the last factor loading being allowed to be freely estimated. For Model 2 (stress to recovery), the *trend* factor loadings were 0 and 1 for the second and third conditions, with the first factor loading being allowed to be freely estimated. For Model 3, the *trend* factor loadings were 1 and 0 for the second and third conditions, with the first condition being allowed to be freely estimated. Because the factor loadings are in the opposite order of sequential time in this model, only the level variable was interpreted. Next, EDNh predictors were included in the model to predict the *level* and the *trend*, and they were allowed to correlate with each other. As is customary, the latent variables of *level* and *trend* were also allowed to correlate with each other (Duncan and Duncan 2009). Results for all models are found in Table 2.

Model 1 Baseline to Stress demonstrated a good fit ($\chi^2 = 1.05$, $p = 0.99$, CFI = 1.00, RMSEA = 0.00). The correlation between the RSA *level* and RSA *trend* was not significant, $r = 0.02$, $p = 0.85$, indicating that the initial RSA *level* did not significantly relate to the slope from baseline to stress. Regarding predictors, none of the EDNh variables significantly predicted the baseline. Regarding the *trend*, the unique variance of EDNh *Social Embeddedness* significantly predicted RSA slope, $\beta\hat{} = -0.31$, $p = 0.008$. Higher rates of childhood social embeddedness predicted less steep slopes in RSA from baseline to stress.

Model 2 Stress to Recovery demonstrated a good fit ($\chi^2 = 1.05$, $p = 0.99$, CFI = 1.00, RMSEA = 0.00). The correlation between RSA *level* and RSA *trend* was significant, $r = -0.41$, $p < 0.001$, indicating that RSA stress is significantly related to the slope from stress to recovery. Two of the EDNh variables significantly predicted RSA *level*, EDNh *Social Embeddedness*, $\beta = -0.40$, $p = 0.035$, and *Positive Home Climate*, $\beta = 0.59$, $p = 0.037$. The higher the reporting of past social embeddedness, the lower the RSA values during the stress condition. Conversely, the higher the positive climate in the woman's history, the higher the RSA values during the stress condition. Regarding the *trend*, the variance of EDNh, social embeddedness, significantly predicted RSA slope, $\beta = 0.21$, $p = 0.008$. Higher rates of childhood social embeddedness predicted steeper slopes in the RSA from stress to recovery.

TABLE 2 | Correlations for all variables.

Variables	1	2	3	4	5	6	7	8	9
1.RSA baseline	1								
2.RSA stress	0.74**	1							
3.RSA recovery	0.81**	0.81**	1						
4. Touch	−0.06	−0.06	−0.08	1					
5. Responsive Social environment	−0.06	0.05	−0.036	0.72**	1				
6. Social embeddedness	−0.09	−0.27*	−0.15	0.49**	0.44**	1			
7. Negative home climate	0.015	−0.04	0.04	−0.47**	−0.45**	−0.24*	1		
8. Positive home climate	0.12	0.22	0.14	0.54**	0.70**	0.35**	−0.53**	1	
9. Self-directed play	−0.04	0.07	−0.01	0.42**	0.36**	0.23**	−0.06	0.30*	1

Abbreviation: RSA, respiratory sinus arrhythmia.
*$p < 0.05$.
**$p < 0.01$.

Model 3 Level of Recovery demonstrated a good fit ($\chi^2 = 1.05$, $p = 0.99$, CFI = 1.00, RMSEA = 0.00). Because this model only investigated the level of recovery, the latent variable of the trend was not interpreted. Regarding the predictors, one of the EDNh variables significantly predicted level RSA and, in the expected direction, *Positive Home Climate*, $\beta = 0.50$, $p = 0.048$. The higher the reporting of past experience of a positive home climate, the higher the level of RSA during the recovery condition.

4 | Discussion

This study investigated the unique influence of each component of the EDN on women's autonomic regulation years later. Two key EDN components were salient predictors of autonomic regulation regarding both vagal tone and vagal flexibility across conditions, but in different ways: social embeddedness and positive home climate.

4.1 | Social Embeddedness Corresponded With Multiple Cardiac Vagal Tone Adaptations

Reported childhood social embeddedness related to cardiac vagal reactivity (reaction to stress) as well as vagal tone during the stress condition. The coefficients in predicting slope were in the opposite direction from baseline to stress and from stress to recovery, which makes sense in light of the expected v-shaped pattern. Childhood social embeddedness predicted less cardiac vagal reactivity (less cardiac vagal withdrawal) as well as increased recovery (more cardiac vagal augmentation) from stress.

Because cardiac vagal adaptability is critical for healthy functioning (Porges 2011), a lack of cardiac vagal reactivity or recovery could indicate maladaptation or psychopathology. A decrease in cardiac vagal activity during the stress condition facilitates increased heart rate and breathing, which indicates greater metabolic output in order to meet the demands of the situation. In this sample, a history of social embeddedness was associated with autonomic adaptability because it both predicted cardiac vagal withdrawal—that is, decreased parasympathetic activity during the stress condition—and also facilitated an increased rate of recovery.

The pattern of autonomic reactivity, as it relates to the history of social embeddedness in childhood, could be described as autonomic stress resilience. Heart rate variability has been described as a biophysiological metric of stress resilience because it is adaptive and leads to beneficial physiological and cognitive outcomes (An et al. 2020). Both relationship quality (Calkins et al. 2008) and social stress (Montirosso et al. 2014) in infancy have been identified as significant, long-term predictors of autonomic functioning, specifically vagal adaptivity. Thus, the finding that childhood social embeddedness was an influential variable of adult autonomic reactivity makes sense in light of the existing literature. What is novel in this study is the finding that social embeddedness predicted *three different adaptive behaviors* for women: it predicted cardiac vagal withdrawal when needed (heart rate acceleration); it predicted steeper slopes from stress to recovery, and it "protected" the women from becoming too stressed (mean level) during a stressful condition. These findings suggest that social embeddedness in childhood may be a protective factor in adulthood, providing general stress resilience.

4.2 | Positive Home Climate Predicted Vagal Tone

The second key finding was that the history of childhood positive home climate predicted cardiac vagal tone during the stress and recovery conditions. The higher the rating of positive home climate in childhood, the greater the vagal tone (cardiac vagal augmentation) in both conditions. Social embeddedness was also associated with cardiac vagal tone, but in the stress condition, the coefficients were in the opposite direction (increased cardiac vagal tone), suggesting that different types of positive experiences in childhood may have differing effects on how women react to stress. Positive climate, for example, may be particularly effective at reducing cardiac vagal tone during stress, whereas social embeddedness may support activation of the social engagement system, potentially activating arousal of the nervous system (Porges 2011).

Because positive home climate *positively* predicted cardiac vagal tone, this suggests that a positive home climate may support higher cardiac vagal tone values in general. Specifically, a positive home climate in childhood may indicate an environment that serves as a parasympathetic regulator, aiding adaptation during changing conditions. Indeed, a positive climate in childhood has been shown to be an important buffer to adverse experiences (Merrick et al. 2019) and critical for neurochemical support of brain development (Shonkoff 2010).

5 | Conclusion

5.1 | Limitations and Future Directions

Several limitations must be mentioned. First, assessment of EDN in childhood was a retrospective self-report measure. Although the EDN is a million-years-old developmental system, empirical investigation of its long-term neurophysiological influence on adults is still nascent. As such, a retrospective self-report of the EDN can be considered a first step with regard to the investigation of its different components. Future research should consider multi-informant approaches to assessing EDN experience and do so longitudinally. Second, we did not examine all EDN components (e.g., soothing perinatal experiences, years-long breastfeeding, nature immersion), which could also be done in additional studies. Third, the sample size was small and relatively homogenous (predominantly White). Future research should include larger samples from more diverse populations, including non-WEIRD populations (western, educated, industrialized, rich, and democratic; Henrich et al. 2010). However, considering the research of the EDN is a nascent area of investigation, this study serves as the first step toward larger empirical investigations.

5.2 | Implications

Autonomic functioning is a key neurobiological indicator of health, supporting physiological flexibility, protecting against stress, and promoting stress resilience in adulthood. The EDN may be essential for providing a context for healthy autonomic functioning development. Further, emerging evidence suggests that healthy cardiac vagal functioning is critical for managing stress behaviors related to healthy parenting (Hale et al. 2024). Providing experiences of social embeddedness and a positive climate in the home may be particularly important for fostering physiological capacities necessary for health, avoiding pathological outcomes in adulthood, and the increasing positive parenting behaviors for the next generation. Future research and interventions should consider implementing the EDN, and specifically, social embeddedness and positive climate in the home when striving to foster both maternal health and positive parenting behaviors.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data and study materials are available upon request from the first author.

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