J Abnorm Child Psychol
DOI 10.1007/s10802-015-0039-2

Dimensions of Maternal Parenting and Infants' Autonomic Functioning Interactively Predict Early Internalizing Behavior Problems

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Abstract Developmental pathways to childhood internalizing behavior problems are complex, with both environmental and child-level factors contributing to their emergence. The authors use data from a prospective longitudinal study (n= 206) to examine the associations between dimensions of caregiving experiences in the first year of life and anxious/depressed and withdrawn behaviors in early childhood. Additionally, the authors examine the extent to which these associations were moderated by infants' autonomic functioning in the first year of life indexed using measures of respiratory sinus arrhythmia (RSA) and heart period (HP). Findings suggest that higher levels of maternal sensitivity in infancy are associated with fewer anxious/depressed and withdrawn behaviors at age 3 years. Negative intrusiveness was found to be positively associated with children's anxious/depressed behaviors but not withdrawn behaviors. Further, moderation analyses suggested that the link between negative intrusive parenting during infancy and subsequent anxious/depressed behaviors is exacerbated for infants with average or low baseline HP and that positive engaging parenting during infancy was negatively related to withdrawn behaviors for infants demonstrating average to high levels baseline HP. Interestingly, RSA was not found to moderate the associations between parenting in infancy and later internalizing behavior problems suggesting that, during infancy, overall autonomic functioning may have greater implications for the development of internalizing behaviors than do parasympathetic influences alone. Implications of these findings and future directions for research are discussed.

Keywords Parenting · Internalizing · Autonomic nervous system · Anxiety · Depression

Childhood internalizing behaviors, including anxious and withdrawn behaviors, are thought to develop as a result of both environmental and individual qualities (El-Sheikh et al. 2013; Hoekstra et al. 2008) and have been shown to interfere with concurrent and long-term social and psychological adjustment (Buck and Dix 2012; Degnan et al. 2010; Van der Voort et al. 2014). Although extant literature suggests that individual psychophysiological and genetic factors contribute to the development and maintenance of internalizing symptomatology (Boomsma et al. 2005; Dietrich et al. 2007), early caregiving experiences play a critical role in shaping children's emotional, behavioral, and physiological regulatory patterns and, thus, subsequent psychopathology including internalizing behaviors (Groh et al. 2012; Van der Voort et al. 2014; Wiggins et al. 2015). Additionally, there is evidence that children's autonomic nervous system (ANS) functioning may moderate the associations between the caregiving environment and internalizing problems (e.g., Hastings et al. 2008; Wetter and El-Sheikh 2012). Thus, consistent with a developmental psychopathology perspective, in order to fully

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Published online: 11 June 2015

understand the emergence and complexities of internalizing problems it is necessary to examine interactive processes across multiple levels of analysis in early life (Cicchetti and Natsuaki 2014).

Internalizing behaviors represent a broad range of behavioral phenotypes that are often divided into two sub-categories: *anxious/depressed* (i.e., fearfulness, sadness) and w*ithdrawn* (i.e., shy, detached) behaviors (Achenbach 1991; Achenbach et al. 2004). As these internalizing behaviors are characterized by different features and may have diverse origins (Van der Voort et al. 2014), examining their antecedents in separate analytic models may provide a clearer understanding of the influences of early caregiving experiences and psychophysiological regulation than studying broad aggregate scores of internalizing behaviors. Because very early temperamental characteristics (e.g., Prior et al. 2000) and parenting behaviors in infancy (Van der Voort et al. 2014) have been shown to predict later internalizing problems, and because research suggests that autonomic regulation has important implications for the influences of the early environment (e.g., Hastings et al. 2008; Wetter and El-Sheikh 2012), developing a comprehensive understanding of the development of internalizing behaviors requires an approach that accounts for the interplay of psychophysiological functioning and caregiving experiences in infancy (Cicchetti and Natsuaki 2014). As such, the current study focused on the interplay between infants' autonomic nervous system activity and caregiving environments in predicting later anxious/depressed and withdrawn behaviors. Additionally, we specifically examined the extent to which infants' autonomic activity may attenuate or amplify the associations between sensitivity and negative intrusive parenting and later anxious/depressed and withdrawn outcomes.

Parenting and Internalizing Behavior Problems

There is evidence that both positive and negative aspects of parenting may influence the development of children's behavior problems (Hoeve et al. 2009). However, there is mixed empirical evidence regarding the impact of early parenting on the development of internalizing problems in particular. While some studies have linked high levels of parental intrusiveness and low levels of sensitivity to the emergence of internalizing behaviors in the first 4 years of life (e.g., Bayer et al. 2006), others have found no evidence for such links (e.g., Campbell et al. 2007; Keiley et al. 2003). For example, a study on the NICHD Early Child Care Research Network sample reported that maternal positive behaviors (e.g., sensitivity, positive regard, and respect for autonomy) from 6 months to first grade were not predictive of internalizing behavior problems in first grade (Campbell et al. 2007). Additionally, negative harsh parenting at age 4 was not related to children's internalizing behaviors in middle childhood (Keiley et al. 2003).

Inconsistent findings could be taken to suggest that the association between parenting and internalizing problems may differ depending on the specific parenting dimensions and qualities of internalizing problems studied (Kok et al. 2013). For example, negative intrusive parenting may be particularly detrimental for children's anxiety behaviors (Van der Bruggen et al. 2008) by increasing the perceptions of threat and reducing perceived control over threat (Chorpita et al. 1998). Negative intrusion may also maintain and exacerbate children's anxiety by denying opportunities for exploration, stifling the growth of autonomy, and restricting the acquisition of skills to cope with stressful events (Barlow 1988). On the contrary, positive parental behaviors may have beneficial implications for shy, inhibited children. Research suggests that positive parental engagement and sensitivity fosters a sense of security and social efficacy in children which facilitates reductions in withdrawn behaviors (Hane et al. 2008).

Extant developmental psychopathology literature suggests that early caregiving behaviors may influence maladaptive outcomes differentially based on children's psychophysiological functioning (Calkins et al. 2013). The inconsistent findings regarding the associations between parenting and internalizing problems emphasize the utility of adopting a transactional approach which accounts for influences at multiple levels including caregiving and child-level factors (Cicchetti and Toth 2009; Hastings et al. 2008). Consistent with recent theoretical frameworks suggesting that children with certain biological characteristics may be more susceptible than others to the effects of the caregiving environment (Boyce and Ellis 2005), it is important to consider child level variables in understanding the effects of parenting on internalizing behaviors.

Physiological Susceptibility to Internalizing Problems

Extant research has shown that children's psychophysiological activity has important implications for the associations between early experience and later psychopathology (Calkins et al. 2013; Hinnant et al. 2015; Mills-Koonce et al. 2014). Much of this work has focused on regulatory functioning, with specific emphases on associated peripheral systems including the autonomic nervous system (Calkins et al. 2013). The autonomic nervous system (ANS) is comprised of two systems: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS fosters mobilization and directs metabolic resources to support active defense behaviors when coping with threats or challenges. In contrast, PNS activity promotes restoration of homeostasis following stressful or arousing situations (Calkins et al.

2013; Dietrich et al. 2007; Porges 2007). Heart rate (HR) or heart period (HP; inverse of heart rate) are considered broad measures of ANS functioning that reflect both SNS and PNS activity (Dietrich et al. 2007; Stevenson-Hinde and Marshall 1999). There is some evidence that increased resting HR in middle childhood, marking heightened autonomic arousal, is associated with higher levels of internalizing problems (Dietrich et al. 2007; Monk et al. 2001). One study reported that HP was negatively associated with behavioral inhibition at age 4.5 years, but only among children who experienced secure attachment relationships with their caregiver (Stevenson-Hinde and Marshall 1999), suggesting that the interplay between ANS activity and the caregiving environment is important for the development of internalizing behaviors.

The associations between parasympathetic nervous system functioning and the development of internalizing problems have received much attention in the literature (El-Sheikh et al. 2013; Shanahan et al. 2014). The activity of the PNS is most often indexed by respiratory sinus arrhythmia (RSA), the variability in heart rate that occurs at the frequency of breathing, which is thought to index the neural control of the heart via the vagus nerve (Porges 2007). High baseline RSA represents greater myelinated vagal control of the heart, which enables the individual to maintain homeostasis in the face of situational change by allowing attention to shift from internal processes to external demands, facilitating the use of adaptive behavioral and emotional regulatory strategies (Calkins et al. 2013). In contrast, low baseline RSA indicates reduced myelinated vagal control that may interfere with the ability to regulate behavioral and emotional state during environmental challenge resulting in hyper-arousal (Porges 2007). Low RSA has been identified as a vulnerability factor that exacerbates the link between exposure to disruptive parental experiences and children's internalizing problems (El-Sheikh et al. 2013; Wetter and El-Sheikh 2012). Because theoretical and empirical work suggests that physiological functioning both is influenced by experience and moderates the influences of experience on outcomes (Boyce and Ellis 2005; Pluess and Belsky 2011), it is possible that aberrant physiological functioning characterized by heightened reactivity to environmental stress contributes to children's increased vigilance and attention to challenges in the environment (Ellis and Boyce 2008) which has implications for the development of internalizing behaviors. In the face of perceived threat, psychophysiological hyper-arousal may contribute to increases in anxiety or withdrawal as a compensation strategy (El-Sheikh et al. 2007; Kagan et al. 1994).

However, such associations may be less straightforward during infancy. For example, two recent studies demonstrated that infants with high (rather than low) baseline RSA were more susceptible to specific caregiving environments (Conradt et al. 2013; Holochwost et al. 2014). It may be the case that infants with high RSA are more attuned and alert to their environments, and are thus more strongly affected by both negative and positive caregiving experiences (Conradt et al. 2013). Due to mixed findings and potential differences in autonomic influence across development from infancy into childhood, there is a need to further understand the nature of early physiological susceptibility to the caregiving environment in the development of internalizing psychopathology.

It's clear that early autonomic functioning has important implications for the associations between early caregiving experiences and later internalizing problems and a large body of evidence suggests that children's PNS activity may be particularly important in this process (El-Sheikh et al. 2001, 2007; Hastings et al. 2008; McLaughlin et al. 2014; Wetter and El-Sheikh 2012). However, it has recently been demonstrated that the associations between physiological functioning and later internalizing problems are complex and seem to involve both parasympathetic and sympathetic influences (Dietrich et al. 2007; El-Sheikh et al. 2013). Therefore, the current study examined baseline RSA, which reflects the status of the PNS at rest (Porges 2007), as well as HP, a broad measure of ANS functioning which reflects the balance between activity of both the PNS and SNS (Dietrich et al. 2007).

The Current Study

There is evidence that childhood internalizing problems develop within a complex matrix of biological and environmental influences (Cicchetti and Natsuaki 2014; Sameroff 2010). However, most of the research on these associations has focused on middle childhood and on distal environmental factors such as martial conflict and parental psychopathology (El-Sheikh et al. 2007). Moreover, as anxious/depressed and withdrawn behaviors may be informed by different developmental processes (Van der Voort et al. 2014), it is important to consider the possibility of differential physiological susceptibility between these two behavioral phenotypes. Although there is work which speaks to comorbidity within and between internalizing behaviors (e.g., Bubier and Drabick 2009), the current study is the first to our knowledge to examine the associations between parenting behaviors during infancy and later anxious/depressed and withdrawn behaviors as well as the extent to which these associations are moderated by infants' autonomic functioning. This study is guided by the following research questions: 1) Are specific parenting behaviors (i.e., sensitivity and negative intrusiveness) during infancy related to early childhood anxious/depressed and withdrawn behaviors? Do these two dimensions of parenting jointly and/or differentially predict children's internalizing outcomes? We hypothesize that sensitive and negative intrusive parenting will significantly predict both anxious/depressed and withdrawn behaviors, controlling for model covariates. 2) Are these links moderated by infants' autonomic functioning as

measured by RSA and HP? Given the extant literature that suggests children's sympathetic and parasympathetic functioning has the potential to attenuate or exacerbate the influence of early experience on later internalizing problems, we hypothesize that both RSA and HP will moderate the associations between caregiving in infancy and children's internalizing behaviors. 3) Do these moderation processes differ between anxious/depressed and withdrawn outcomes? We refrain from making a hypothesis regarding differential patterns of moderation between anxious/depressed and withdrawn behaviors given the paucity of research on specific qualities of internalizing behaviors at this age. Successfully addressing the proposed research questions will contribute to our understanding of the etiology of internalizing problems and may have implications for targeted intervention.

Methods

Participants

Participants in the current study were recruited by the Durham Child Health and Development Study (DCHDS) when their children were 3 months old. The DCHDS is a prospective longitudinal study of 206 full-term infants and their families. The study included only infants who were healthy, full-term, and born without significant complications. Families were recruited from a largely urban community with fliers and postings at birth and parenting classes, as well as through phone contact via birth records. Participants were recruited in accordance with a stratified sampling plan to help ensure variation in racial- and poverty-related developmental processes and attempts were made to ensure that there was approximately equal representation across racial categories and income distribution. The sample was 56 % African-American and 44 % European-American and approximately 53 % were low income (below 200 % of the poverty level). Infant race was determined by the mother or primary caregiver; income status was assessed based on size of the family in relation to their household income in accordance with the 2002 federal poverty guidelines. Mothers' average age was 30.70 years (SD=5.7) and had completed an average of 14.64 years (SD=2.5) of education at the 36 month visit. Demographic information was collected during the first visit at 2 months of age and updated at each subsequent visit. The current analyses examine observational and questionnaire data from the home visits that occurred when infants were 6, 12, and 36 months old. At each of these visits infants and their mothers participated in several joint and individual tasks and completion of questionnaire and interviews by mother.

Measures

Parenting Behaviors Mothers and their infant were observed during a free play task as part of the home visit completed when the infants were 6 and 12 months of age. A set of standard toys were arranged on a blanket and the mothers were asked to play with their infants as they normally would on a typical day. The mother-child free play task was structured to last 10 minutes. All interactions were videotaped and later viewed by trained and reliable coders who rated the interactions using 5-point subscales to measure parental sensitivity, intrusiveness, detachment, stimulation of development, positive regard, negative regard, and animation. Similar measures have been used by the National Institute of Child Health and Human Development Study of Early Child Care (1997), the Family Life Project (Blair et al. 2008), and other reports based on the current Durham Child health and Development Study Sample.

Previous factor analysis supported the creation of two composite measures of maternal parenting at 6 and 12 months. The first composite negative intrusive parenting and included measures of intrusiveness and negative regard. The second composite, what we refer to as sensitivity, included measures of sensitivity, detachment (reverse scored), stimulation of development, positive regard, and animation. Negative intrusion and sensitivity were negatively correlated at 6 months ($r=-0.31$, $p<0.05$) and 12 months of age ($r=-0.50$, $p<0.05$). Additionally, measures of negative intrusion and sensitivity demonstrated stability from 6 to 12 months ($r=0.39$, $p<0.01$ and $r=0.67$, $p<0.01$, respectively). Because measures of parenting were fairly stable in the first year of life and because our hypotheses were not specific to time period, an unweighted average of sensitive and negative intrusive parenting at 6 months (mean=3.2, SD=0.81 and mean=2.5, SD=0.91, respectively) and 12 months (mean=3.1, SD=0.76 and mean=2.5, SD=0.85, respectively) were created to provide a more accurate representation of caregiving during infancy.

Internalizing Behaviors Internalizing behaviors were measured using the Child Behavior Checklist (CBCL; Achenbach and Rescorla 2000; Achenbach et al. 2004) which was included in a packet of questionnaires completed by mothers prior to each lab visit. The CBCL is a standardized assessment that obtains a parental rating of children's behavioral/emotional problems and provides an overall behavioral index of seven subscales which include emotionally reactive, anxious/depressed, somatic complaints, withdrawn, sleep problems, attention problems, and aggressive behavior. Mothers rate their child on each item that describes the child currently or within the last 2 months. The current study used measures of anxious/depressed and withdrawn behaviors collected at 36 months. Examples of items that comprise the measure of anxious/depressed behaviors include the extent to which the

child is unhappy without good reason, nervous or anxious, fearful, is overly dependent on adults, and is sad or depressed. Examples of items that comprise the measure of withdrawn behaviors include the extent to which children fail to answer when spoken to, are unresponsive to affection, express little interest in the things around them, and are generally withdrawn and uninvolved. Achenbach and Rescorla (2000) report that interparental agreement was significant across all ages (r=0.60–0.63), that all sub-scales showed good test-retest reliability (r=0.71–0.93; p<0.001).

Respiratory Sinus Arrhythmia and Heart Period Respiratory sinus arrhythmia (RSA) is measured as the variation in interbeat intervals linked to respiration and is used as a specific index of parasympathetic functioning of the ANS. Heart Period (HP) is a measure of the average interbeat interval (IBI; the length of time between heart beats) and is used as an index of broad ANS functioning. The Mini Logger 2000 was used to collect IBIs (Mini Logger 2000; Mini-Mitter Corp., Bend, OR). Researchers placed two electrodes on the child's chest at the beginning of the 6 and 12 month visits for a 2–4 min measure of baseline cardiac function while at rest. Electrodes were connected to a preamplifier which transmitted IBIs to a monitor. Data files were then transferred to a computer for artifact editing and analysis. The files were edited by two reliable researchers using MXEdit software (Delta Biometrics, Bethesda, MD). Porges' (U.S. Patent No. 4,510,944, 1985) method of calculating RSA and HP were used, in which a moving polynomial filter is used to remove frequencies lying outside a normal physiological range, and the estimate of RSA is reported in units of $\ln(ms)^2$. RSA and HP were calculated every 15 seconds for the baseline period and the mean of the epochs from 6 to 12 months was used to represent infants' autonomic functioning in the first year in life in this study. Larger values of HP indicate lower heart rate and larger values of RSA suggest greater vagal tone.

Additional Covariates *Child's sex* and *race* were collected at the time of recruitment. *Family income* was calculated as an unweighted average of total family income from 6 to 36 months. *Child's age* at 36 months was included as a covariate to account for random variation in scheduling and participant availability. An average of *infant height* at 3 and 6 months, which aligns with the measurement of RSA and HP, was included as a covariate given the associations between body size and heart rate (r= *0*.17, p<0.05) observed in our sample.

Analytic Strategy

The primary analytic strategy involved estimating a series of OLS regression models. In order to avoid issues with multicollinearity, separate models were estimated for RSA and HP. First, children's anxious/depressed and withdrawn behaviors at 36 months were separately regressed on children's early autonomic functioning, early sensitive and negative intrusive caregiving experiences, and model covariates. Second, OLS regression models were estimated to examine the extent to which the associations between caregiving and later anxious/depressed and withdrawn behaviors are moderated by children's early autonomic functioning. Both parenting interactions (sensitivity X HP/RSA and negative intrusion X HP/RSA) were included in the initial models and non-significant interactions were trimmed for the sake of parsimony. In addition to these analyses and in an attempt to more clearly understand the associations between caregiving and children's internalizing behaviors, we also estimated an exploratory model to test the extent to which maternal sensitivity and negative intrusion interactively predict children's internalizing behaviors. Significant interactions were probed using the online utility and computational tools for probing 2-way interaction effects in multiple linear regressions (Preacher et al. 2006). Model estimates and p-values are reported rounded to the hundredths place and model predictors, covariates and outcomes were mean-centered to support interpretation.

Of the full 206 participants in the DCHDS, 20 (9.7 %) were missing heart rate data in infancy, 14 (6.7 %) were missing data on parenting, and 28 (13.6 %) were missing data on internalizing behaviors at 36 months. As such, complete case analyses (n=154) included only participants who had parenting and heart rate data in infancy and internalizing behavior data at 36 months. Participants missing data did not significantly differ from those who were included on sex, $X^2(1)$= 1.08, p=0.29, or income, $t(204)$=1.54, p=0.13. Participants missing data were more likely to be African-American, $X^2(1)$=5.84, p<0.05.

Multiple imputation (MI) was used to address missingness. The iterative imputation approach allows full use of the data and protects against biased estimates (Schafer 1997; Schafer and Graham 2002). A total of 10 imputed datasets were generated using PROC MI in SAS, version 9.3 of SAS System for Windows. Although MI tends to yield conservative estimates, this approach with 10 imputations is 95 % efficient with 50 % missing information. Relative efficiency estimates in the current analyses exceeded 96 % for each parameter. Informed by pooled estimates and variances across imputed datasets, analyses were completed using PROC MIANALYZE in SAS. All models were also estimated using complete case models and the main effect and interactive associations remained unchanged across methodological approaches. Coefficients and standard errors are reported from the MI analyses and the simple slopes and regions of significance for significant interactions were obtained from the complete case models.

Results

Descriptive Statistics

Table 1 presents the bivariate correlations, means, standard deviations, and ranges for the model covariates and variables of interest. Measures of sensitivity and negative intrusion during infancy were significantly correlated with race and income. Sensitivity during infancy is negatively correlated with children's anxious/depressed and withdrawn behaviors at 36 months and negative intrusion during infancy is positively correlated with anxious/depressed behaviors at age 36 months. Measures of RSA and HP were highly correlated.

Hierarchical OLS Regression Models

A series of hierarchical regression models were estimated to test the influences of parenting behaviors during infancy and infants' basal autonomic functioning on children's later anxious/depressed and withdrawn behaviors as well as the extent to which the associations between parenting and later anxious/depressed and withdrawn behaviors are moderated by children's ANS functioning. First, children's anxious/depressed behaviors at 36 months were regressed on infant RSA, sensitivity during infancy, negative intrusion during infancy, and a set of covariates which included family income from 6 to 36 months, infants' gender, age, height, and age in months at the 3 year lab visit. Next, interactions between sensitivity and then negative intrusion and infants' RSA were entered into regression models. This process was repeated but with children's withdrawn behaviors at 36 months as the outcome. Heart period was then substituted for RSA and the series of models were re-estimated. Finally, in addition to investigating the extent to which infants' autonomic functioning moderates the associations between caregiving and internalizing behaviors, we also estimated an exploratory model to test the extent to which maternal sensitivity and negative intrusion interactively predict children's internalizing behaviors. Standardized coefficients, standard errors, and R^2 statistics for each of the OLS regression models involving children's autonomic functioning can be found in Table 2. Models investigating the interactive association between sensitivity and negative intrusion in the prediction of internalizing behaviors are reported in the text but not Table 2.

Anxious/Depressed Behaviors

Parenting The main effects model that included RSA indicated that sensitivity (b=−0.50, p<0.05) during infancy predict children's anxious/depressed behaviors at 36 months. Similarly, the main effects model that included HP indicated that sensitivity (b=−0.49, p<0.05) during infancy predicts children's anxious/depressed behaviors at 36 months. The associations between negative intrusion and children's anxious/depressed behaviors at 36 months approached significance in both the RSA and HP main effect models (b=0.41, p<0.10 in both models). Additional analyses revealed that negative intrusive parenting and sensitivity do not interactively predict children's anxious/depressed behaviors, although this interaction approached significance (p<0.10).

Respiratory Sinus Arrhythmia Investigation of the interactive effects in model two indicated that RSA did not moderate the associations between sensitivity and children's anxious/

Table 1 Bivariate correlations between model outcomes

	1	2	3	4	5	6	7	8	9	10	11
1. Sex (0 = male)	–										
2. Race (0 = African American)	−0.08	–									
3. Average Household Income	−0.02	0.28**	–								
4. Infant Height	−0.27**	0.11	0.02	–							
5. Child Age (36)	−0.15	0.08	0.12	0.03	–						
6. Infant Heart Period	−0.06	0.08	0.16*	0.17*	0.04	–					
7. Infant RSA	−0.07	−0.04	0.02	0.10	0.08	0.60**	–				
8. Sensitivity	−0.04	0.36**	0.41**	0.09	0.01	0.01	−0.13	–			
9. Negative Intrusion	0.02	−0.43**	−0.37**	0.02	−0.19	−0.03	0.03	−0.45**	–		
10. Anxiety/Depression (36 m)	0.03	−0.18*	−0.18*	0.05	0.05	−0.02	0.01	−0.28**	0.26**	–	
11. Withdrawn Behaviors (36 m)	−0.08	−0.09	−0.11	−0.02	−0.01	−0.05	−0.01	−0.21**	0.14	0.57**	–
Number	206	206	206	201	178	186	186	192	192	178	178
Mean	0.48	0.43	3.1	25.6	35.5	427.7	3.4	3.2	2.5	1.4	1.1
Standard Deviation	0.50	0.49	2.4	1.2	0.72	35.8	0.85	0.74	0.76	1.8	1.7
Min./Max	–	–	0.04/13.9	21.5/28.8	34/ 39	335.8/ 573.53	1.1/5.7	1.1/5	1/ 4.75	0/ 14	0/11

p<0.05*, p<0.01**; *RSA* Respiratory Sinus Arrhythmia; Appropriate correlational approaches were used to account for continuous and categorical data

Table 2 Hierarchical regression models predicting internalizing behaviors at age 3

	Anxious/Depressed behaviors				Withdrawn behaviors			
	RSA Model 1 b (SE)	RSA Model 2 b (SE)	HP Model 1 b (SE)	HP Model 2 b (SE)	RSA Model 1 b (SE)	RSA Model 2 b (SE)	HP Model 1 b (SE)	HP Model 2 b (SE)
Sex (0 = male)	0.25 (0.27)	0.29 (0.28)	0.25 (0.27)	0.28 (0.27)	−0.43 (0.29)^	−0.37 (0.29)	−0.42 (0.29)^	−0.39 (0.28)
Race (0 = AA)	−0.12 (0.32)	−0.13 (0.31)	−0.11 (0.32)	−0.10 (0.31)	−0.12 (0.34)	−0.16 (0.34)	−0.11 (0.33)	−0.13 (0.34)
Family Income	−0.01 (0.06)	−0.01 (0.06)	−0.00 (0.06)	−0.01 (0.06)	−0.01 (0.06)	−0.01 (0.06)	−0.01 (0.06)	−0.01 (0.06)
Infant Height	0.15 (0.12)	0.15 (0.12)	0.15 (0.12)	0.15 (0.12)	−0.05 (0.12)	−0.08 (0.12)	−0.05 (0.12)	−0.08 (0.12)
Child Age (36 m)	0.25 (0.17)	0.25 (0.18)	0.25 (0.17)	0.24 (0.17)	0.01 (0.19)	−0.04 (0.19)	−0.01 (0.19)	−0.02 (0.18)
ANS Measure	−0.05 (0.16)	−0.02 (0.16)	−0.01 (0.01)	−0.01 (0.01)	−0.10 (0.16)	−0.07 (0.16)	−0.01 (0.01)	−0.01 (0.01)
Sensitivity	−0.50 (0.20)*	−0.46 (0.20)*	−0.49 (0.21)*	−0.48 (0.20)*	−0.40 (0.20)*	−0.38 (0.20)^	−0.38 (0.20)^	−0.43 (0.20)*
Negative Intrusion	0.41 (0.24)^	0.42 (24)^	0.41 (0.24)^	0.47 (0.24)^	0.06 (0.21)	0.07 (0.22)	0.06 (0.21)	0.02 (0.22)
Sensitive Caregiving x ANS Measure	–	−0.02 (0.26)	–	–	–	−0.51 (0.26)^	–	−0.01 (0.01)*
Negative Intrusion x ANS Measure	–	−0.32 (0.21)^	–	−0.01 (0.01)*	–	−0.20 (0.20)	–	–

$p \leq 0.10^{\wedge}$, $p \leq 0.05$*; *ANS* Autonomic Nervous System; *RSA* Respiratory Sinus Arrhythmia; *HP* Heart Period; *AA* African American; Trimmed models are presented for the second heart period model for both outcomes

depressed behaviors. Although, the interaction between negativity and RSA approached significance in the prediction of children's anxious/depressed behaviors, the interaction was not probed because it was not significant in the trimmed model.

Heart Period Model two indicated that negative intrusion (trimmed model: $b=-0.01$, $p<0.05$), but not sensitivity during infancy interacted with infants' baseline HP to predict later anxious/depressed behaviors. The significant interaction between negative intrusion and infants' HP was probed at 1 standard deviation above and below the mean for infants' baseline HP (Fig. 1). The positive association between negative intrusion during infancy and children's later anxious/depressed behaviors was significant for children at (mean simple slope=0.55 [SE=0.23], $t=2.4$, $p=0.02$) or below (−1 SD simple slope=0.99 [SE=0.32], $t=3.1$, $p=0.01$) the mean for baseline HP during infancy. The lower bound of the region of significance was 7.76 indicating that the interactive association infants' HP and negative intrusion in the prediction of anxious/depressed behaviors is not significant for infants who demonstrated baseline HP above the sample mean of zero (mean-centered). The findings indicate that the risk for exhibiting later anxious/depressed behaviors as a function of experiencing negative intrusion during infancy is exacerbated by average to low levels of baseline HP during infancy.

Withdrawn Behaviors

Parenting The main effects model that included RSA indicated that sensitivity ($b=-0.40$, $p \leq 0.05$), but not negative intrusion, during infancy predicts children's withdrawn behaviors at 36 months. Similarly, the main effects model that included HP indicated that sensitivity ($b=-0.38$, $p<0.10$), but not negative intrusion, during infancy is associated with children's withdrawn behaviors at 3 years. Additional analyses revealed that negative intrusive and sensitive parenting interactively predict children's withdrawn behaviors ($b=-0.64$, $p<0.05$). Given the main effect associations between sensitivity and children's internalizing behaviors, simple slopes were obtained at different levels of negative intrusion. Simple slope analyses revealed that the negative association between sensitivity during infancy and children's later withdrawn behaviors was significant for infants experiencing mean levels (mean simple slope=−0.54 [SE=0.23], $t=2.5$, $p=0.01$) or above mean levels (+1 SD simple slope=−1.06 [SE=0.32], $t=3.3$, $p=0.01$) of negative intrusive parenting. The upper bound of the region of significance was −0.17 indicating that the association between sensitivity and children's withdrawn behaviors is not modified by negative intrusion for infants who experience negative intrusive parenting that is below the sample mean of zero (mean-centered). These findings indicate that high levels of negative intrusion may contribute to children's withdrawn behaviors in the absence of sensitive caregiving but that this association is attenuated in the presence of sensitive caregiving.

Respiratory Sinus Arrhythmia Investigation of the interactive effects in model two indicated that RSA did not moderate the associations between negative intrusion and children's withdrawn behaviors. Although, the interaction between sensitivity and RSA approached significance in the prediction of

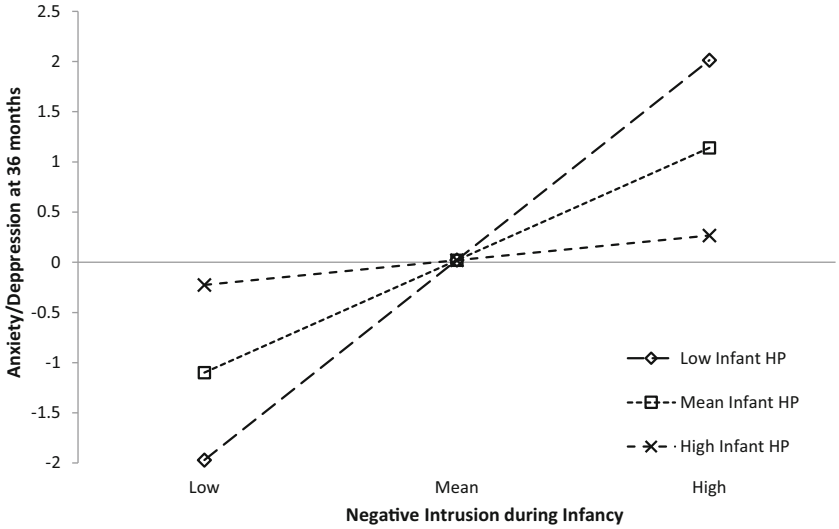

Fig. 1 The relationship between negative intrusion during infancy and anxiety/depression in early childhood is plotted as a function of child's baseline HP during infancy. The simple slopes for children at and below the mean of baseline HP during infancy are significantly different from zero.

children's withdrawn behaviors, the interaction was not probed because it was not significant in the trimmed model.

Heart Period Model two indicated that sensitive (trimmed model: $b=-0.01$, $p\leq 0.05$), but not negative intrusive, parenting during infancy interacted with infants' baseline HP to predict later withdrawn behaviors. The significant interaction between sensitivity and infants' HP was probed at 1 standard deviation above and below the mean for infants' baseline HP (Fig. 2). The negative association between sensitivity during infancy and children's later withdrawn behaviors was significant for children at (mean simple slope=−0.54 [SE=0.23], $t=2.2$, $p=0$ 0.02) or above (+1 SD simple slope=−1.04 [SE=0.33], $t=3.0$, $p=0.01$) the mean for baseline HP during infancy. The upper bound of the region of significance was −5.2 indicating that the interactive association between infants' HP and sensitivity in the prediction of withdrawn behaviors is not significant for infants who demonstrated baseline HP far below the sample mean of zero (mean-centered). The findings indicate that the negative association between sensitivity during infancy and children's later withdrawn behaviors is stronger for individuals demonstrating average to high levels baseline HP functioning during infancy.

Discussion

Internalizing psychopathology is a complex heterogeneous phenomenon, the development of which involves both psychophysiological and environmental processes. Consistent with a developmental psychopathology perspective, the current study examined the interplay between early parenting behaviors and infants' autonomic functioning in the prediction of later internalizing problems. Anxious/depressed and withdrawn outcomes were examined in separate models in an attempt to disaggregate the heterogeneity within internalizing problems more generally. Findings from this study demonstrate that early parenting behaviors predict later anxious/depressed and withdrawn behaviors. Further, significant interaction effects indicate that infants' HP (but not RSA) moderates these associations. Importantly, differential patterns of findings emerged for anxious/depressed and withdrawn behaviors, which suggests that these outcomes may follow partially distinct etiological pathways.

Consistent with previous research (e.g., Bayer et al. 2006), higher levels of maternal sensitivity during infancy predicted fewer anxious/depressed and withdrawn behaviors at age 3. Additionally, the positive associations between negative intrusion and children's anxious/depressed behaviors approached significance and, although the main effect associations between negative intrusion and children's withdrawn behaviors were not significant, a significant interaction between negative intrusion and sensitivity suggests that negative intrusive caregiving behaviors in infancy are associated with children's withdrawn behaviors in the absence of sensitive caregiving. Further, this association is attenuated in the presence of sensitive caregiving. The early parent–child relationship plays an important role in the development of internalizing psychopathology because the regulatory patterns that develop within these relationships shape children's interpretation of environmental input and the expression of emotions and behaviors, particularly under stress or challenge (Groh et al. 2012). The main effect associations observed in this study would suggest that maternal sensitivity fosters the development of adaptive emotion regulation skills that facilitate children's ability to cope with challenge (Duncombe et al. 2012; Sroufe et al. 2010; Sroufe 1996), resulting in less anxious and withdrawn behaviors. Further, negative and intrusive parenting practices may evoke emotional distress in infants, who gradually learn that primary relationships do not provide support and safety

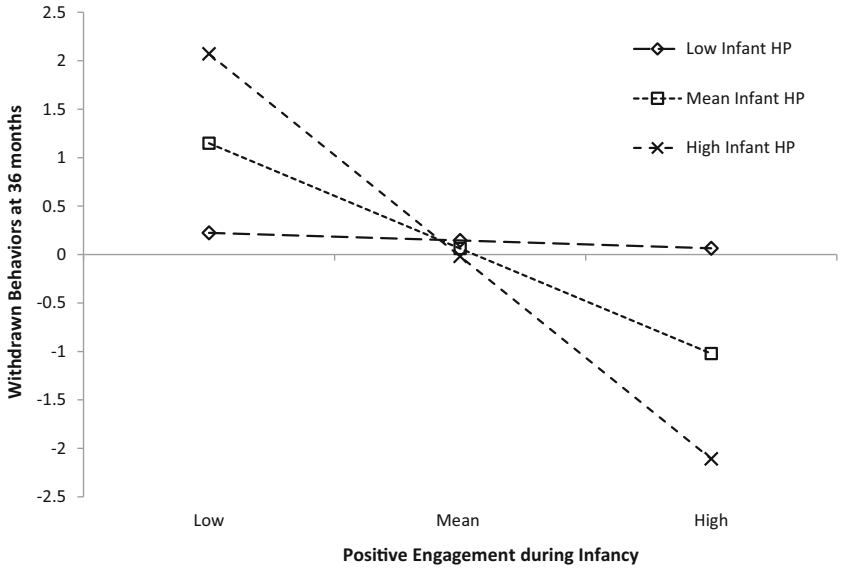

Fig. 2 The relationship between sensitivity during infancy and withdrawn behaviors in early childhood is plotted as a function of child's baseline HP during infancy. The simple slopes for children at and above the mean of baseline HP during infancy are significantly different from zero

(Bretherton and Munholland 1999; Madigan et al. 2006). As a result, children may perceive their environments as threatening and lack the appropriate regulatory mechanisms to modulate these negative feelings (Bayer et al. 2006). Contrary to study hypotheses and previous work that has linked overprotective, intrusive parenting to social withdrawal (Rubin and Coplan 2004), the current study found main effect no links between maternal negative intrusiveness and children's withdrawn behaviors. One possible explanation for this inconsistency may be that different aspects of intrusive parenting and social withdrawal were included in the measurement used in previous work of Rubin and his colleagues (Rubin and Coplan 2004). For example, Rubin and his colleagues included an over-protective component of intrusive parenting, and distinguished between socially reticent and solitary passive withdrawn behaviors, whereas the current study focuses on maternal harsh intrusion and negative regard, and employed an overall measure of social withdrawal that does not differentiate between weary/depressed vs. voluntary withdrawn behaviors. Additionally, although the current study does not address bidirectional associations between caregiving and children's internalizing behaviors, it is possible that parents of withdrawn children may not exhibit negative intrusiveness in early stages of development, and it is only when children's social withdrawal becomes salient that they try to influence or change their children's behavior by exerting negative control (Burgess et al. 2001). Despite the lack of direct associations, the current study does provide support for possible associations between negative intrusive parenting and children's withdrawn behaviors when experienced in the absence of sensitive caregiving.

In line with previous research and study hypotheses (e.g., El-Sheikh et al. 2013; Shanahan et al. 2014), findings from this study demonstrated that infants' autonomic functioning moderates the links between early parenting and later internalizing problems. Interestingly, the patterns of moderated associations differed between anxious/depressed and withdrawn outcomes. Graphical examination of simple slopes suggest that the link between negative intrusive parenting during infancy and subsequent anxious/depressed behaviors is exacerbated for infants with average or low baseline HP. Low resting HP (high HR) is a marker of autonomic over arousal which may reflect high levels of distress and fearfulness in infancy (Kagan and Snidman 1999) and these findings suggest that that the development of autonomy and adaptive coping is undermined by negative intrusive parenting behaviors, particularly for children who demonstrate average or low HP, which contributes to intensifying anxiety problems (Hastings et al. 2008).

The current study also found that positive engaging parenting during infancy was negatively related to withdrawn behaviors for infants demonstrating average to high levels baseline HP. High resting HP (low HR) is an indicator of autonomic under arousal, which has been shown to operate as a susceptibility factor in the presence of salient family experiences (El-Sheikh et al. 2013). Although we found a main effect of positive engaging parenting on later withdrawn behaviors, moderation analyses suggest that, in the presence of positive engaging parenting, children with high baseline HP demonstrate less withdrawn behaviors. However, in the absence of positive engaging parenting, high baseline HP is associated with more withdrawn behaviors. These findings partially reflect those of Stevenson-Hinde and Marshall (1999) who found that, among children who were insecurely attached and presumably experienced less sensitive caregiving (Ainsworth and Bowlby 1991; Bowlby 1969), those with high baseline HP were more likely to demonstrate behavioral inhibition, thought to be a precursor of later withdrawn behaviors

(Burgess et al. 2001), than those with low baseline HP (Stevenson-Hinde and Marshall 1999). Positive and engaging parent–child relationships may support the development of the competencies necessary for positive peer interactions such as impulse control (Bernier et al. 2010), empathy (Strayer and Roberts 2004), and prosocial behavior (Hastings et al. 2007) which enhance social competence and reduce the risk for social withdrawal and isolation.

Contrary to study hypotheses and previous findings of older children (El-Sheikh et al. 2001, 2007; Hastings et al. 2008; McLaughlin et al. 2014; Wetter and El-Sheikh 2012), we did not observe significant interactions between infants' RSA and parenting in the prediction of internalizing problems. These null findings are most interesting when considered in relation to the significant interactions found between HP and parenting in the prediction of internalizing problems. It is possible that during infancy overall autonomic functioning may have greater implications for the development of internalizing behaviors than do parasympathetic influences alone. Although the use of a broad ANS function measure does not enable us to untangle the relative importance of sympathetic versus parasympathetic functioning, our findings do stress the need to incorporate specific SNS measures (e.g., galvanic skin response, preejection period) into future research to further elucidate its role in these developmental processes.

The current study has a number of strengths including a longitudinal design, observational measurement of parenting behaviors in infancy, the use of a diverse sample, and the inclusion of both behavioral and biological levels of analysis. However, the findings should be interpreted in the context of the following limitations. First, although we did not find significant associations between infants' PNS activity and later internalizing behaviors, the use of a broad measure of autonomic functioning does not allow for specific conclusions to be drawn about the differential influence of sympathetic and parasympathetic systems. As it is possible that these systems have distinctive implications for emotional and behavioral functioning, examining them separately may further enhance the understanding of internalizing problems (El-Sheikh et al. 2013). Second, because the stability and maintenance of internalizing problems is known to fluctuate later in development (Wiggins et al. 2015), further research is needed in order to understand whether the effects of these early processes persist throughout childhood. Finally, the use of a community sample in this study, rather than a clinical sample, restricted the extent to which our graphed estimates of the moderating relation between autonomic functioning and early caregiving (Figs. 1 and 2) were able to predict anxious/depressed and withdrawn behaviors at clinically relevant levels. Although, we were successful in demonstrating a link between early experiences and significantly elevated anxiety and withdrawn behaviors in early childhood and the use of a community sample may aid the generalizability of these findings, the use of an older, clinically informed, sample might yield stronger results.

Despite these limitations the present study contributes to our understanding of mechanisms through which internalizing problems emerge in early childhood. Findings from this study demonstrate that the interactions between biological and environmental influences may not be straight forward. Infants' physiological susceptibility may vary depending on the dimension of the environment (positive vs. negative parenting practices) and the outcome of interest (anxious/depressed vs. withdrawn behaviors). Future research that captures the interactive relationships between early experience and psychophysiological functioning may benefit from considering different qualities of the same experiential construct (rather than one continuum) and utilizing measurement of subconstructs of problem behaviors. Further, a useful future direction would be to investigate the associations between children's exposure to other stressful or negative events and the development of internalizing behaviors as well as the extent to which these associations are moderated by children's psychophysiological functioning in early life. Such an approach enables a nuanced understanding of the processes that underlie psychopathology, providing conceptual grounds for tailored intervention and prevention programs.

The developmental psychopathology perspective considers development to be a dynamic and interactive process where multiple factors, or levels of a factor, are considered in context rather than in isolation (Cicchetti and Dawson 2002; Rutter and Sroufe 2000). This theoretical approach suggests that that processes occurring in early life play a fundamental role in the etiology of disorder and that early patterns of behavior may indicate risk for later disorder even before the disorder is present (Cicchetti 2014). Understanding early interactive developmental processes that contribute to the stabilization of internalizing behaviors is important so that interventions can target these processes before stabilization occurs. The findings in the current study contribute to our understanding of potential interactive mechanisms that inform etiological pathways to internalizing behavior problems which will promote future research on the topic but also support clinicians' understanding of factors that impact the efficacy and effects of interventions operating at various levels of developmental influence.

Acknowledgments This study was supported by The North Carolina Child Development Research Collaborative, which is funded by the National Science Foundation through Children's Research Initiative Grant (BCS-0126475). We thank all the parents and children who participated in the Durham Child Health and Development Study and the research assistants for their valuable efforts in collecting this data.

This work was supported in part by a postdoctoral fellowship provided by the National Institute of Child Health and Human Development (T32-HD07376) through the Center for Developmental Science, University of North Carolina at Chapel Hill, to Nicholas J. Wagner.

Conflict of Interest The authors declare that they have no conflict of interest.

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