Differential Associations of Childhood Abuse and Neglect With Adult Autonomic Regulation and Mood-Related Pathology

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ABSTRACT

Objective: This study assessed whether different types of childhood maltreatment (i.e., abuse versus neglect) had differential relationships with heart rate variability (HRV) and baroreflex sensitivity. In addition, this study tested the indirect effect of maltreatment subtypes on adult mood-related psychopathology via HRV, and whether these relationships differed in those with HRV above and below established clinical cutoffs.

Methods: Secondary analysis was performed using the Midlife Development in the United States data set ($N = 967$; $M_{age} = 55$; 58.4% female; 75.9% White). In a single study visit, autonomic measurements were captured at rest, during two cognitive stressors (Stroop and MATH tasks), and during recovery after the tasks. Structural equation modeling was used to assess the relationships between key variables during all three measurement periods.

Results: Resting pathways from abuse and neglect to baroreflex sensitivity were nonsignificant, as was the pathway from HRV to mood-related pathology. Notably, greater abuse was significantly predictive of lower HRV (standardized $\beta = -0.42$, $p = .009$), whereas greater neglect was significantly predictive of higher HRV (standardized $\beta = 0.32$, $p = .034$). In addition, higher abuse was significantly predictive of greater adult symptoms (standardized $\beta = 0.39$, $p < .001$), but neglect was not found to be related to adult mood-related pathology. Significant relationships between variables were only found in those with low HRV.

Conclusions: Although cross-sectional, our findings provide further evidence that low HRV may be a transdiagnostic endophenotype for mood-related pathology and suggest that greater differentiation between abuse and neglect is appropriate when investigating the impact of childhood maltreatment on adult health outcomes.

Key words: childhood maltreatment, autonomic functioning, heart rate variability, baroreflex, anxiety, depression.

INTRODUCTION

Childhood maltreatment is a significant public health concern, with one in seven children in the United States experiencing abuse and neglect within the past year alone (1). Exposure to maltreatment during childhood can influence both biological and psychological development and is associated with a wide range of maladaptive physical and mental health outcomes in adulthood (2), particularly mood disorders such as anxiety and depression (3). Childhood maltreatment is posited to contribute to these health concerns through a "biological embedding" of the maltreatment, which likely occurs through developmental alterations to the biological systems responsible for responding to stress (4). The experience of childhood maltreatment includes several different types of exposures such as physical, sexual, and emotional abuse, as well as physical and emotional neglect (5). Notably, few studies have directly assessed how biological embedding of these maltreatment subtypes may play out into specific health outcomes in adulthood (6).

The autonomic nervous system is the body's first line of defense against a detected stressor and comprises two branches: the sympathetic nervous system (commonly known as the "flight-or-flight" system) and the parasympathetic nervous system (sometimes referred to as the "rest-and-digest" system) (7). The parasympathetic nervous system is governed primarily by the vagus nerve, which acts as a bidirectional pathway between the brain and most major organs including the lungs, viscera, and heart (8,9). Because of the role of the vagus in regulating the parasympathetic response to stress, measurement of autonomic activity

BIC = Bayesian information criterion, **BP** = blood pressure, **BRS** = baroreflex sensitivity, **CFI** = Comparative Fit Index, **CTQ** = Childhood Trauma Questionnaire, **HR** = heart rate, **HRV** = heart rate variability, **MASQ** = Mood and Anxiety Symptom Questionnaire, **MIDUS** = Midlife Development in the United States, **MLR** = maximum likelihood estimation robust to skew, **RMSEA** = root mean square error of approximation, **RMSSD** = root mean square of successive differences, **TLI** = Tucker-Lewis Index

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has often centered on cardiovascular markers regulated by vagal activity, such as heart rate variability (HRV) and baroreflex sensitivity (BRS) (10). HRV is an index capturing beat-to-beat variation in heart rate (HR) and is widely used as a measure of effective vagal control over the heart (11). Higher HRV is largely known as a marker for a healthier and more adaptive autonomic functioning, whereas lower HRV has been associated with a range of both physical and psychological disorders (12–14). BRS measures the activity of the baroreflex, a vagally regulated process that maintains blood pressure (BP) levels through a dynamic feedback loop that lowers HR in response to increasing BP (15). Baroreceptors in the aortic arch are innervated by the vagus, and vagal cholinergic signaling regulates the beat-to-beat changes in HR, which follow detected changes in BP (16). Impairment in BRS has shown to be predictive of cardiovascular disease later in life (17), and although its association with affective states is largely unknown, preliminary research has been observed BRS impairment in patients with depression and anxiety (18).

Developmental researchers have repeatedly observed that exposure to childhood abuse and neglect is associated with decreased parasympathetic activity at rest and in response to acute stress; however, findings have not always been consistent. A recent systematic review from McLaughlin and colleagues (6) found that current evidence largely supports a dimensional model of childhood adversity, which posits that early threat-related maltreatment exposures (such as physical, sexual, and emotional abuse) and early deprivation-related exposures (such as physical and emotional neglect) differ in terms of their neurobiological consequences during development. For example, threat-related exposures were found to be more consistently related to decreased limbic structure volumes and increased amygdala reactivity/decreased prefrontal cortex activity in response to acute stress, whereas deprivation-related exposures were more likely to be associated with reduced volume and thickness of frontoparietal structures such as the dorsolateral prefrontal cortex and superior parietal cortex. However, no studies to date have explored these dimensional differences in the relationship between maltreatment experiences and autonomic regulation in adulthood.

The literature investigating childhood maltreatment and autonomic regulation in adulthood is similarly complicated, and, to our knowledge, only three studies have assessed this relationship using nonclinical samples. A study by Buisman et al. (19) found that parents with history of neglect displayed patterns of greater sympathetic reactivity in response to their child, which were not observed in parents with a history of abuse. A recent population-based study (20) found that cumulative maltreatment exposure scores were associated with impaired BRS and lower resting HRV, but the relationships were no longer significant after adjusting for socioeconomic and demographic characteristics. Another recent study (21) observed that those with a history of childhood maltreatment had higher resting HR and prolonged HR recovery in response to an acute stress task than those with no such history. Notably, no differences in resting HRV were found between those with a history of maltreatment and those without; however, an analysis of exposure subtypes showed that those with a history of physical abuse had higher HR and HRV during sleep, which may suggest prolonged parasympathetic withdrawal in those with this type of exposure.

Understanding how patterns of autonomic regulation may be dysregulated in those with a history of childhood maltreatment may shed a light on pathways by which vulnerability to mood-related psychopathology in adulthood is conferred. Markers of autonomic functioning, such as HRV, have been associated with emotional regulation (9). For example, persons with low HRV show greater difficulties regulating emotions (22), and recent meta-analyses have concluded that HRV is lower in persons with depression (23) or posttraumatic stress disorder (24) than in those without these disorders. Because survivors of childhood maltreatment are known to be at risk for the development of such mood disorders later in life, it is important to identify the biological patterns that may contribute to this vulnerability. In addition, mounting evidence suggests that low HRV may be an endophenotype for several psychological disorders (9), which raises the possibility of a nonlinear relationship between HRV and psychological distress, such that those with low HRV may be at greater risk for the development of psychological disorders than those with high HRV. Jarczok and colleagues (25) first provided evidence for a clinically meaningful cutoff for HRV such that those below a certain value were at significantly elevated risk for cardiovascular health concerns; however, more research is needed to determine whether this cutoff is meaningful in terms of elevated risk of mood-related symptoms as well. If higher HRV does indeed serve as a protective factor against the development of mood-related symptoms, one would expect the relationship between severity of childhood maltreatment and adult mood-related psychopathology to be strongest at low levels of HRV and weakest at higher levels. However, direct investigation of the potential nature of this relationship has not yet been conducted.

This study had three primary aims. First, this study sought to investigate whether threat-related maltreatment exposures (such as physical, sexual, and emotional abuse) and deprivation-related maltreatment exposures (such as physical neglect, emotional neglect) were associated with differential autonomic patterns in adulthood both at rest and in response to an acute stressor. Second, we sought to test HRV as a potential mediator of the relationship between maltreatment exposure subtypes and severity of mood-related pathology in adulthood. Third, we aimed to assess whether the relationships between these variables differed in those with clinically high HRV and those with clinically low HRV. To do this, secondary data analysis was conducted from the second wave of the Midlife Development in the United States (MIDUS) study Biomarker Project. We hypothesized that greater severity of abuse-related exposures would be associated with lower HRV and BRS, both at rest and in response to an acute stressor, whereas neglect would not be associated with these autonomic impairments. In addition, we hypothesized an indirect effect of childhood maltreatment subtypes on adult mood-related pathology via HRV activity at rest and in response to an acute stressor. Lastly, we hypothesized that the relationships between childhood maltreatment subtypes, HRV, and mood-related psychopathology would be stronger in magnitude in those with low HRV than in those with high HRV.

METHODS

Participants

Adults older than 18 years were recruited from areas surrounding three large universities in the United States, located in Madison, WI; Washington, DC; and Los Angeles, CA, over a 5-year period between January 2004 and December 2009. A total of 1059 participants were enrolled and completed some portion of study

activities. For our secondary analysis, participants endorsing a history of cardiovascular disease, myocardial infarction, or currently using a pacemaker were excluded from analysis, as these conditions highly influence autonomic patterns both at rest and in response to acute stress (11). This resulted in a final sample of 967 participants who completed at least some portion of the psychophysiological protocol. Our final sample was 58.4% female (n = 564) and 41.6% male (n = 403), with a mean (standard deviation) age of 55 (10.64) years. Our sample identified themselves as 75.9% White (n = 734), 2.3% African American (n = 22), 0.7% Asian or Pacific Islander (n = 7), and 3.3% ethnically Hispanic (n = 32), with the remainder of the sample declining to self-report (n = 172). The mean education level of our sample was 1 to 2 years of college, and the average household income was $51,295 per year. Our sample was relatively low in terms of mood-related symptoms, with mean scores across anxiety and depression scales reported at approximately 30% of the maximal possible score on each subscale (reported means in Table S1, Supplemental Digital Content, http://links.lww.com/PSYMED/A955).

Procedure

Institutional review board approval was gained at each of the three MIDUS study sites, and informed consent was obtained from all participants before study activities. After the consent process, participants completed demographic information and were then connected to the electrocardiogram (ECG) for physiological data collection. Two consecutive resting epochs of 5 minutes each were first collected while the participant was asked to sit quietly in a chair. After resting measurement collection of HRV and BRS, participants were counterbalanced to complete one of two cognitive stressor tasks: the MATH or the Stroop tasks. The MATH task is a mental arithmetic task designed for use in laboratory studies of cardiovascular stress and reactivity. The task involves trials of three different stimuli presentations: a math problem appearing for 2.0 seconds, the word "Equals" for 1.5 seconds, and a solution to the problem that appears for 1.0 second. The participant is then asked to press one of two keys on a keypad to indicate whether the presented solution was correct. Participants must answer within the 1.0-second period, or their response is recorded as incorrect. There are five levels of difficulty for this task, and all participants begin at level 3. Correct initial responses will prompt a step up in difficulty for the remaining presentations, whereas incorrect initial responses will result in a step down in difficulty. The number of trials varied by the participant's response times, with all participants completing the task within 4 to 6 minutes. The Stroop task, on the other hand, presents the words of four different color names (blue, green, yellow, or red) in a font color that either matches or does not match the name of the color. The name of the color appeared on the screen, and participants were asked to press one of four keys in front of them, which corresponded to the color of the letters of the word rather than the color name. The rate of stimuli presentation varied as a function of task performance to standardize the stressfulness of the task among all participants. Those who initially answer accurately were then presented with a more rapid stimuli presentation rate, and those who answered less accurately had a slower rate of stimuli presentation. Participants completed their first cognitive stressor and afterward were asked to rest for 5 minutes quietly, to collect recovery measurements. After a 5-minute recovery epoch, participants completed the second cognitive stressor task. After the second cognitive stressor task, there was a final 5-minute resting period while recovery measurements were collected from the participants. After physiological data collection, participants completed the self-report questionnaires. After completion of study tasks, participants were compensated for their time. All data collected from this study are publicly available at the following link: https://midus.colectica.org/.

Measures

Childhood Trauma Questionnaire

The Childhood Trauma Questionnaire (CTQ) is a 25-item self-report questionnaire measuring severity of exposure to childhood maltreatment across five domains (emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect). Participants were asked to report how often a particular statement was true for them during childhood (e.g., "I didn't have enough to eat," "I believe that I was physically abused.") on a scale from 1 to 5, corresponding to descriptive statements ranging from "Never true" to "Very often true." Each subscale contained five statements, resulting in the potential for scores to range from 5 to 25 for each of the five domains. Subscales were totaled in accordance with previously established guidelines (26) to assess the severity of exposure to abuse and neglect maltreatment subtypes in childhood.

Mood and Anxiety Symptom Questionnaire

The Mood and Anxiety Symptom Questionnaire (MASQ) is a 64-item self-report questionnaire measuring the presence of depression and anxiety symptoms over the past week. Four subscales were used to assess anxious symptoms, anxious arousal, depressive symptoms, and anhedonic depression. Participants were asked to endorse how much a particular symptom had bothered them that week from 1 to 5, with the scale corresponding to descriptive ranging from "Not at all" to "Extremely." The four subscales were totaled in accordance with previously established methods (27) to assess the severity of ongoing symptoms in each domain.

Heart Rate Variability

HRV was collected via a three-lead ECG at a sampling rate of 500 Hz, and the captured high-frequency RR intervals (bandwidth 0.15–0.40 Hz, ms^2 units) were used to calculate all indices of HRV. ECG sensors were placed on the left and right shoulders, and on the left lower side of the torso. Root mean square of successive differences (RMSSD) was calculated through measurement of time differences between RR intervals in milliseconds. These values are then squared, the result is averaged, and finally, the square root of the total is calculated. RMSSD values were then log transformed to improve normality of distribution. Resting HRV values were collected during the two 5-minute epochs of rest before the first cognitive stressor tasks. To measure HRV reactivity to the two counterbalanced cognitive stressor tasks, two change scores were created: one by subtracting the participant's resting RMSSD from their RMSSD after the MATH stressor task (representing the change in RMSSD from resting to the MATH task) and the other by subtracting their resting RMSSD from their RMSSD after the Stroop stressor task (representing the change in RMSSD from resting to the Stroop task). Measurement of HRV recovery after the stressor tasks was calculated similarly, with two change scores

created: one by subtracting the participant's RMSSD after the MATH stressor task from the RMSSD of the recovery period after the MATH task (representing the change in RMSSD from the MATH epoch to the recovery epoch) and the other by subtracting their RMSSD after the Stroop stressor task from the RMSSD of the recovery period after the Stroop task (representing the change in RMSSD from the Stroop epoch to the recovery epoch).

Baroreflex Sensitivity

To observe the engagement of the baroreflex in the alteration of BP through changes in HR, both BP and HR were measured at rest, in reactivity to acute stress, and during recovery from acute stress. HR was measured as mentioned previously using high-frequency ECG recording at a sampling rate of 500 Hz, with RR intervals converted to beats per minute units. BP was measured using a Finometer BP cuff that was placed on the participant's middle finger of their nondominant hand, as well as a cuff placed on the upper arm on the same side as the finger cuff. Indices of BRS were measured using a sequence method approach. Three or more BP values that increase or decrease consistently increasing or decreasing are considered a "sequence" that represents engagement of the baroreflex. These sequences are then used to calculate BRS during each of the collection periods. BRS is calculated by first identifying the corresponding BP and ECG data during each period and subtracting 250 milliseconds from all BP times to adjust for the known delay in the Nexfin BP recording monitor. The diastolic records were then removed, the RR intervals were computed, and data occurring during bad intervals from both BPs and RRs are removed. Sequences of three or more consecutive BP increases or decreases were then identified, and the corresponding RR intervals matched with the BP sequences. Linear regression was then used to estimate the slope of each sequence, and unwanted sequences (those with more than one BP reading within 1 RR interval, any RR interval greater than 2 seconds) are removed. The mean slope was then created from the remaining sequences. One representative mean slope was created for each epoch: one for the resting period, one for each of the two cognitive stressor tasks (MATH and Stroop), and one for each of the two recovery periods after the stressor tasks.

Statistical Analysis

The primary goals of this study were to assess a) whether meaningful differences in abuse- and neglect-related childhood maltreatment exposures influenced adult autonomic functioning, and b) whether there was a significant indirect effect of maltreatment exposure subtypes on adult mood-related psychopathology via HRV. In addition, this study sought to assess whether those relationships may differ among those with high HRV and those with low HRV. As such, a three separate multiple group structural equation models were performed using R statistical software (28) version 4.1.1 "Kick Things" (2021-08-10). These models examined the relationship between abuse and neglect severity at three separate epochs of physiological functioning: at rest using resting measurements of HRV and BRS (resting model), in response to the MATH and Stroop cognitive stressors (reactivity model), and during the recovery period after the cognitive stressor tasks (recovery model). To examine these relationships among those with high and low HRV, two groups were created using an established transdiagnostic RMSSD value threshold of 25 (25), with the models structured the same way for both the low and high HRV groups. Age, sex, education level, household income, and hypertensive medication use were assessed as potential covariates of HRV and BRS at the bivariate level. Age and hypertensive medication use were found to be associated with both HRV and BRS functioning at each epoch; therefore, these variables were included as covariates in all three models as direct predictors of the HRV and BRS latent variables. Full-information maximum likelihood was used to estimate values missing within the data set for all three models. Measurement and structural details for each of the models are presented hereinafter. Structural paths for the three models are illustrated in Figure 1. Codes for all analyses performed are available upon request.

Resting Model

In line with McLaughlin and colleagues' (6) work supporting a dimensional model of childhood adversity, this study used subscales from the CTQ to create two latent variables, Abuse (representing severity of childhood threat-related exposures) and Neglect (representing severity of childhood deprivation-related exposure types). The physical abuse, sexual abuse, and emotional abuse subscales served as the three indicators for latent variable Abuse, and the physical neglect and emotional neglect subscales served as two indicators for latent variable Neglect. Because the experience of childhood maltreatment is known to increase the risk of other maltreatment-related exposures and bivariate analyses revealed that subscales of our CTQ measure were highly correlated with one another across our conceptual abuse and neglect domains (Table S2, Supplemental Digital Content, http://links.lww.com/PSYMED/A955), we correlated the errors of the two latent variables to account for this relationship.

In considering the physiological variables in our model, we created a latent variable for Resting HRV, which comprised the two resting epoch measurements taken at the beginning of the psychophysiological protocol. Because only one measurement of BRS was taken during this period, we used this measurement as an observed variable and no latent variable was created. Structural paths from latent variables Abuse and Neglect to physiological markers HRV and BRS were created to assess the relationship between severity of these exposure subtypes and HRV and BRS activity at rest. Because measurements for Resting HRV and BRS are highly related, the errors of these variables were correlated to account for this relationship. In addition, age, sex, and medication use were set as direct predictors of latent variable Resting HRV and observed variable resting BRS to adjust for the influence of these potential covariates in the final model.

All four of the MASQ subscales were used as indicators for a single latent variable Mood Related Pathology. Because all four subscales demonstrate strong, positive correlations significant at the $p < .001$ with one another (Table S1, Supplemental Digital Content, http://links.lww.com/PSYMED/A955), this approach is supported statistically. A structural path from HRV to latent variable Mood Related Pathology was created to assess the potential indirect effects of HRV in the relationship between maltreatment exposure subtype severity and mood-related pathology in adulthood. The relationship between childhood maltreatment and mood-related psychopathology is well established (2); therefore, we also added direct paths from Abuse and Neglect to our endogenous outcome variable Mood Related Pathology. This model was assessed and found to meet both rank and order conditions

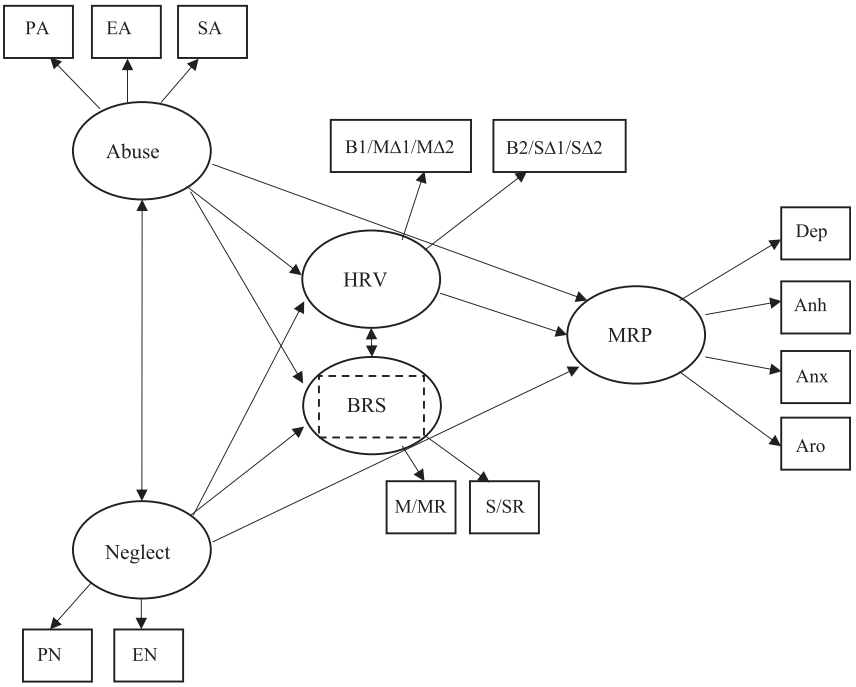

FIGURE 1. Path model for resting, reactivity, and recovery epochs. Path model representing analyses performed, which assess the potentially mediating role of ANS dysregulation in the relationship between CM exposure types and mood-related pathology in adulthood during three different epochs of the psychophysiological protocol: resting, reactivity (during cognitive stressor tasks), and recovery (at rest after the tasks). Parameter estimates are reported in Table 1. Structural paths remained the same throughout the three models; however, BRS was entered as an observed variable in the baseline model and a latent variable comprising two epochs in the reactivity and recovery models. Covariates age, sex, and medication use were adjusted for in each of the three models. ANS = autonomic nervous system; CM = cumulative maltreatment; PA = physical abuse; SA = sexual abuse; EA = emotional abuse; PN = physical neglect; EN = emotional neglect; HRV = heart rate variability; BRS = baroreflex sensitivity; MRP = mood-related psychopathology; B1 = baseline 1 RMSSD; B2 = baseline 2 RMSSD; Dep = depression; Anh = Anhedonia; Anx = anxiety; Aro = arousal; RMSSD = root mean square of successive differences.

proposed by Bollen (29) and is therefore identified. No further constraints were placed on the model to assess the freely estimated parameters of all paths.

As with linear regression models, assumptions are made regarding normality of endogenous variables in the estimation of structural equation model parameter estimates. Because the severity of each of these exposure subtypes is unlikely to take a normal Gaussian distribution in the population and our sample included both maltreatment-exposed and maltreatment-unexposed individuals, normality of the CTQ subscales was assessed. All CTQ variables were found to be highly right skewed (with values of skewness ranging from 0.92 to 3.02). In addition, we anticipated that mood symptoms were unlikely to assume normal distribution in our sample and skewness was once again assessed for each of these indicators. Once again, our variables were found to be highly right skewed, with values ranging from 1.3 to 2.15. Skew present within endogenous latent variables is known to influence parameter estimates such that it increases the risk of making a type I error (30). To address this issue, maximum likelihood robust to skew (MLR) estimation was used to assess this model. MLR corrects the inflated standard error values that are known to occur in models that violate normality assumptions by using the Yuan-Bentler method, which scales a constant representing the amount of average multivariate kurtosis present in the model. This constant then serves as a correction factor, which the traditional goodness-of-fit indices are divided by to obtain corrected values (31). HRV group assignments were entered among estimation commands with the high HRV group comprising those with a resting RMSSD of 25 or greater and with the low HRV group comprising those with an RMSSD of 24.99 or lower. Pathways were assessed according to the same specifications in each of the two HRV groups.

Reactivity Model

Measurement considerations for the creation of exogenous latent variables Abuse and Neglect, as well as endogenous outcome variable Mood Related Pathology, were performed consistently with the resting model discussed previously. The two reactivity change scores served as indicators for the latent variable HRV Reactivity. BRS measurements for the MATH and Stroop epochs were used as indicators for the creation of latent variable Stressor BRS. The errors of latent variables HRV Reactivity and Stressor BRS were correlated to account for the relationship between them. As with the resting model, age, sex, and medication use were set as direct predictors of latent variables HRV Reactivity and Stressor BRS to adjust for the influence of these variables. Structural paths for this model were consistent with the resting model, with direct paths from Abuse and Neglect to both HRV and BRS, as well as paths from Abuse, Neglect, and HRV Reactivity to Mood Related Pathology. As with the resting model, MLR estimation was used to assess this model and the model was found to meet both rank and

order conditions. No further constraints were placed on the model to assess the freely estimated parameters of all paths. HRV group assignments were entered among estimation commands in accordance with the resting model.

Recovery Model

As with the reactivity model, measurement considerations for the creation of latent variables Abuse, Neglect, and Mood Related Pathology were made in accordance with the resting model. The two recovery change scores served as indicators for the latent variable HRV Recovery. BRS measurements were taken during the recovery periods after both the MATH and Stroop tasks, and the measurements for these epochs were used as indicators for the creation of latent variable BRS Recovery. The errors of latent variables HRV Recovery and BRS Recovery were correlated to account for the relationship between them. As with the other models, age, sex, and medication use were set as direct predictors of latent variables HRV Recovery and BRS Recovery to adjust for the influence of these variables. Structural paths for this model were consistent with resting, with paths from Abuse and Neglect to both HRV Recovery and BRS Recovery, as well as paths from Abuse, Neglect, and HRV Recovery to Mood Related Pathology being assessed. As with the resting and reactivity model, this model was found to meet both rank and order conditions and is therefore identified. No further constraints were placed on the model to assess the freely estimated parameters of all paths. MLR estimation was used to assess this model, consistent with resting and recovery models. HRV group assignments were entered among estimation commands in accordance with the resting model.

Testing Indices of Model Fit

To assess whether the data supported exploring these relationships in those with high versus low HRV, the three models were first run both with and without the multiple group specification, and model fit indices were compared. A lower Bayesian information criterion (BIC) value indicates a more suitable fit for the data (32) when comparing models, and the three multiple group models were found to yield lower BICs when compared with their non–multiple group alternative models (resting BIC of 59,052.46 compared with 61,624.56, reactivity BIC of 61,146.31 compared with 63,141.35, and recovery BIC of 61,590.05 compared with 63,460.46). As such, the multiple group path analysis was used for all three models.

To assess overall fit for the resting, reactivity, and recovery models, MLR-adjusted indices of fit were used, such as the root mean square error of approximation (RMSEA), the Comparative Fit Index (CFI), and the Tucker-Lewis Index (TLI). Although benchmarks for these fit indices are all highly contested (33), this study followed the suggested values of a 0.08 threshold for an acceptable RMSEA value, and a 0.90 threshold value for the CFI and TLI values as proposed by Browne et al. (34).

RESULTS

Results from the resting model yielded a scaled χ^2 test that was statistically significant: $\chi^2(55) = 493.14$, $p < .001$. Although this does indicate that the model may not be the best fit for the data, the χ^2 test is known to be sensitive to inflation by large sample sizes (35). The tests for other indices of fit yielded more acceptable values, with the RMSEA showing an adjusted value of 0.07, and the CFI and TLI showing values of 0.94 and 0.92, respectively. Parameter estimates for the direct structural paths can be found in Table 1. No significant relationships were found between variables in the group with high HRV. In those with low HRV, the paths from latent variables Abuse and Neglect to BRS were not significant; however, the pathways from Abuse (standardized $\beta = -0.42$, $p = .009$) and Neglect (standardized $\beta = 0.32$, $p = .034$) to resting HRV were both found to be significant. HRV was not found to be significantly related to Mood Related Pathology. Similarly, Neglect was not found to be predictive of Mood Related Pathology; however, the path from Abuse to Mood Related Pathology was significant (standardized $\beta = 0.39$, $p < .001$). Indirect effects were additionally assessed, but no significant indirect effects were observed among our variables ($p = .62$).

Results of the scaled χ^2 test for the reactivity model were similarly poor, with $\chi^2(88) = 575.46$, $p < .001$. Other overall model fit indices were within acceptable ranges but with an adjusted RMSEA of 0.07, a CFI of 0.93, and a TLI of 0.91. As with the resting model, no significant relationships were found between variables in the group with high HRV. In those with low HRV, direct structural paths from latent variables Abuse and Neglect to HRV Reactivity were not significant ($p = .78$ and $p = .90$, respectively), nor was the path from HRV Reactivity to Mood Related Pathology. The path from Neglect to Stressor BRS was not found to be

TABLE 1. Results From Final Structural Analyses of Path Models

	Baseline		Reactivity		Recovery	
Paths	β	SE	β	SE	β	SE
Abuse ➔ HRV						
Low HRV	−0.42**	0.032	0.04	0.015	0.12	0.014
High HRV	−0.08	0.018	−0.08	0.022	0.02	0.017
Neglect ➔ HRV						
Low HRV	0.32*	0.032	−0.02	0.016	−0.16	0.015
High HRV	0.06	0.023	0.03	0.027	0.02	0.021
Abuse ➔ BRS						
Low HRV	−0.32	0.077	−0.23*	.062	−0.16	0.07
High HRV	0.10	0.162	0.18	.129	0.01	0.146
Neglect ➔ BRS						
Low HRV	0.17	0.081	0.13	0.067	0.05	0.077
High HRV	−0.15	0.195	−0.19	0.169	−0.07	0.181
HRV ➔ Psychopathology						
Low HRV	0.03	0.585	0.03	0.928	0.01	1.43
High HRV	0.05	1.53	0.04	1.628	0.01	1.96
Abuse ➔ Psychopathology						
Low HRV	0.39*	0.427	0.35*	0.412	0.35*	0.413
High HRV	0.30	0.405	0.30	0.413	0.30	0.405
Neglect ➔ Psychopathology						
Low HRV	0.05	0.419	0.08	0.404	0.09	0.403
High HRV	0.04	0.435	0.04	0.446	0.04	0.434

SE = standard error; HRV = heart rate variability; BRS = baroreflex sensitivity.

$N = 967$. Maximum likelihood robust to skew was used for all parameters estimates.

*Standardized variables, significant at the .05 level (two-tailed).

**Standardized variables, significant at the .01 level (two-tailed).

significant; however, Abuse was significantly associated with Stressor BRS (standardized $\beta = -0.23$, $p = .038$).

The path from Neglect to Mood Related Pathology was nonsignificant; however, the path from Abuse to Mood Related Pathology was once again statistically significant (standardized $\beta = 0.35$, $p < .001$). Indirect effects were similarly nonsignificant ($p = .77$).

Our recovery model–scaled χ^2 test yielded a value of $\chi^2(88) = 533.56$, $p < .001$. As with resting and reactivity models, the other overall model fit indices were below conventional benchmarks indicating adequate model fit, with an adjusted RMSEA of 0.07, a CFI of 0.94, and a TLI of 0.92. As with resting and reactivity, no significant relationships were observed between the target variables in those with high HRV. In those with low HRV, the direct structural paths for the recovery model from latent variables Abuse and Neglect to HRV Recovery ($p = .43$ and $p = .27$, respectively), and BRS Recovery ($p = .090$ and $p = .62$, respectively) were not significant, nor was the path from HRV Recovery to latent variable Mood Related Pathology. The direct path from Neglect to Mood Related Pathology was similarly nonsignificant; however, the direct path from Abuse to Mood Related Pathology was statistically significant (standardized $\beta = 0.35$, $p < .001$). As with the resting and reactivity models, indirect effects were nonsignificant ($p = .58$).

Exploratory analyses were conducted to assess whether these three multiple group models differed between men and women, as well as those above and below the median age. Results of these analyses did not observe noticeable differences in terms of the patterns or directionality of coefficients for key relationships in comparison with the results of the main analyses. Exploratory analyses results are included in Tables S3 to S6, Supplemental Digital Content, http://links.lww.com/PSYMED/A955.

DISCUSSION

The primary aim of the current study was to assess whether severity of threat-related childhood maltreatment exposures (such as physical, emotional, and sexual abuse) and deprivation-related exposures (such as physical and emotional neglect) was differentially associated with impairments in autonomic reactivity both at rest and in response to acute stress. Second, this study aimed to assess the potential indirect effects of HRV functioning in the relationship between maltreatment exposure subtypes and severity of mood-related psychopathology in adulthood. Lastly, we sought to assess whether the relationships between childhood maltreatment exposures, autonomic functioning, and adult mood-related symptoms differed in those with high versus low HRV. Notably, no significant relationships were found between target variables in those with high HRV, including between severity of maltreatment exposure subtypes and adult mood-related pathology. Childhood maltreatment is a well-established risk factor for the development of anxiety and depression in adulthood (3); the fact that no relationship was observed in this group implicates autonomic functioning as a potential moderator in the vulnerability of childhood maltreatment survivors to adult mood-related pathology. High HRV may in fact serve as a protective factor against such symptoms in this population; however, further research is needed to determine the full nature of the role that HRV may play in the risk for or resilience to mood-related pathology.

Results within the low HRV group displayed differential associations in the relationship between maltreatment exposure subtypes and autonomic functioning. In the resting model, no relationship was found between maltreatment exposures and BRS functioning; however, severity of abuse (standardized $\beta = -0.42$, $p = .009$) and severity of neglect (standardized $\beta = 0.32$, $p = .034$) were both found to be associated with resting HRV. Notably, these two pathways differ in terms of direction, indicating that higher severity of abuse-related exposures is associated with lower HRV and that higher severity of neglect-related exposures is associated with higher HRV in this sample. These findings are consistent with the dimensional model of childhood adversity, which states that threat-related exposures and deprivation-related exposures have differential neurobiological effects. In addition, threat-related exposures have been shown to lead to a more hyperreactive emotional neurocircuitry (6), which may be due to lower resting parasympathetic activity (9). Lower parasympathetic activity results in lower resting HRV (a less efficient and responsive vagal control of cardiac activity), which may then contribute to a blunted autonomic reactivity in response to threat. Although deprivation-related exposures have not been observed to promote these alterations in the emotional neurocircuitry responsible for responding to threat, the positive relationship observed in this sample is surprising. Higher HRV is typically associated with greater emotion regulation; it may be that neglect-related exposures promoted greater regulation strategies within our sample. The pathways between exposure subtypes and HRV were not significant within the stress reactivity or recovery epochs; however, it is interesting to note that the direction of the nonsignificant coefficients was consistent across all three models. Although we did not observe relationships between maltreatment exposure subtypes and BRS at rest, we did observe a significant relationship during the stressor task epoch such that those with higher severity of abuse displayed lower BRS in those with low HRV. This further implicates abuse-related exposures as being a specific risk factor for impairment in autonomic functioning. These findings provide support for greater differentiation of cumulative maltreatment exposure subtypes in those investigating the biological underpinnings of childhood maltreatment survivors' vulnerability to adult pathology.

Although the associations between neglect and mood-related pathology were nonsignificant, the pathways from severity of abuse to severity of mood-related pathology were statistically significant in all three models. This suggests that threat-related exposures may provide a greater risk of anxiety and depression symptoms in adulthood than deprivation-related exposures in those with low HRV. This is an important consideration worthy of future research, as exposure type is rarely considered in investigations of the link between childhood maltreatment and adult psychopathology. In fact, cumulative exposure scores such as Adverse Childhood Experience scores are one of the most common ways to assess this relationship (36). Our results provide some evidence that collapsing across maltreatment exposure subtypes may be mitigating or even obscuring the very relationships these studies are attempting to assess.

Our findings may also provide some insight into the inconsistency of results in previous investigations of the relationship between childhood maltreatment and autonomic functioning in adulthood. Associations between exposure to childhood maltreatment and adult vagally mediated cardiovascular processes such as HRV and BRS may in fact be nonlinear in nonclinical samples; because previous research has exclusively examined these relationships

using linear models, this may have contributed to the lack of findings by recent population-based studies (20,21). In addition, low HRV has repeatedly shown to be associated with poor emotion regulation and psychological distress (9). As our study failed to observe a relationship between childhood maltreatment and mood-related symptoms in those with high HRV, previous investigations of these relationships using clinical samples may have unknowingly been oversampling those with lower HRV than the general population. A recent meta-analysis (37) noted that both age and psychopathology moderated observed relationships between early life stress and HRV, such that stronger relationships were observed in older, more symptomatic samples. This is an important consideration for interpreting the findings from our study, which was primarily composed of older participants with lower depression and anxiety symptoms. Although clinically meaningful thresholds have not been established for the MASQ subscales, mean levels in our samples (reported in Table S2, Supplemental Digital Content, http://links.lww.com/PSYMED/A955) were approximately 30% of the maximum score on each of the four symptom cluster scales. It is a strength of our sample that we were able to assess autonomic functioning in a nonclinical sample with lower levels of symptoms; however, the age of our sample may have influenced the magnitude of our observed relationships. Further research is necessary at different developmental stages to determine to what extent these factors influence autonomic functioning in survivors of childhood maltreatment, particularly in terms of maltreatment exposure subtypes.

In considering these results, it is important to keep several limitations in mind. First, the cross-sectional nature of this study prevents any casual links from being assessed. Investigations into the biological underpinnings of the relationship between childhood maltreatment and adult mood-related psychopathology require extensive longitudinal methodology, something that this secondary data analysis cannot provide. Relatedly, the mean age of our sample was 55 years, which further complicates the attempt to investigate childhood exposures and adult outcomes; most of our participants would have had multiple intervening decades between exposure and assessment, which could influence our findings. In addition, because our study was conducted as a secondary data analysis of a large, national study, the self-report measures used may not be optimal for investigating differential influences of threat and deprivation related maltreatment exposures on adult outcomes. Structured clinical interviews are the criterion standard for assessing the presence or absence of anxiety and depression symptoms, and our study used a self-report that focused only on severity of symptoms over the past month. Similarly, self-report measures may not be the best way to assess exposure to maltreatment because it relies on both accurate retrospective reporting and honest self-disclosure, two elements that are challenging to ensure. In general, respondents have been observed to underreport childhood maltreatment-related experiences on retrospective self-report measures (38), which is likely to lessen the effectiveness of their use in investigations such as these, particularly in an older sample. Lastly, subscales of our childhood maltreatment measure were highly correlated with one another, even across our dimensional categories. A recent meta-analysis of the CTQ measure observed that a third "emotional exposures" relationship may be warranted, as emotional abuse and emotional neglect in particular are highly correlated in the population. Assessment of abuse, neglect, and emotional exposures may be an area for researchers to consider in future explorations of the influence of maltreatment exposure subtypes on adult health outcomes.

Although results from this study do not provide support for the role of adult HRV as a potentially mediating link between childhood maltreatment exposure and adult mood-related pathology, the lack of an association between severity of maltreatment and mood symptoms in those with high HRV does implicate autonomic functioning as a potential moderator in this relationship. As increasing evidence supports low HRV as a transdiagnostic endophenotype for both physical and mental health disorders, understanding the nature of this potential moderation is highly important. In addition, the observed differences in the relationships between abuse-related exposures and neglect-related exposures and both autonomic and psychological functioning highlight the need for greater differentiation in future studies seeking to understand the vulnerability of childhood maltreatment survivors to physical and mental disease. Understanding the differential contributions that these experiences may have both biologically and psychologically could assist clinicians in improving detection for and treatment of those most at risk for psychological sequelae after exposure to maltreatment in childhood.

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