Title
Child temperament and teacher relationship interactively predict cortisol expression: The prism of classroom climate

Journal
Development and Psychopathology, 29(5)

ISSN
0954-5794

Authors
Roubinov, Danielle S
Hagan, Melissa J
Boyce, W Thomas
et al.

Publication Date
2017-12-01

DOI
10.1017/s0954579417001389

Peer reviewed

HHS Public Access
Author manuscript
Dev Psychopathol. Author manuscript; available in PMC 2022 November 14.

Published in final edited form as:
Dev Psychopathol. 2017 December ; 29(5): 1763–1775. doi:10.1017/S0954579417001389.

Child temperament and teacher relationship interactively predict cortisol expression: The prism of classroom climate

Danielle S. Roubinov, PhD,
University of California San Francisco

Melissa J. Hagan, PhD, MPH,
San Francisco State University & University of California, San Francisco

W. Thomas Boyce, MD,
University of California San Francisco

Marilyn J. Essex,
University of Wisconsin, Madison

Nicole R. Bush, PhD
University of California, San Francisco

Abstract

Entry into kindergarten is a developmental milestone that children may differentially experience as stressful, with implications for variability in neurobiological functioning. Guided by the *goodness-of-fit* framework, this study tested the hypothesis that kindergarten children's (N = 338) daily cortisol would be affected by the "match" or "mismatch" between children's temperament and qualities of the classroom relational context. The robustness of these associations was also explored among a separate sample of children in third grade (N = 165). Results among kindergarten children showed negative affectivity and over-controlled temperament were positively related to cortisol expression within classrooms characterized by lower levels of teacher motivational support, but there was no relation between temperament and cortisol when motivational support was higher. Among third-grade children, negative affectivity was marginally positively related to cortisol at lower levels of teacher-child closeness and unrelated at higher levels of teacher-child closeness. Findings suggest children's cortisol expression depends on the extent to which specific temperamental characteristics "fit" within the relational and contextual qualities of the classroom environment, particularly as children navigate the new roles and relationships that emerge during the transition to formal schooling. Developmentally-informed neurobiological research in classrooms may contribute to tailored programmatic efforts to support children's school adjustment.

Keywords

temperament; teacher-child relationship; classroom; cortisol; goodness-of-fit

Corresponding Author: Danielle S. Roubinov, University of California, San Francisco, Department of Pediatrics, 3333 California Avenue, Suite 465, San Francisco, CA, 94118; Phone: (415) 476-7285; Fax: (415) 476-7744; danielle.roubinov@ucsf.edu.

Temperament is a child's emotional and behavioral style across settings and contexts (Rothbart & Bates, 1998), with a broad reach that helps explain the *what, when, where, how, and why* of children's responses to environmental challenges. It is biologically-based and can contribute to particular profiles of neurobiological functioning, rendering it a key consideration in the study of stress-sensitive physiological systems (Bijttebier & Roeyers, 2009; Muris & Ollendick, 2005; Rothbart & Bates, 1998). Prior research has shown direct associations between certain temperamental traits and cortisol, the hormonal end product of the corticotropin releasing hormone (CRH) system that activates the hypothalamic-pituitary-adrenal (HPA) axis (Kryski et al., 2013; Spinrad et al., 2009). However, as this body of research has matured, it has advanced beyond the study of main effects to examine additional factors that may moderate associations between temperament and children's cortisol. The concept of *goodness-of-fit* has guided much of this more recent research, positing that child outcomes are *jointly* or *interactively* determined by a child's particular temperament and the degree to which the social and emotional environment provides an appropriate "match" for that temperament (Chess & Thomas, 1999). This framework suggests the need to consider the context of children's primary relationships when examining associations between temperament and cortisol expression.

The preponderance of temperament research has focused on *family-based* relational and contextual factors that may moderate the association between temperament and children's emotional and behavioral health. As children reach school age, however, primary relationships extend beyond those that develop within the family environment to include those that are formed in the classroom. As such, characteristics of the teacher-child relationship may also interact with child temperamental style, exacerbating or buffering associations with children's health. Much less is known about the moderating effect of teacher-child relationship, particularly in relation to children's biological health. This paper begins with a review of temperament and its dimensionality, followed by a summary of extant literature that has explored interactionist perspectives, including limited research that has explored temperament-by-classroom context interactions on children's neurobiological functioning. Guided by the goodness-of-fit framework, the present study tested the hypothesis that the relation between temperamental traits and children's cortisol expression depends on the extent to which such characteristics "fit" with relational and contextual qualities of the classroom environment among kindergarten children. As a test of the robustness of our results, we also examined these relations within a smaller sample of children in third grade.

Temperament: Definitions & Dimensions

Temperament has long been an important focus across various areas of developmental research, which is likely due to its early emergence, stability over time, and powerful influence on children's adaptive and maladaptive functioning. It is considered a multidimensional construct, and a number of models have been proposed to capture its structure. Rothbart (Rothbart, 1989; Rothbart, 2007) conceptualizes temperament as "constitutionally-based individual differences in reactivity and self-regulation" that span the domains of emotion, activity, and attention (Rothbart & Bates, 2006, p. 100). Three primary dimensions have been shown to reliably index reactivity and self-regulation across multiple cultures and contexts: negative affectivity, surgency, and effortful control (Rothbart, Ahadi, Hershey, & Fisher, 2001).

There is extensive cross-sectional and prospective evidence showing strong associations between each of these dimensions of temperament and various indices of child maladjustment (e.g., Eisenberg et al., 2009). *Negative affectivity*, or negative emotionality, refers to sensitivity to threat and negative environmental stimuli; in the context of a stressor, this sensitivity predisposes the child to feel discomfort, anger, fear or sadness, and to resist being soothed (Buss & Plomin, 1984; Rothbart, 2007). Negative affectivity is at the core of what has been referred to as a “difficult temperament” (Thomas & Chess, 1977) and is a robust predictor of many negative outcomes including poor physical and psychological health (Eisenberg et al., 2009; Lahey, 2009). *Surgency* reflects behavioral re(activity) and a tendency toward approach-related behavior (Buss & Plomin, 1984). Although not inherently problematic, high levels of surgency may serve as a risk factor for the development of behavioral issues when children are in environments intolerant of high behavioral activity or in settings with rigid rules for appropriate behavior (Berdan, Keane, & Calkins, 2008). Gunnar and colleagues (2003) suggest that the extent to which surgency becomes problematic is determined by children’s capacity to regulate their activity levels to match the demands of the context. *Effortful control* comprises regulatory capacities, including task persistence, attentional focusing, and the self-regulation of emotions and behaviors (Compas, Connor-Smith, & Jaser, 2004). High levels of effortful control may enable a child with high surgency to modulate his or her own behavior through inhibitory and/or attentional control (Rothbart & Bates, 2006). When considered in conjunction, the levels of surgency and effortful control converge to create temperamental profiles of reactive under-control and over-control (Eisenberg et al., 2004). An over-controlled temperament is characterized by low activity and high control, potentially resulting in behaviors that are rigid and withdrawn (Eisenberg et al., 2009). Conversely, an under-controlled temperament is characterized by extreme activity and low control, a pattern that has been associated with greater externalizing problems and lower social competence (Eisenberg et al., 1997). Dimensions of temperamental over-control and under-control may be particularly salient to children’s adjustment during developmental transitions – such as entry into kindergarten – in which children are exposed to new environments, routines, and boundary setting.

An Interactionist Perspective: Goodness-of-Fit Framework

The biological and behavioral manifestations of temperament do not unfold in isolation of the environment. Nearly four decades ago, Thomas and Chess proposed a *goodness-of-fit* framework that suggests that children’s development is a function of the “fit” or “match” between temperamental domains and environmental demands (Thomas & Chess, 1977). More specifically, temperament-context fit is evident when “the properties of the environment and its expectations and demands are in accord with the organism’s own capacities, characteristics, and style of behaving” (Chess & Thomas, 1999, p. 3). Within this model, specific domains of temperament do not bear direct relations with adaptive or maladaptive outcomes; rather, the extent to which temperament serves as a risk or protective factor depends upon its functionality within the constraints and opportunities posed by the environment (Windle & Lerner, 1986).

There is extensive empirical support for the importance of fit between the family context and temperament in the prediction of children's psychological health (Rothbart & Bates, 2006). For example, the association between temperamental irritability and children's depressive symptoms has been shown to vary as a function of parental warmth, whereby irritable children evidenced greater depressive symptoms in the context of low parental warmth as compared to high parental warmth (Oldehinkel, Veenstra, Ormel, De Winter, & Verhulst, 2006). Similarly, high levels of irritability have emerged as a risk factor for internalizing problems, but only in the context of highly controlling, intrusive parenting (Morris et al., 2002). Additionally, children's fearfulness and negative emotionality have been associated with greater internalizing and externalizing symptoms when negative maternal control was higher (Gilliom & Shaw, 2004). Interactive effects between child temperament and parenting quality have also been observed in the prediction of school-related adjustment, such as social skills and academic outcomes (Stright, Gallagher, & Kelley, 2008).

The teacher-child relationship and broader classroom environment are crucial contexts for children's development (Breeman et al., 2015; Griggs, Gagnon, Huelsman, Kidder-Ashley, & Ballard, 2009; Hamre & Pianta, 2001), operating together as an additional source of influence alongside the family environment, particularly during children's initial entry into novel academic settings (Sanson, Hemphill, & Smart, 2004). Although goodness-of-fit models have primarily explored adjustment as a function of the correspondence between temperament and family factors, the framework may similarly apply to interactions between children's temperament and qualities of the school context. Temperament exerts an important influence on classroom processes, affecting teachers' perceptions and treatment of children, as well as the manner in which children process classroom experiences (Rothbart & Jones, 1998). Particular teaching styles, teacher-child relationship qualities, and methods of classroom management may "match" the needs of children with certain temperament profiles more than others. Theoretically, children who have an over-controlled temperament may particularly benefit from a teacher-child relationship characterized by warmth and the nurturance of exploration. In contrast, the challenges that accompany an under-controlled temperament may be best met by a context that is characterized by management and structure.

Research specific to school contexts is scarce and often diverges from traditional definitions of fit or correspondence (e.g., "good fit" has been defined as a match between children's actual temperaments and teachers' reports of ideal temperament; Sanson et al., 2004). Findings from this limited body of research are suggestive, however. Essex and colleagues found that the relation of temperamental inhibition to mental health problems was exacerbated by higher than average levels of teacher-child conflict and attenuated by lower than average levels of teacher-child conflict. Among disinhibited children, parallel associations were observed for teacher-child closeness: the influence of disinhibition on mental health problems was exacerbated by low closeness and attenuated by high closeness (Essex, Armstrong, Burk, Goldsmith, & Boyce, 2011a). Qualities of the teacher-child relationship have also been shown to moderate the influence of negative affectivity on behavior problems at school (McCormick, Turbeville, Barnes, & McClowry, 2014) and that of effortful control on children's psychosocial adjustment (Myers & Morris, 2009). However, additional research is needed to examine the potential moderating role of broader measures of classroom climate on relations between children's temperament and biological health.

Temperament, Context, and Neurobiological Functioning

On a daily basis, temperament and contextual influences interact to shape how children appraise and encode stressful and non-stressful events, how they feel in relation to these events, and how they respond behaviorally and biologically (Rueda & Rothbart, 2009). In recent years, there has been an increase in attention to relations between temperament and neuroendocrine stress response system functioning. As one of the primary arms of the stress response system, the hypothalamus-pituitary-adrenal (HPA) axis regulates longer-term patterns of stress responsivity through a series of hormonal processes that culminate in the release of its end product, cortisol. Healthy activity of the HPA axis and reactivity/ regulation of cortisol is involved in a variety of adaptive psychobiological responses to stress (e.g., increased cardiovascular functioning, suppression of nonessential biological functions, emotional-laden information processing, alterations to sensory thresholds; Abbott et al., 2003; de Kloet, 2010). However, chronically excessive or deficient HPA axis responses can lead to negative physical health outcomes, including hypertension, diabetes, ulcers, osteoporosis, and poor cardiovascular functioning (McEwen & Wingfield, 2003; Sapolsky, 2002) and have also been implicated as a key biological pathway through which stress exposure influences physical and psychological health across the lifespan (Essex et al., 2011b; Gunnar & Vazquez, 2006). Elucidating the early determinants of dysregulated cortisol expression has important implications for prevention and intervention efforts in the development of psychopathology and poor health outcomes.

HPA axis functioning is sensitive to the quality of early life experiences (Bush, Obradovic, Adler, & Boyce, 2011; Gunnar & Donzella, 2002), and expression of cortisol varies with individual differences in how stressors are perceived and meaning ascribed to challenging events (Dickerson & Kemeny, 2004). Since temperament influences children's appraisal of their environment and patterns of behavioral responding, it follows that temperamental traits may be associated with cortisol activity in response to new social environments or environmental demands. Indeed, higher levels of surgency have been associated with higher morning and evening cortisol levels during the transition to a new school year (Davis, Bruce, & Gunnar, 2002) and increased cortisol expression on school days relative to weekend days among elementary-age children (Davis, Donzella, Krueger, & Gunnar, 1999). Higher cortisol responses to stress have also been observed among preschool children who exhibited greater surgency and effortful control (Donzella, Gunnar, Krueger, & Alwin, 2000) and those with greater temperamental fearfulness (Talge, Donzella, & Gunnar, 2008). However, the magnitude of these associations is often quite variable across studies (Gunnar, 2001; Phillips, Fox, & Gunnar, 2011). It has thus been argued that relations between children's temperamental characteristics and HPA axis functioning are sensitive to context (Gunnar et al., 2003) and potentially moderated by early social and relational experiences (Hastings et al., 2011), highlighting the need to examine potential interactive processes.

Investigations of temperament-by-context interactions have focused primarily on the effects of goodness-of-fit (or lack thereof) on children's behavioral or mental health outcomes, with less attention to the prediction of biological or physical health. Only a few studies have examined moderated associations between temperament and cortisol, and have generally focused on the effects of parenting quality on the relation between temperamental inhibition and children's cortisol reactivity (Hastings et al., 2011; Kertes et al., 2009). Despite the salience of school contexts to children's development, to our knowledge, only one study has examined interactive effects of temperament and relationship factors on cortisol activity in the school setting. Tarullo, Mliner, and Gunnar (2011) reported an interaction between children's temperament and peer relationship quality. Inhibited children exhibited increased cortisol over the course of the school year when social integration and peer friendship quality was higher than average, suggesting that more intensive socialization functioned as a stressful experience for behaviorally inhibited children. Together, these studies provide a foundation on which to hypothesize interactions between children's temperament and the classroom context on daily cortisol output.

The Current Study

In the present investigation, we used a multi-method, multi-rater, prospective study design to extend the goodness-of-fit framework in two novel ways: 1) moving beyond the family environment to consider interactions between child temperament and qualities of the classroom environment, and 2) examining how temperament and classroom climate interactively predict a biological indicator of stress system functioning, daily cortisol output. Primary analyses were carried out on data from a diverse sample of children during their kindergarten year, a developmental period characterized by exposure to new roles and responsibilities during which the influence of the classroom environment may be particularly important to physiological functioning. To explore the robustness of associations outside of this sample and at a later time point in development, we also evaluated the potential for temperament and classroom climate to interact in the prediction of cortisol output in a separate, smaller sample of older children in third grade.

Methods

Data for the present analyses were drawn from two studies, the Peers and Wellness Study (PAWS) and the Wisconsin Study of Families and Work (WSFW). A separate description of the sample and methods for each study is provided below.

PAWS Participants

Participants were a community sample of children who participated in a larger longitudinal project of adversity, social relationships, and mental and physical health during the kindergarten year. The sample included 338 children (175 males and 163 females) ranging in age from 4 to 6 years old (M = 5.32, SD = 0.32). The sample was ethnically diverse, as demonstrated by the following distribution: 19% African American, 11% Asian, 43% European or Caucasian, 4% Latino, 22% Multiethnic, and 2% Other. Caregiver-reported data on children's functioning was primarily provided by mothers (87%), followed by biological fathers (9%), adoptive mothers (2.5%), biological grandmothers (0.6%), and individuals with other relationships with the child (0.9%). All caregivers will be hereafter referred to as parents.

PAWS Procedures

Recruitment occurred in fall of the kindergarten year from six public schools from the Oakland, Albany, and Berkeley Unified School Districts in the San Francisco Bay Area. Data were collected in three waves (2003-2005) from children in 29 kindergarten classroom headed by 17 teachers (several teachers participated in successive years of data collection). Schools were chosen in order to ensure that the participating children and families represented the socio-demographic characteristics of the larger metropolitan region. All families with a child who was a member of a participating classroom were invited to take part in the study and were only excluded due to lack of fluency in English or Spanish that would have prevented adequate comprehension of the questionnaires.

Data collection occurred during fall, winter, and spring of the kindergarten year. Prior to data collection, parents and teachers provided informed consent and children provided assent to participate. All parties were compensated for their time and effort; parents and children received $100 in gift certificates over the course of the kindergarten year, teachers were given $30 per each completed child assessment, and schools were awarded $20 for each child enrolled.

PAWS Measures

Demographics.—Parents provided data on child and family background characteristics using questionnaires mailed to their home in fall of the kindergarten year. Questions evaluated socioeconomic status, family structure, parents' marital status, children's race/ethnicity, and other demographic information.

Temperament.—Children's temperament was evaluated by parental report on the Very Short Form of the Child Behavior Questionnaire (CBQ-VSF; Putnam, Jacobs, Garstein & Rothbart, 2010), a 36-item measure based on the standard Child Behavior Questionnaire (CBQ; Mary K Rothbart, Ahadi, & Hershey, 1994), which was administered via home mailing in winter of the kindergarten year. Consistent with the standard CBQ, items on the CBQ-VSF are rated on a scale from 1 (*extremely untrue of your child*) to 7 (*extremely true of your child)* or as not applicable when the child has not been observed in the situation in question, and yield three broad factors of Negative Affectivity, Surgency, and Effortful Control (Putnam & Rothbart, 2010). Internal consistency scores of the factors in the present sample were as follows: Negative affectivity $\alpha = 0.73$, Surgency $\alpha = 0.68$, and Effortful Control $\alpha = 0.75$.

As described above, indices of surgency and effortful control may be combined to create meaningful profiles of under-controlled and over-controlled temperament. Following procedures outlined by Gunnar et al. (2003), we combined scores on the Surgency domain with reverse-scored totals on Effortful Control to create a Surgency-Effortful Control index. Lower scores on the resulting index represent more inhibited and over-controlled temperaments, and higher scores designate more disinhibited and under-controlled temperaments.

Teacher-child relationship and instructional climate.—Qualities of the teacher-child relationship and instructional environment in the classroom were evaluated with teachers' report on the Assessment of Learner-Centered Practices (ALCP; Deakin Crick, McCombs, Haddons, Broadfoot, & Tew, 2007; McCombs, Daniels, & Perry, 1998), which was completed in spring of the kindergarten year. The ALCP evaluates teachers' manner of interacting with students and the extent of child-focused classroom instructional practices across three domains: Creates positive relationships (e.g., *I demonstrate to each student that I like him/her as an individual*), Provides motivational support for learning (e.g., *I provide positive emotional support and encouragement to students who are insecure about performing well*), and Facilitates thinking and learning (e.g., *I help students learn how to do their work better*). Items were rated on a 4-point scale ranging from 1 (*almost never*) to 4 (*almost always*).

Daily salivary cortisol expression.—Cortisol was sampled from children during the first and last 20 minutes of the school day during morning and afternoon kindergarten classes on three consecutive school days for a total of six collections in spring of the kindergarten year. Children did not eat or drink during the half hour period prior to sampling and were then provided with cotton rolls to chew until they became saturated. The cotton rolls were deposited in Salivette tubes (Sarstedt, Nümberg, Germany) and frozen at −7°C until they were shipped to the University of Dresden for assay using a commercial immunoassay with chemiluminescence detection (Cortisol Luminescence Immunoassay; IBL-Hamburg, Hamburg, Germany). The detection limit of the assay was 0.41 nmol/l with mean inter- and intrassay variations of 8.5% and 6.1%, respectively. Values over 55 nmol/l were considered unreliable and were discarded (less than 1% of sample met this criteria). Seven children were excluded from analyses due to use of prescription medications with known effects on salivary cortisol levels (e.g., human growth hormone, exogenous glucocorticoids).

Cortisol values were $\log_{10}$-transformed to correct for deviations from normality. The average cortisol values and times of collection were computed across the six samples and area under the curve with respect to ground (AUCg) was calculated using the method of Pruessner and colleagues (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). Cortisol AUCg reflects total cortisol output (Pruessner et al., 2003) and, as computed in the present study, provided a measure of children's chronic HPA arousal during the kindergarten day averaged over three school days.

WSFW Participants

This sample consisted of 165 children in third grade (90 females, 75 males) and their parents and teachers who were participating in a larger longitudinal study of the family environment, school experiences, and children's physical and socioemotional development. The sample demographics reflected the composition of the larger Midwest area from which individuals were recruited (3% African-American, 2.4% Asian/Pacific Islander, 90% Caucasian, <1% Hispanic, 3% Indian/Alaska native, 1.2% Other).

WSFW Procedures

Originally, a total of 570 pregnant women and their partners were recruited for a study of maternity leave and family health from prenatal clinics in Milwaukee and Madison based on the following eligibility criteria among women: age 18 or older, in the second trimester of pregnancy, living with the baby's biological father, and either employed or full-time homemaker. Data used in the present analyses were collected during two assessment time points from the larger study: when children were 4.5 years and in third grade (approximately 9 years old). At the time of the third grade assessment, nearly four-fifths (79%, n = 448) of families from the initial cohort remained in the study. Equipment malfunction resulted in a loss of salivary cortisol data for a random subset of participants and thus the present analyses only included children for whom viable cortisol data was available at the third grade assessment (37%, n = 165). Parents and teachers provided informed consent to participate prior to the beginning of data collected. Parents were compensated $100 and children received a toy and book. School policies precluded some teachers from accepting compensation for their participation; thus, teachers from all participating schools were given the opportunity to select a book for their library.

WSFW Measures

Demographics.—During interviews and via responses to mailed questionnaires administered during the second trimester of pregnancy, mothers and fathers provided data on personal background characteristics, including marital status, ethnicity, and household structure. Parents' socioeconomic status was assessed repeatedly throughout the larger longitudinal project. In order to most closely parallel the PAWS models, analyses using the WSFW data included measures of family socioeconomic status (a composite of education and income) collected when children were 4.5 years old.

Temperament.—Children's temperament was evaluated at age 4.5 via maternal report on a modified version of the Children's Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001), an extended version of the same measure that was used to assess temperament in the PAWS study (see above). Items were evaluated on a 7-point scale from 1 (*extremely untrue of your child*) to 7 (*extremely true of your child*) with an additional response option if the item was not applicable to the child. Analogous to the measure of temperament used in the PAWS analyses, subscales on the CBQ were composited to reflect Negativity Affectivity (Withdrawal-related Negativity and Approach-related Negativity; α = 0.51), Surgency (Activity Level and Approach; α = 0.66), and Effortful Control (Attentional Focusing and Inhibitory Control; 0.72). To parallel the measurement approach in the PAWS study, the Surgency and Effortful Control scales were combined to reflect the extent to which child temperament was more inhibited and over-controlled versus more disinhibited and under-controlled.

Teacher-child relationship.—Qualities of the teacher-child relationship were collected during spring of grade 3 using teachers' report on a shortened version of the Teacher-Child Closeness Scale from the Student-Teacher Relationship Scale (STRS; Pianta, 1996; Pianta et al., 1995). The Closeness scale assesses aspects of positivity, warmth, responsiveness, and support between teachers and children within the classroom instructional environment.

Example items include: *If upset, this child will seek comfort from you* and *You share an affectionate, warm relationship with this child*. Scale scores were constructed as the mean of five items that were rated on a scale of 1 (*definitely does not apply*) to 5 (*definitely applies*) and internal consistency was good ($\alpha = 0.79$).

Daily salivary cortisol expression.—At grade 3, children provided saliva samples for three consecutive days at three collection times: after waking (before brushing teeth or consuming any food/liquids), between 3pm and 7pm (prior to eating dinner), and immediately before going to bed. In order to construct a measure of cortisol secretion comparable to PAWS, only the first two samples (after waking and afternoon) were used in the calculation of AUCg. Cortisol was assessed in duplicate using a highly reliable salivary enzyme immunoassay kits (Salimetrics, State College, PA). The detection sensitivity limit of the assay was 0.02 mg/dL and mean inter- and intra-assay variation was 7.4% and 3.8%, respectively. Exclusion criteria mirrored those applied in PAWS: cases with values over 55 nmol/l (n = 1, less than 1% of sample provided samples that exceeded this value) or who reported use of prescription medication that likely affected cortisol (n = 3) were excluded. Additionally, a select few participants (n = 6, less than 4% of the sample) provided samples that while biologically plausible, were exceptionally high relative to the remainder of the sample (> 4 standard deviations above the raw mean) and were omitted from analyses. Cortisol values were $\log_{10}$-transformed to normalize the distribution, and calculation of AUCg proceeded in the manner detailed above for PAWS analyses.

Statistical Analysis Plan

PAWS.—Multilevel linear modeling was conducted using SPSS MIXED to account for the hierarchical structure of the data (i.e., children nested within teachers' classrooms). Models evaluated the impact of temperament (*Negative affectivity or Under-controlled/ Over-controlled*), classroom climate (*Positive relationships*, *Motivational support*, and *Facilitates thinking* on the ALCP), and their interaction on cortisol AUCg, controlling for sex, ethnicity and socioeconomic status. All predictors and the interaction term were entered as fixed effects. The distributions of the ALCP scales were negatively skewed, precluding the probing of interactions at standard cut points (i.e., one standard deviation above and below the mean; Aiken, West, & Reno, 1991). Rather, the distributional properties of the ALCP subscales were examined to determine the most appropriate levels at which to examine significant interactions. Thus, lower scorers were represented by ALCP subscale of < 4 on *Positive Relationships* or ≤ 3 on *Motivational Support* and *Facilitates Thinking,* while scores of 4 on *Positive Relationships* or > 3 on *Motivational Support* and *Facilitates Thinking* designated higher scorers. Socioeconomic status (a composite of standardized education and income) and ethnicity (dummy coded variables; Caucasian and ethnic minority) were included as covariates in all analyses due to previously reported relations with cortisol AUCg (see Bush et al., 2011). Analyses also adjusted for child sex given prior research that has observed differences in associations between temperament or social behavior and cortisol between males and females in early childhood (Dettling, Gunnar, & Donzella, 1999; Tout, de Haan, Campbell, & Gunnar, 1998).

WSFW.—The statistical approach for WSFW mirrored that of PAWS, with the exception of the multilevel framework: children in the WSFW were not clustered within classrooms, precluding the necessity of a modeling strategy that accounted for nestedness. Multiple regression models tested the interactive influence of temperament (*Negative affectivity* or *Under-controlled/Over-controlled*) and classroom climate (*Teacher-child closeness*) on cortisol AUCg in the WSFW, statistically controlling for sex, ethnicity and socioeconomic status. Reflecting the general tendency of teachers to report a highly close relationship with their students, measures of teacher-child closeness in the WSFW were somewhat negatively skewed. As done in PAWS, the distribution of the classroom climate measure was explored in order to dichotomize the sample for analyses. Scores below 4 were recoded to reflect lower levels of teacher-child closeness, while scores of 4 and higher indicated greater levels of teacher-child closeness.

Results

PAWS

See Table 1 for zero-order correlations between key study variables.

Negative affectivity.—The first set of models investigated the main and interactive effects of children's negative affectivity and each of the three indicators of classroom climate on children's cortisol expression. There was a significant positive association between negative affectivity and cortisol ($p = .005$), however this main effect was qualified by a significant interaction between negative affectivity and motivational support for learning ($p = .044$; see Table 2). The f^2 effect size was .13, indicating a small-to-medium effect (Cohen, 1988). Analyses of simple slopes (see Figure 1) indicated that children's negative affectivity was positively related to total cortisol output within classroom climates characterized by lower levels of motivational support for learning ($b = .070$, SE = .024, $p < .01$). However, there was no relation between children's negative affectivity and cortisol when motivational support was high ($b = .014$, SE = .013, $p = .28$). Children's cortisol was not predicted by the interaction of negative affectivity with other characteristics of the classroom environment as measured by the ALCP, including Creates positive relationships ($p = .972$) and Facilitates thinking and learning ($p = .176$).

Over-controlled/Under-controlled.—The second set of models explored the predictive influence of over-controlled and under-controlled temperament classroom climate on cortisol AUCg. Again, lower scores reflect a temperament characterized by lower surgency and higher effortful control (i.e., over-controlled), whereas higher scores reflect the converse. There was a significant negative association between control and cortisol, such that those who appeared more over-controlled exhibited higher levels of cortisol ($p = .023$). However, this significant main effect should be interpreted in the context of a significant interaction between over-controlled/under-controlled and motivational support for learning ($p = .046$, see Table 2; $f^2 = .07$). Probing the interaction revealed significantly greater cortisol output among more over-controlled children as compared to under-controlled children when motivational support for learning was low ($b = -.056$, SE = .026, $p = .023$), but no relation between children's over-controlled/under-controlled temperament and cortisol output was found when the classroom climate was higher in motivational support for learning ($b = -.003$, SE = .011, $p = .774$; see Figure 2). Consistent with prior analyses of kindergarten children's negative affectivity, over-controlled/under-controlled temperament did not interact with other classroom climate variables in the prediction of cortisol characteristics (Creates positive relationships, $p = .543$; Facilitates thinking and learning, $p = .267$).

WSFW

See Table 3 for zero-order correlations among key study variables.

Negative affectivity.—Following the same analytic plan, we first tested the moderating influence of teacher-child closeness on the relation between negative affectivity and cortisol AUCg among children who were in the third grade. A marginally significant interaction emerged ($p = .083$; see Table 4). The associated effect size was smaller than that of the comparable PAWS negative affectivity model but is still considered to be a small-to-medium effect ($f^2 = .08$; Cohen, 1988). Given our intent to confirm the robustness of the patterns of association found within PAWS analyses, we graphed the simple slopes in order to ascertain whether the pattern of interaction was similar (see Figure 3). Indeed, there was a non-significant, trend-level positive slope between negative affectivity and total cortisol output in the context of lower levels of teacher-child closeness ($b = .113$, SE = .062, $p = .072$), similar to the significant positive association observed between negative affectivity and cortisol in the context of lower levels of motivational support within the PAWS sample. The slope representing the association between negative affectivity and cortisol at higher levels of teacher-child closeness appeared flat ($b = -.009$, SE = .031, $p = .764$), paralleling the null association between negative affectivity and cortisol observed at higher levels of motivational support within the PAWS sample.

Over-controlled/Under-controlled.—The results of the models testing the interaction of over-controlled/under-controlled temperament and teacher-child closeness in the third grade sample are presented in Table 4. Neither the interaction, nor the main effects of temperament and teacher-child relationship were significant predictors of cortisol within this older sample.

Discussion

The initiation of formal schooling is a developmental milestone that most children must navigate. There are notable individual differences in the nature of that transition and the extent to which children experience it as stressful. Children's temperament and qualities of the classroom environment represent person- and contextual-level factors, respectively, that shape children's functioning in educational settings. The *goodness-of-fit* hypothesis, as well as other interactionist perspectives, provide a useful framework for understanding the integrated effects of these multilevel influences, suggesting that temperamental qualities exert their influence through their "match" (or "mismatch") to the contextual demands of the environment. The goodness-of-fit hypothesis has been tested primarily by examining the interaction between early temperament and quality of parenting in the prediction of children's psychological health outcomes. Based on and extending the *goodness-of-fit* model, the present study tested the hypothesis that children's temperament would interact with relational and contextual features of the classroom environment to predict children's daily cortisol output, a biological indicator of the stress response. In a racially, ethnically, and economically diverse sample of children in kindergarten, results indicated that greater parent-rated negative affectivity and over-controlled temperament were associated with greater cortisol output during the school day, but only in the context of lower than average levels of motivational support from the teacher. Additional analyses based on a different sample of children in third grade revealed a similar, albeit marginally significant, positive relation between children's negative affectivity and cortisol output when teacher-child closeness was low, providing added evidence for the robustness of the interactive association found in the younger sample. However, among the sample of older children, the interaction of temperamental over-control/under-control and the classroom context did not significantly predict cortisol.

Temperament and Children's Daily Cortisol: Moderation by Classroom Climate

Entry into kindergarten marks a period of new developments in and challenges to children's social, emotional, and behavioral functioning. During this time, children take on new roles of student and classmate, navigate relations with a new peer group and additional caregiving figures, and learn and abide by novel rules and boundaries (Boyce et al., 1995). In the current study, children whose temperaments were characterized by high negative affectivity or low surgency and high effortful control (i.e., over-controlled qualities) exhibited heightened activation of the neuroendocrine stress system if the classroom environment lacked a certain level of encouragement and nurturance for children's learning. Interpreted within the goodness-of-fit framework, findings suggest a "mismatch" or "poor fit" between children with more difficult temperaments and lower levels of teacher-directed motivational support for learning, contributing to greater HPA axis arousal. Conversely, when children with more temperamental negative affectivity or over-control were in classroom environments characterized by higher than average levels of motivational support, they evidenced levels of HPA axis arousal similar to that of less negative and less over-controlled children. Although HPA axis arousal is a normative response to social stress, ongoing or prolonged activations of the HPA axis may increase vulnerability to stress-related physical and mental health problems later in life (Juster, McEwen, & Lupien, 2010). The findings of the present study suggest that a kindergarten classroom environment with relatively lower levels of motivational support may exacerbate the positive relation between children's temperamental negative affectivity and/or over-control and higher cortisol output.

There were some unique patterns within our findings among children in kindergarten. Of the three indictors of classroom climate assessed by the ALCP, only the measure of motivational support for learning emerged as a significant moderator of the relation between children's temperament and HPA axis activity. Indicators of warmth in the teacher-child relationship (Creates positive relationships) and teachers' specific efforts to help students complete their work (Facilitates learning and thinking) did not emerge as significant moderators. Notably, teachers' motivational support for learning is assessed with items that are both affective (e.g., *I provide positive emotional support and encouragement to students who* *are insecure about performing well*) and process- or performance-oriented (e.g., *I tell my students it's okay to make mistakes*), essentially drawing upon concepts that are separately assessed by the two other ALCP scales. Adjustment to the school context requires successful navigation of tasks within both relational and achievement domains, and it may be the case that a highly supportive, encouraging learning environment exerts a stronger influence on children's physiological adjustment than indicators of relationship quality or achievement alone, particularly for children with difficult temperaments.

A secondary aim of the current study was to explore the robustness of the interaction effects in an older sample of children attending third grade. The interaction of over-controlled/under-controlled temperament and the classroom climate that predicted daily cortisol among kindergarten children was not observed among children in third grade. However, the interaction of negative affectivity and classroom climate in this older sample revealed a remarkably similar pattern to the significant associations found in the primary sample of young children. Although findings did not reach conventional levels of statistical significance in the older sample, they were associated at the trend level, and graphical display of the data demonstrated a non-significant positive association between negative affectivity and cortisol output in the context of low levels of teacher-child closeness. The similarity in the pattern of results related to negative affectivity across both studies is notable and provides a foundation for future longitudinal research on factors that moderate how children's temperament relates to developmental processes and outcomes in the classroom. The measures of classroom climate across the PAWS and WSFW studies captured teachers' warmth, sensitivity, and responsivity, and highlight the strong influence of these relational and contextual qualities in attenuating the influence of children's negative affectivity on elevated cortisol output. Moreover, these supportive aspects of the teacher-child relationship bear similarity to measures of positive parenting that have been shown to moderate the relation between negative temperament and children's socioemotional and behavioral outcomes (Mesman et al., 2009).

In considering the differences in results across PAWS and WSFW, it should be noted that the samples differed in demographics, sample size, place of cortisol collection, and the specific measures that were used to evaluate children's temperament and classroom climate, precluding the WSFW analyses from being a true replication of those conducted in PAWS. Aside from these methodological differences, there are also developmental differences in the meaning and significance of school attendance between kindergarten children (the majority of whom were navigating this transition for the first time) and children in third grade (for whom the academic environment is not novel). These distinctions may shape how the classroom climate is experienced as stressful or challenging, with downstream effects on HPA axis activity. Particularly in relation to children's temperamental over-control/under-control, it may be the case that other qualities of the academic environment, such as children's peer relationships, exert a stronger moderating influence than the teacher-child relationship among children in third grade as compared to younger children.

The goodness-of-fit theory guided the models tested within the current study, however findings are consistent with other interactionist perspectives that suggest nuanced relations between individual-level factors and the environment in the prediction of children's adjustment. *Biological sensitivity to context* suggests that heightened reactivity increases children's sensitivity to the protective factors within supportive environments, but also elevates susceptibility to risk if present within stressful environments (Boyce & Ellis, 2005). Paralleling this theory, Belsky and colleagues have proposed that behavioral or phenotypic (e.g., temperament), endophenotypic (e.g., physiological reactivity), and genetic factors contribute to *differential susceptibility* to positive and negative qualities of the environment, particularly parental rearing (Belsky & Pluess, 2009). The biological sensitivity to context and differential susceptibility models have historically emphasized different individual-level moderators and the degree to which nature (versus nurture) is implicated in shaping such differences, but the models are conceptually tethered by an interactionist perspective on the influence of child characteristics and environmental context on adjustment outcomes. Indeed, they are now sometimes referred to together as "differential neurobiological susceptibility" (DNS) theories (Bush & Boyce, 2016; Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011). Consistent with these theories, results of the present study suggest that children's temperamental characteristics do not operate as uniform determinants of HPA axis arousal, but rather interact with qualities of the classroom relational context to determine physiological activity across the school day. However, direct support for DNS requires the presence of a clear crossover effect (i.e., high temperamental reactivity is associated with better outcomes in supportive conditions and worse outcomes in adverse conditions as compared to low temperamental reactivity). The absence of cross-over effects in the current study may suggest that such frameworks do not always capture the nature of relations between temperament and classroom context on children's neurobiological functioning. It has also been suggested that such effects may be less likely to emerge when variables are measured in different physiological or psychological domains (e.g., temperament and neurobiological functioning) (Essex et al., 2011a).

As the aforementioned frameworks have primarily been tested in the context of the early family environment, the current study represents a significant contribution to understanding how such interactive influences unfold in the school setting. An extensive body of research supports the strong independent influences of the classroom and teacher-child relationship on children's academic, social and behavioral functioning (Ferreira et al., 2016; Hernández et al., 2016). Results from the current study extend this body of work in two ways. First, the demonstrated interaction between temperament and classroom climate highlights the need to examine "fit" between the two, rather than either variable in isolation. Secondly, the interactive effects of temperament and classroom qualities predicted a key indicator of neurobiological stress system functioning. These findings suggest that academic environment may be of similar importance to the family context in shaping the influence of children's temperamental characteristics on stress-sensitive biological systems.

Limitations

There are several limitations that bear consideration in assessing the findings of the present study. Although we used a strong multi-informant, multi-method approach to assess variables of interest, parent report of children's temperament and teachers' report of the classroom relational context may be influenced by social desirability biases; thus, behavioral or observational measures would bolster confidence in our conclusions. Children's HPA axis arousal was measured through repeated cortisol sampling over the course of three days. Although this approach provides a more reliable assessment than would be garnered through a single day's collection, cortisol was only measured in the morning and afternoon during the school day and would be strengthened by more frequent measures throughout the day (Adam & Kumari, 2009). As noted above, a number of other psychosocial and contextual variables not measures in the current study may also affect physiological responses to stress (e.g., coping, attention, peer relationships) and are fruitful areas for future research.

Implications and Conclusions

Children's successful transition to kindergarten is of paramount importance for children's later academic achievement (Cooper, Moore, Powers, Cleveland, & Greenberg, 2014). Nearly one-third of children experience "some problems" and another 16% experience "many problems" when they begin kindergarten (Rimm-Kaufman, Pianta, & Cox, 2000) and many parents feel unprepared to support their children's ability to meet the academic, social, and behavioral expectations of school attendance (McIntyre, Eckert, Fiese, DiGennaro, & Wildenger, 2007). Child-level factors, including children's cognitive abilities and socioemotional competences, have been identified as important determinants of the ease or difficulty with which children transition to kindergarten (Schulting, Malone, & Dodge, 2005). Results of the current study also bring attention to the salience of children's temperament on the kindergarten transition and, as outlined by ecological models of children's development, highlight how such individual factors do not act in isolation of the larger classroom and teacher-child relational contexts in which they are embedded (Bronfenbrenner, 1977).

In sum, the present study provides support for the moderating influence of the teacher-child relationship and classroom climate on associations between children's temperamental qualities and physiological stress regulation, particularly during the initial transition to kindergarten. Rather than operating uniformly, the physiological consequences of difficult temperamental traits may depend on the qualities of the context in which they unfold. Our results suggest that it may be valuable to consider the responsivity of neurobiological processes to school-based environmental and relational factors within the implementation and evaluation of interventions to promote children's positive adjustment within academic environments. Efforts to train educators in developing healthy teacher-student relationships and supporting children's optimal school functioning may benefit from addressing the complex interactions of children's temperament within varied classroom climates. Incorporating physiological measures can also provide a more comprehensive understanding of the multilevel, interactive processes that shape children's functioning as they spend increasing amounts of time outside the family setting.

Source of Funding:

This study was supported by grants from the National Institute of Mental Health (W. Thomas Boyce: R01 MH62320; Marilyn Essex: R01 MH44340, P50 MH052354), the MacArthur Foundation Research Network on Psychopathology and Development (Boyce and Essex), and the Canadian Institute for Advanced Research (Boyce).

References

Adam EK, & Kumari M (2009). Assessing salivary cortisol in large-scale, epidemiological research. Psychoneuroendocrinology, 34(10), 1423–1436. doi:10.1016/j.psyneuen.2009.06.011 [PubMed: 19647372]

Aiken LS, West SG, & Reno RR (1991). Multiple regression: Testing and interpreting interactions. Thousand Oaks, CA: Sage.

Belsky J, & Pluess M (2009). Beyond diathesis stress: differential susceptibility to environmental influences. Psychological Bulletin, 135(6), 885. doi:10.1037/a0017376 [PubMed: 19883141]

Berdan LE, Keane SP, & Calkins SD (2008). Temperament and externalizing behavior: social preference and perceived acceptance as protective factors. Developmental Psychology, 44(4), 957–968. doi:10.1037/0012-1649.44.4.957 [PubMed: 18605827]

Bijttebier P, & Roeyers H (2009). Temperament and vulnerability to psychopathology: Introduction to the special section. Journal of Abnormal Child Psychology, 37(3), 305–308. doi:10.1007/s10802-009-9308-2 [PubMed: 19225877]

Boyce WT, Adams S, Tschann JM, Cohen F, Wara D, & Gunnar MR (1995). Adrenocortical and behavioral predictors of immune responses to starting school. Pediatric Research, 38(6), 1009–1017. doi:10.1203/00006450-199512000-00030 [PubMed: 8618776]

Boyce WT, & Ellis BJ (2005). Biological sensitivity to context: I. An evolutionary–developmental theory of the origins and functions of stress reactivity. Development and Psychopathology, 17(e2), 271–301. doi:10.1017/S0954579405050145 [PubMed: 16761546]

Breeman L, Wubbels T, van Lier P, Verhulst F, Van der Ende J, Maras A, … Tick N (2015). Teacher characteristics, social classroom relationships, and children's social, emotional, and behavioral classroom adjustment in special education. Journal of School Psychology, 53(1), 87–103. doi:10.1016/j.jsp.2014.11.005 [PubMed: 25636262]

Bronfenbrenner U (1977). Toward an experimental ecology of human development. American Psychologist, 32(7), 513. doi:10.1037/0003-066X.32.7.513

Bush NR, & Boyce WT (2016). Differential sensitivity to context: Implications for developmental psychopathology. In Cicchetti D (Ed.), Developmental psychopathology (pp. 107–137). Hoboken, NJ: Wiley.

Bush NR, Obradovic J, Adler N, & Boyce WT (2011). Kindergarten stressors and cumulative adrenocortical activation: the "first straws" of allostatic load? Development and Psychopathology, 23(4), 1089–1106. doi:10.1017/S0954579411000514 [PubMed: 22018083]

Buss AH, & Plomin R (1984). Temperament: Early developing personality traits. Hillsdale, NJ: Lawrence Earlbaum Associates.

Chess S, & Thomas A (1999). Goodness of fit: Clinical applications from infancy through adult life. Philadelphia, PA: Brunner/Mazel.

Cohen J (1988). Statistical power analysis for the behavioural sciences. Hillside, NJ: Lawrence Earlbaum Associates.

Compas BE, Connor-Smith J, & Jaser SS (2004). Temperament, stress reactivity, and coping: Implications for depression in childhood and adolescence. Journal of Clinical Child and Adolescent Psychology, 33(1), 21–31. doi: 10.1207/S15374424JCCP3301_3 [PubMed: 15028538]

Cooper BR, Moore JE, Powers C, Cleveland M, & Greenberg MT (2014). Patterns of early reading and social skills associated with academic success in elementary school. Early Education and Development, 25(8), 1248–1264. doi: 10.1080/10409289.2014.932236

Davis EP, Bruce J, & Gunnar MR (2002). The anterior attention network: Associations with temperament and neuroendocrine activity in 6-year-old children. Developmental Psychobiology, 40(1), 43–56. doi:10.1002/dev.10012 [PubMed: 11835150]

Davis EP, Donzella B, Krueger WK, & Gunnar MR (1999). The start of a new school year: Individual differences in salivary cortisol response in relation to child temperament. Developmental Psychobiology, 35(3), 188–196. doi:10.1002/(SICI)1098-2302(199911)35:3<188::AID-DEV3>3.0.CO;2-K [PubMed: 10531531]

Deakin Crick R, McCombs B, Haddon A, Broadfoot P, & Tew M (2007). The ecology of learning: factors contributing to learner-centred classroom cultures. Research Papers in Education, 22(3), 267–307. doi:10.1080/02671520701497555

Dettling AC, Gunnar MR, & Donzella B (1999). Cortisol levels of young children in full-day childcare centers: relations with age and temperament. Psychoneuroendocrinology, 24(5), 519–536. doi:10.1016/S0306-4530(99)00009-8 [PubMed: 10378239]

Dickerson SS, & Kemeny ME (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. Psychological Bulletin, 130(3), 355. doi: 10.1037/0033-2909.130.3.355 [PubMed: 15122924]

Donzella B, Gunnar MR, Krueger WK, & Alwin J (2000). Cortisol and vagal tone responses to competitive challenge in preschoolers: Associations with temperament. Developmental Psychobiology, 37(4), 209–220. doi:10.1002/1098-2302(2000)37:4<209::AID-DEV1>3.0.CO;2-S [PubMed: 11084602]

Eisenberg N, Fabes RA, Shepard SA, Murphy BC, Guthrie IK, Jones S, … Maszk P (1997). Contemporaneous and longitudinal prediction of children's social functioning from regulation and emotionality. Child Development, 68(4), 642–664. doi: 10.1111/j.1467-8624.1997.tb04227.x [PubMed: 9306644]

Eisenberg N, Spinrad TL, Fabes RA, Reiser M, Cumberland A, Shepard SA, … Thompson M (2004). The relations of effortful control and impulsivity to children's resiliency and adjustment. Child Development, 75(1), 25–46. doi:10.1111/j.1467-8624.2004.00652.x [PubMed: 15015673]

Eisenberg N, Valiente C, Spinrad TL, Cumberland A, Liew J, Reiser M, … Losoya SH (2009). Longitudinal relations of children's effortful control, impulsivity, and negative emotionality to their externalizing, internalizing, and co-occurring behavior problems. Developmental Psychology, 45(4), 988–1008. doi:10.1037/a0016213 [PubMed: 19586175]

Ellis BJ, Boyce WT, Belsky J, Bakermans-Kranenburg MJ, & Van IJzendoorn MH (2011). Differential susceptibility to the environment: An evolutionary–neurodevelopmental theory. Development and Psychopathology, 23(01), 7–28. doi: 10.1017/S0954579410000611 [PubMed: 21262036]

Essex MJ, Armstrong JM, Burk LR, Goldsmith HH, & Boyce WT (2011a). Biological sensitivity to context moderates the effects of the early teacher–child relationship on the development of mental health by adolescence. Development and Psychopathology, 23(01), 149–161. doi:10.1017/S0954579410000702 [PubMed: 21262045]

Essex MJ, Shirtcliff EA, Burk LR, Ruttle PL, Klein MH, Slattery MJ, … Armstrong JM (2011b). Influence of early life stress on later hypothalamic–pituitary–adrenal axis functioning and its covariation with mental health symptoms: A study of the allostatic process from childhood into adolescence. Development and Psychopathology, 23(04), 1039–1058. doi:10.1017/S0954579411000484 [PubMed: 22018080]

Ferreira T, Cadima J, Matias M, Vieira JM, Leal T, & Matos PM (2016). Preschool Children's Prosocial Behavior: The Role of Mother–Child, Father–Child and Teacher–Child Relationships. Journal of Child and Family Studies, 25(6), 1829–1839. doi: 10.1007/s10826-016-0369-x

Gilliom M, & Shaw DS (2004). Codevelopment of externalizing and internalizing problems in early childhood. Development and Psychopathology, 16(02), 313–333. doi: 10.1017/S0954579404044530 [PubMed: 15487598]

Griggs MS, Gagnon SG, Huelsman TJ, Kidder-Ashley P, & Ballard M (2009). Student-teacher relationships matter: Moderating influences between temperament and preschool social competence. Psychology in the Schools, 46(6), 553–567. doi: 10.1002/pits.20397

Gunnar MR (2001). The role of glucocorticoids in anxiety disorders: A critical analysis. In Vassey MW & Dadds M (Eds.), The developmental psychopathology of anxiety (pp. 143–159). New York, NY: Oxford University Press.

Gunnar MR, & Donzella B (2002). Social regulation of the cortisol levels in early human development. Psychoneuroendocrinology, 27(1), 199–220. doi:10.1016/S0306-4530(01)00045-2 [PubMed: 11750779]

Gunnar MR, Sebanc AM, Tout K, Donzella B, & van Dulmen MM (2003). Peer rejection, temperament, and cortisol activity in preschoolers. Developmental Psychobiology, 43(4), 346–368. doi:10.1002/dev.10144 [PubMed: 15027418]

Gunnar MR, & Vazquez D (2006). Stress neurobiology and developmental psychopathology. In Cicchetti D & Cohen DJ (Eds.), Developmental Psychopathology (pp. 533–577). Hoboken, NJ: John Wiley & Sons, Inc.

Hamre BK, & Pianta RC (2001). Early teacher–child relationships and the trajectory of children's school outcomes through eighth grade. Child Development, 72(2), 625–638. doi: 10.1111/1467-8624.00301 [PubMed: 11333089]

Hastings PD, Ruttle PL, Serbin LA, Mills RS, Stack DM, & Schwartzman AE (2011). Adrenocortical responses to strangers in preschoolers: Relations with parenting, temperament, and psychopathology. Developmental Psychobiology, 53(7), 694–710. doi: 10.1002/dev.20545 [PubMed: 21432849]

Hernández MM, Eisenberg N, Valiente C, VanSchyndel SK, Spinrad TL, Silva KM, … Thompson MS (2016). Emotional expression in school context, social relationships, and academic adjustment in kindergarten. Emotion, 16(4), 553–566. doi: 10.1037/emo0000147 [PubMed: 26751629]

Juster R-P, McEwen BS, & Lupien SJ (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. Neuroscience & Biobehavioral Reviews, 35(1), 2–16. doi:10.1016/j.neubiorev.2009.10.002 [PubMed: 19822172]

Kertes DA, Donzella B, Talge NM, Garvin MC, Van Ryzin MJ, & Gunnar MR (2009). Inhibited temperament and parent emotional availability differentially predict young children's cortisol responses to novel social and nonsocial events. Developmental Psychobiology, 51(7), 521–532. doi:10.1002/dev.20390 [PubMed: 19676107]

Kryski KR, Dougherty LR, Dyson MW, Olino TM, Laptook RS, Klein DN, & Hayden EP (2013). Effortful control and parenting: Associations with HPA axis reactivity in early childhood. Developmental Science, 16(4), 531–541. doi: 10.1111/desc.12050 [PubMed: 23786471]

Lahey BB (2009). Public health significance of neuroticism. American Psychologist, 64(4), 241–256. doi:10.1037/a0015309 [PubMed: 19449983]

McCombs BL, Daniels DH, & Perry KE (1998). Children's and teacher' perceptions of learner-centered practices, and student motivation: Implications for early schooling. The Elementary School Journal, 109(1), 16–35. doi: 10.1086/592365

McCormick MP, Turbeville AR, Barnes SP, & McClowry SG (2014). Challenging Temperament, Teacher–Child Relationships, and Behavior Problems in Urban Low-Income Children: A Longitudinal Examination. Early Education and Development, 25(8), 1198–1218. doi:10.1080/10409289.2014.915676

McEwen BS, & Wingfield JC (2003). The concept of allostasis in biology and biomedicine. Hormones and Behavior, 43(1), 2–15. doi:10.1016/S0018-506X(02)00024-7 [PubMed: 12614627]

McIntyre LL, Eckert TL, Fiese BH, DiGennaro FD, & Wildenger LK (2007). Transition to kindergarten: Family experiences and involvement. Early Childhood Education Journal, 35(1), 83–88. doi:10.1007/s10643-007-0175-6

Mesman J, Stoel R, Bakermans-Kranenburg MJ, van IJzendoorn MH, Juffer F, Koot HM, & Alink LR (2009). Predicting growth curves of early childhood externalizing problems: Differential susceptibility of children with difficult temperament. Journal of Abnormal Child Psychology, 37(5), 625–636. doi: 10.1007/s10802-009-9298-0 [PubMed: 19184403]

Morris AS, Silk JS, Steinberg L, Sessa FM, Avenevoli S, & Essex MJ (2002). Temperamental vulnerability and negative parenting as interacting predictors of child adjustment. Journal of Marriage and Family, 64(2), 461–471. doi:10.1111/j.1741-3737.2002.00461.x

Muris P, & Ollendick TH (2005). The role of temperament in the etiology of child psychopathology. Clinical Child and Family Psychology Review, 8(4), 271–289. doi: 10.1007/s10567-005-8809-y [PubMed: 16362256]

Myers SS, & Morris AS (2009). Examining associations between effortful control and teacher–child relationships in relation to Head Start children's socioemotional adjustment. Early Education and Development, 20(5), 756–774. doi:10.1080/10409280802571244 [PubMed: 24000274]

Oldehinkel AJ, Veenstra R, Ormel J, De Winter AF, & Verhulst FC (2006). Temperament, parenting, and depressive symptoms in a population sample of preadolescents. Journal of Child Psychology and Psychiatry, 47(7), 684–695. doi: 10.1111/j.1469-7610.2005.01535.x [PubMed: 16790003]

Phillips DA, Fox NA, & Gunnar MR (2011). Same place, different experiences: Bringing individual differences to research in child care. Child Development Perspectives, 5(1), 44–49. doi:10.1111/j.1750-8606.2010.00155.x

Pianta RC (1996). Manual and Scoring Guide for the Student-Teacher Relationship Scale. Unpublished manuscript, University of Virginia, Charlottsville, VA.

Pianta RC, Steinberg MS, & Rollins KB (1995). The first two years of school: Teacher-child relationships and deflections in children's classroom adjustment. Development and Psychopathology, 7(2), 295–312. doi:10.1017/S0954579400006519

Pruessner JC, Kirschbaum C, Meinlschmid G, & Hellhammer DH (2003). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. Psychoneuroendocrinology, 28(7), 916–931. doi:10.1016/S0306-4530(02)00108-7 [PubMed: 12892658]

Putnam S, Jacobs J, Garstein M, & Rothbart M (2010, March). Development and assessment of short and very short forms of the Early Childhood Behavior Questionnaire. Poster session presented at the International Conference on Infant Studies, Baltimore, MD.

Rimm-Kaufman SE, Pianta RC, & Cox MJ (2000). Teachers' judgments of problems in the transition to kindergarten. Early Childhood Research Quarterly, 15(2), 147–166. doi: 10.1016/S0885-2006(00)00049-1

Rothbart M, & Bates J (1998). Temperament. In Damon W (Ser. Ed.) & Eisenberg N (Vol. Ed.), Handbook of child psychology: Vol. 4. Social, emotional, and personality development (pp. 105–176): New York, NY: John Wiley & Sons, Inc.

Rothbart M, & Bates J (2006). Temperament. In Eisenberg N, Damon W, & Lerner R (Eds.), Handbook of child psychology: Vol 3. Social, emotional, and personality development (pp. 99–166). Hoboken, NJ: John Wiley & Sons, Inc.

Rothbart MK (1989). Temperament in childhood: A framework. In Kohnstamm G, Bates J, & Rothbart MK (Eds.), Temperament in childhood (pp. 59–73). Chichester, UK: John Wiley & Sons, Inc.

Rothbart MK (2007). Temperament, development, and personality. Current Directions in Psychological Science, 16(4), 207–212. doi: 10.1111/j.1467-8721.2007.00505.x

Rothbart MK, Ahadi SA, & Hershey KL (1994). Temperament and social behavior in childhood. Merrill-Palmer Quarterly (1982-), 21–39. http://www.jstor.org/stable/23087906

Rothbart MK, Ahadi SA, Hershey KL, & Fisher P (2001). Investigations of temperament at three to seven years: The Children's Behavior Questionnaire. Child Development, 72(5), 1394–1408. doi:10.1111/1467-8624.00355 [PubMed: 11699677]

Rothbart MK, & Jones LB (1998). Temperament, self-regulation, and education. School Psychology Review, 27(4), 479–491.

Rueda MR, & Rothbart MK (2009). The influence of temperament on the development of coping: The role of maturation and experience. New Directions for Child and Adolescent Development, 2009(124), 19–31. doi:10.1002/cd.240 [PubMed: 19536792]

Sanson A, Hemphill SA, & Smart D (2004). Connections between temperament and social development: A review. Social Development, 13(1), 142–170. doi:10.1046/j.1467-9507.2004.00261.x

Sapolsky RM (2002). Endocrinology of the stress-response. In Becker J, Breedlove S, Crews D, & McCarthy M (Eds.), Behavioral Endocrinology, 2nd edition (pp. 409–450). Cambridge, MA: MIT Press.

Schulting AB, Malone PS, & Dodge KA (2005). The effect of school-based kindergarten transition policies and practices on child academic outcomes. Developmental Psychology, 41(6), 860–871. doi:10.1037/0012-1649.41.6.860 [PubMed: 16351333]

Spinrad TL, Eisenberg N, Granger DA, Eggum ND, Sallquist J, Haugen R, … Hofer C (2009). Individual differences in preschoolers' salivary cortisol and alpha-amylase reactivity: Relations to temperament and maladjustment. Hormones and Behavior, 56(1), 133–139. doi:10.1016/j.yhbeh.2009.03.020 [PubMed: 19348808]

Stright AD, Gallagher KC, & Kelley K (2008). Infant temperament moderates relations between maternal parenting in early childhood and children's adjustment in first grade. Child Development, 79(1), 186–200. doi:10.1111/j.1467-8624.2007.01119.x [PubMed: 18269517]

Talge NM, Donzella B, & Gunnar MR (2008). Fearful temperament and stress reactivity among preschool-aged children. Infant and Child Development, 17(4), 427–445. doi: 10.1002/icd.585 [PubMed: 19122850]

Tarullo AR, Mliner S, & Gunnar MR (2011). Inhibition and exuberance in preschool classrooms: Associations with peer social experiences and changes in cortisol across the preschool year. Developmental Psychology, 47(5), 1374–1388. doi:10.1037/a0024093 [PubMed: 21688898]

Thomas A, & Chess S (1977). Temperament and development. New York, NY: Brunner/Mazel.

Tout K, de Haan M, Campbell EK, & Gunnar MR (1998). Social behavior correlates of cortisol activity in child care: gender differences and time-of-day effects. Child Development, 69(5), 1247–1262. doi:10.1111/j.1467-8624.1998.tb06209.x [PubMed: 9839413]

Windle M, & Lerner RM (1986). Reassessing the dimensions of temperamental individuality across the life span: The Revised Dimensions of Temperament Survey (DOTS-R). Journal of Adolescent Research, 1(2), 213–229. doi:10.1177/074355488612007

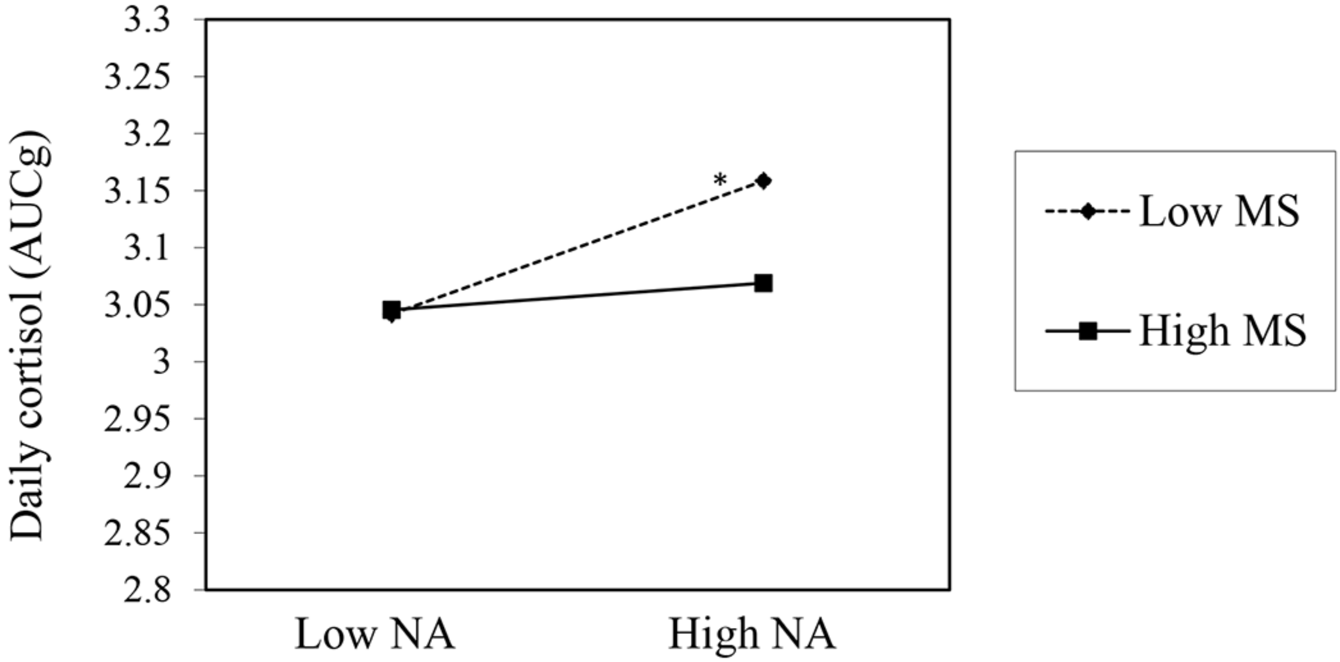

Figure 1.

PAWS: Interaction between negative affectivity and motivational support in the prediction of daily cortisol. NA = Negative affectivity; MS = Motivational support for learning

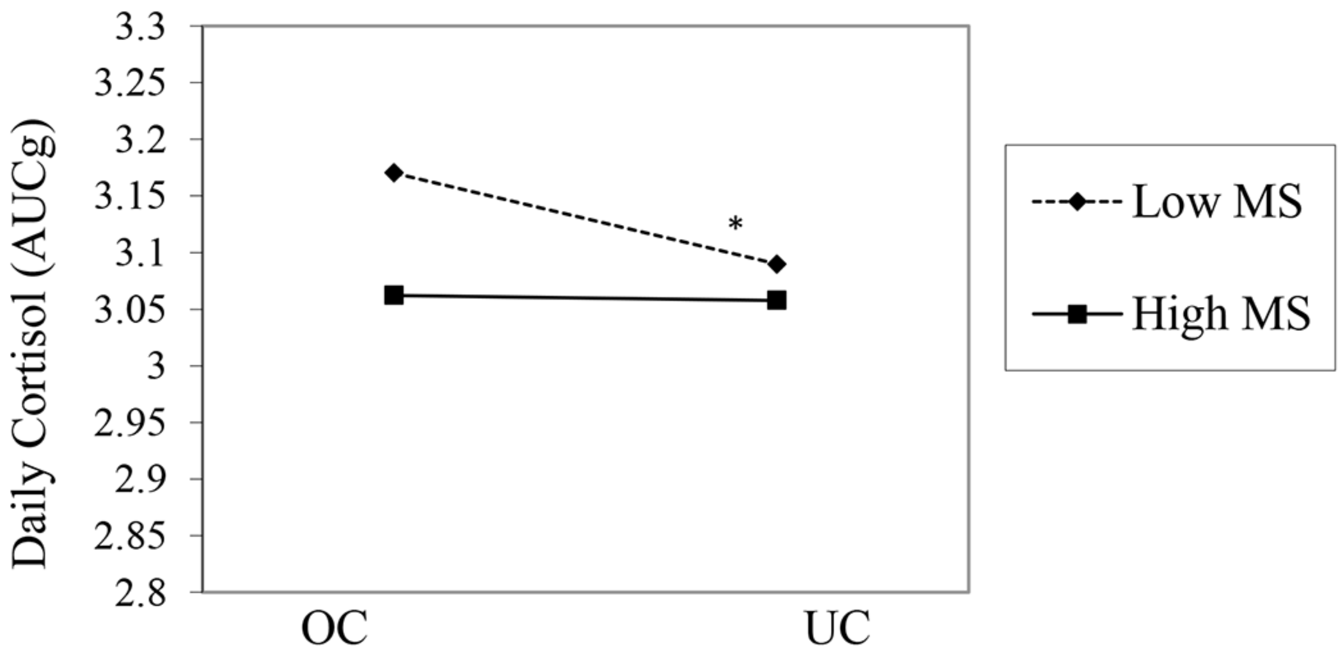

Figure 2.

PAWS: Interaction between Over-controlled/Under-controlled temperament and motivational support in the prediction of daily cortisol. OC = Over-controlled; UC = Under-controlled; MS = Motivational support for learning

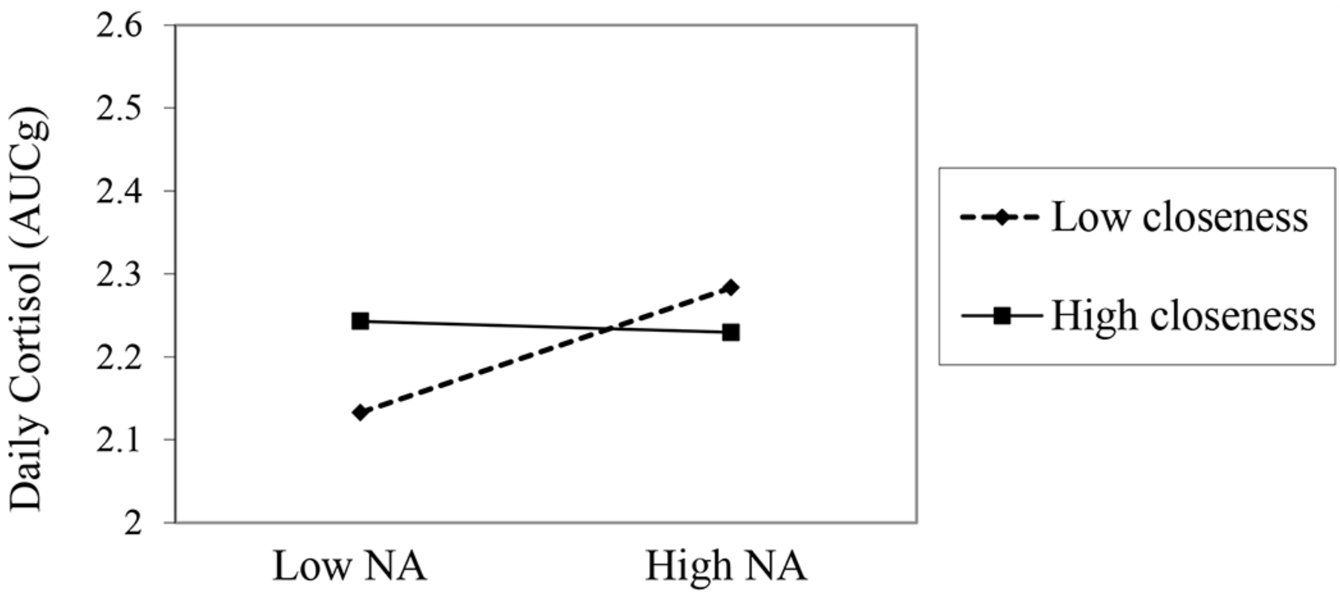

Figure 3.
WSFW: Interaction between negative affectivity and teacher-child closeness in the prediction of daily cortisol. NA = Negative affectivity

Table 1

Zero order correlations of PAWS key study variables

	1	2	3	4	5	6	7	8
1. Child sex	--							
2. Family socioeconomic status	.11 *	--						
3. Child race/ethnicity	−.02	.47	--					
4. Negative affectivity	.06	−.04	−.02	--				
5. Over-controlled/Under-controlled	−.30 **	−.11	.06	−.09	--			
6. ALCP Creates positive relationships	.02	.22 **	.20 **	.01	−.10 †	--		
7. ALCP Provides motivational support	−.01	.24 **	.26 **	−.06	−.12 *	.47 **	--	
8. ALCP Facilitates learning and thinking	−.003	.24 **	.20 **	−.02	−.12 *	.47 **	.42 **	--
9. Cortisol	−.05	−.35	−.28 **	.10†	.07	−.17 **	−.14 **	−.05

Note. Sex coded as 0 = Male, 1 = Female; Ethnicity coded as 0 = Non-Caucasian, 1 = Caucasian;

* $p \leq .05$,

** $p \leq .01$,

† $p \leq .10$

Author Manuscript

Author Manuscript

Author Manuscript

Table 2

Regression coefficients in the PAWS model of children's cortisol as a function of temperament, classroom climate, and their interaction

	Coefficient	**SE**	***p***
Negative affectivity			
Sex	.023	.019	.236
Race/ethnicity	−.012	.021	.557
Socioeconomic status	−.024	.015	.108
Negative affectivity	.070	.025	.005
Provides motivational support for learning (MS)	−.043	.078	.585
Negative affectivity x MS	−.057	.028	.044
Over-controlled/Under-controlled			
Sex	.020	.020	.318
Race/ethnicity	−.008	.021	.721
Socioeconomic status	−.026	.015	.087
Over-controlled/Under-controlled	−.056	.025	.023
Provides motivational support for learning (MS)	−.070	.081	.389
Over-controlled/Under-controlled x MS	.053	.026	.046

Note. Sex coded as 0 = Male, 1 = Female; Ethnicity coded as 0 = Non-Caucasian, 1 = Caucasian

Table 3

Zero order correlations of WSFW key study variables

	1	2	3	4	5	6	7
1. Child sex	--						
2. Family socioeconomic status	.10	--					
3. Family race/ethnicity	.16[†]	−.05	--				
4. Negative affectivity	−.02	.07	−.08	--			
5. Over-controlled/Under-controlled	−.18[*]	−.23[**]	−.001	.17[*]	--		
6. Teacher-child closeness	.14[†]	.14	.03	−.09	.07	--	
7. Cortisol	−.001	.08	−.22[**]	.05	.003	.03	--

Note. Sex coded as 0 = Male, 1 = Female; Ethnicity coded as 1 = Caucasian, 2 = Non-Caucasian;

[*] $p \leq .05$,

[**] $p \leq .01$,

[†] $p \leq .10$

Author Manuscript

Author Manuscript

Author Manuscript

Table 4

Regression coefficients in the WSFW model of children's cortisol as a function of temperament, classroom climate, and their interaction

	Coefficient	SE	*p*
Negative affectivity			
Sex	.007	.037	.853
Race/ethnicity	−.134	.056	.019
Socioeconomic status	−.005	.021	.830
Negative affectivity	.113	.062	.072
Teacher-child closeness	.028	.041	.499
Negative affectivity x teacher-child closeness	−.123	.070	.083
Over-controlled/Under-controlled			
Sex	.020	.038	.599
Ethnicity	−.147	.057	.010
Socioeconomic status	−.009	.022	.671
Over-controlled/Under-controlled	−.035	.028	.218
Teacher-child closeness	.026	.041	.536
Over-controlled/Under-controlled x teacher-child closeness	.045	.033	.171

Note. Sex coded as 0 = Male, 1 = Female; Ethnicity coded as 0 = Caucasian, 1 = Non-Caucasian