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Harsh discipline and behavior problems: The moderating effects of cortisol and alpha-amylase

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ABSTRACT

Numerous studies link harsh discipline to adjustment problems in youth, yet not all individuals exposed to harsh discipline develop behavior problems. Contemporary theory suggests that this relationship could be moderated by individual differences in environmentally sensitive biological systems. This study investigated whether the interaction between hypothalamic-pituitary-adrenal (HPA) activity and autonomic nervous system (ANS) arousal moderated the link between harsh discipline and behavior problems. Three saliva samples were collected on a single day from 425 inner city youth (50% male, age 11–12 years, 80% African American) and were later assayed for cortisol (HPA) and alpha-amylase (ANS). Problem behavior was assessed by self- and parent-report using the Child Behavior Checklist. Youth also reported the level of harsh discipline that they experienced. Harsh discipline was positively associated with externalizing and internalizing problems only when there were asymmetrical profiles of HPA activity and ANS arousal. This pattern was evident for boys but not girls. Findings are discussed in relation to prevailing theories suggesting that biological susceptibility translates adversity into risk for behavior problems.

1. Introduction

Harsh parenting behavior encompasses a wide spectrum of physical and verbal behavior toward offspring including corporal punishment, shouting, and threats (Reid, Patterson, & Snyder, 2002). Studies report that children's exposure to these negative parenting behaviors early in life is associated with later adjustment problems including higher rates of aggressive behavior (Gershoff, 2002; Gershoff, Lansford, Sexton, Davis-Kean, & Sameroff, 2012) and anxiety and depression (McLoyd, Kaplan, Hardaway, & Wood, 2007; Rodriguez, 2003; Wang & Kenny, 2014). It is noteworthy that these findings have been corroborated in many countries and cultures (e.g., Csorba et al., 2001; Steely & Rohner, 2006). Nevertheless, these effects are not universal in the sense that not all individuals raised in such adverse family circumstances express behavior problems later in life—adversity places some at risk, but others are resilient (e.g., Toth & Cicchetti, 2013).

Developmental science has drawn upon notions of *diathesis-stress* and *differential susceptibility* to explain these individual differences (Belsky & Pluess, 2009; Monroe & Simons, 1991). The diathesis-stress model (or dual hazard model) postulates that biological vulnerability is exacerbated by environmental adversity (Monroe & Simons, 1991; Raine, 2005). In contrast, differential susceptibility emphasizes the role of individual differences in developmental plasticity. That is, individuals with high plasticity are assumed to be more affected by either supportive or adverse features of their social environments, whereas individuals with low plasticity show less biobehavioral reactivity to their circumstances regardless of the valence (Belsky & Pluess, 2009). Central to both models is the notion that environmentally sensitive biological systems moderate the effects of adversity on the development of behavior problems. Most recently, researchers have operationalized individual differences in environmentally responsive biological processes as related to problem behavior with a multi-system approach and tested main and interactive effects

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of, hypothalamic-pituitary-adrenal (HPA) axis activity and autonomic nervous system (ANS) arousal (Chen et al., 2014; El-Sheikh, Erath, Buckhalt, Granger, & Mize, 2008; Gordis, Granger, Susman, & Trickett, 2006). In the present study we attempt to extend our understanding about these complex relationships to new limits by investigating whether the interaction between HPA activity and ANS arousal moderates the link between harsh discipline and behavior problems in a large sample (N = 425) of predominantly low socioeconomic status, urban dwelling African American children (50% male, 11–12 years of age).

The psychobiology of the stress response has two major components, the HPA axis and the ANS. Activation of the HPA axis culminates in the secretion of cortisol into circulation. This response is relatively slow (in minutes) as the primary signaling molecules with this system, must be synthesized de novo. Studies have shown that HPA axis activation is more likely to occur when the situation is novel or unfamiliar, uncontrollable, involves social evaluative threat, and generates emotional distress (Gerra et al., 2001; Kirschbaum & Hellhammer, 1994; Peters et al., 1998; Schommer, Hellhammer, & Kirschbaum, 2003). HPA axis reactivity and regulation is considered a "defeat reaction" (Henry, 1993). By contrast, activation of the ANS occurs very rapidly (in seconds) and involves the release of catecholamines into the blood stream (e.g., Chrousos & Gold, 1992; Lundberg & Frankenhaeuser, 1980). ANS arousal facilitates fast and diffuse reactions which are collectively known as "fight or flight" responses and include changes in physiology such as elevated heart rate and blood pressure (Cannon, 1914). ANS activation is considered a "defense reaction" (Folkow, 1985; Henry, 1993) – an active, effortful response to environmental demands that are manageable and controllable (Lovallo & Thomas, 2000; Schommer et al., 2003). Individual differences in the levels of HPA axis activity and ANS arousal can be estimated non-invasively by assessing salivary cortisol and alpha-amylase (sAA) (Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007; Hellhammer, Kirschbaum, & Belkien, 1987; Kirschbaum & Hellhammer, 1994; Nater & Rohleder, 2009).

The nature of the coordination between the ANS and HPA axis reactivity and regulation in response to environmental demands is complex. At the molecular and cellular level, it is assumed that activity of the HPA axis has potential *permissive*, *stimulating*, *suppressive* and *preparative* actions on the ANS (Sapolsky, Romero, & Munck, 2000). Permissive actions are typically associated with levels of cortisol whereas the other three actions are linked to acute stress-induced change in cortisol production. At the behavioral level, Bauer and colleagues (2002) proposed two working models which have been used extensively to explore the coordinated effects of the ANS and HPA on problem behavior. They hypothesized that an optimal level, the medium level, of arousal is associated with the least risk of behavior problems based on the classic theories and empirical research concerning arousal and performance. In the *additive model* it is assume that the HPA and ANS augment each other's effect. Thus, asymmetrical profiles of HPA axis and ANS (i.e., low HPA axis activity and high ANS arousal, or high HPA axis activity and low ANS arousal) would achieve the optimal arousal level and be associated with the lowest levels of behavior problems. In contrast, in the *interactive model* the two systems are assumed to work in a suppressive fashion, that is, one suppresses the other's effect. Thus, symmetrical profiles of HPA axis and ANS (i.e., concurrently high or concurrently low levels of HPA axis activity and ANS arousal) would achieve the optimal arousal level and be associated with the least levels of behavior problems.

Multiple studies test these theoretical models but to date findings are incomplete. Stress-related cortisol reactivity was found to be negatively associated with aggression but only among those with corresponding low sAA reactivity (Gordis et al., 2006). By contrast, cortisol levels were positively associated with both externalizing and internalizing problems but only among those with high sAA levels, and no relation was detected between cortisol and behavior problems among those with low sAA levels (El-Sheikh et al., 2008). In the largest study (N = 429), Chen et al. (2014) reported that cortisol levels were negatively associated with both externalizing and internalizing problems but only among those with low sAA levels.

2. Present study

This study aimed to test the individual and interactive effects of harsh discipline, cortisol and sAA on externalizing and internalizing problems. We employed a multiple time point assessment strategy for salivary sAA and cortisol and used a latent variable approach as a tactic to isolate the variance in each salivary analyte attributable to stable individual differences (Booth, Granger, & Shirtcliff, 2008; Out, Bakermans-Kranenburg, Granger, Cobbaert, & van IJzendoorn, 2011; Out, Granger, Sephton, & Segerstrom, 2013; Taylor et al., 2012). Variability in HPA axis activity or ANS arousal at any given moment can derive from trait-like intrinsic differences, activity attributable to momentary situational influence (e.g., Adam, 2006), and measurement error (Kenny & Zautra, 2001). By minimizing the influence of variation in salivary analytes attributable to momentary situational influence (and measurement error) we expected to increase the probability of revealing the relationship between harsh discipline, stress psychobiology, and problem behavior in our models.

Given the HPA axis has the potential to exert a permissive/augmenting action on the ANS (e.g., Sapolsky et al., 2000), we anticipated an *additive* rather than *interactive* model would reflect the nature of the combined effects of HPA axis and ANS (Bauer, Quas, & Boyce, 2002). Thus, asymmetrical instead of symmetrical profiles would be associated with the optimal arousal levels. Built on this prediction, we widened the frame of reference provided by Bauer et al.'s models by incorporating a biosocial component. That is, following the logic of *differential susceptibility*, we viewed asymmetrical profiles as an index of plasticity. Correspondingly, individuals expressing asymmetrical profiles would display the highest levels of behavior problems when experiencing high levels of harsh discipline but would display the lowest levels of behavior problems when experiencing low levels of harsh discipline. In contrast, following the logic of *diathesis-stress*, symmetrical profiles was viewed as biological vulnerability with a resulting arousal level being too high or too low. Symmetrical profiles would be associated with the highest levels of behavior problems when individuals experienced high levels of harsh discipline because they would possess both biological and environmental vulnerability. We hypothesized that our test of the relationship between harsh discipline, stress psychobiology, and behavior problems would reveal support for the *differential susceptibility* rather than *diathesis-stress* model.

3. Methods

3.1. Overview

Boys and girls aged 11 and 12 years were enrolled from 2008 to 2012 in the Philadelphia Healthy Brains and Behavior (HBB) project. HBB aimed to identify risk and protective factors for aggression and to test the effectiveness of the treatments (i.e., cognitive behavior therapy and nutrition supplements) for children with high levels of aggressive behaviors. Participants were recruited by advertisements within the city of Philadelphia and contiguous suburbs. Participants completed an initial assessment at time 1 and were followed up one year later. The initial assessment included the collection of biological, psychological, physical, demographic and social data. Exclusion criteria were diagnosis of a psychotic disorder, mental retardation, pregnancy, a pervasive developmental disorder or current medication use with the potential to interfere with the measurement of salivary analytes such as steroid based anti-inflammatory (more details see Granger, Hibel, Fortunato, & Kapelewski, 2009). There were 446 children in the HBB project. For a comprehensive description of the larger project see Liu et al. (2013). The data used in the present analyses were collected during the study's initial assessment. Participants and their caregivers came to the university laboratories where data were collected. Caregivers gave informed consent and youth gave assent after description of the study was given. The HBB project was approved by the University of Pennsylvania and the Philadelphia Department of Health institutional review boards. Parents/caregivers were compensated with gift cards for their participation.

3.2. Participants

Of the 446 available participants, 21 had missing data on key measures (i.e., harsh discipline or saliva samples) and were therefore excluded from the analysis (see Section 3.6). The final analytic sample comprised 425 participants (50.12% male). On average they were 11.87 years old (SD = .60). The sample included participants who identified themselves as African-American (N = 341), White (N = 50), or other/mixed race/ethnicity (N = 34). On average, the household monthly income was \$2994.56 (SD = \$3173.39). Regarding caregiver marital status, 17.65% were divorced or separated, 56.71% never married, and 24.94% were married and living with their spouses (.71% were missing marital status data).

3.3. Behavioral assessments

3.3.1. Behavior problems

Child behavior problems were assessed with the Child Behavior Checklist (CBCL; parent-report) and the Youth Self-Report (YSR) (Achenbach & Rescorla, 2001). Both CBCL and YSR can be scored in terms of two broadband scales: one for externalizing behavior problems, including rule-breaking behavior and aggressive behavior syndrome subscales; and one for internalizing behavior problems, including anxious/depressed, withdrawn/depressed, and somatic complaints syndrome subscales. Externalizing and internalizing problem scales have excellent test–retest reliability and internal consistency (Achenbach & Rescorla, 2001).

Normalized T scores derived from national samples were used in all analyses and descriptive statistics are reported in Table 1. For both externalizing and internalizing problems scales, scores above 63 are within the clinical range. Based on parent-reported behavior problems, 19.4% of the participant had externalizing problems above clinical level, and 16.7% had internalizing problems above clinical level. Based on self-reported behavior problems, 13.0% of the participants had externalizing problems above clinical level, and 20.7% had internalizing problems above clinical level.

3.3.2. Harsh discipline

Harsh discipline was measured via the Conflict Tactics Scale (CTS; Strauss, 1979). The frequency of certain discipline behaviors by parents in the past 12 months were assessed on a 6-point scale by the children (0 = *never*; 5 = *most of the time*). Physically harsh discipline was measured by the CTS minor assault/corporal punishment subscale (Strauss, Hamby, Finkelhor, Moore, & Runyan, 1998). This subscale has 3 items, including "parents throwing something at you"; "pushing, grabbing or shoving you"; and "slapping or spanking you". Following Wang and Kenny (2014), we used three items from the psychological aggression subscale of CTS to measure verbally harsh discipline, including "parents insulting or swearing at you"; "doing or saying something to spite you"; and "threatening to hit or throw something at you". Children's responses to all six items were summed to form a composite score for harsh discipline (Chronbach's α = .86).

3.4. Collection of saliva and determination of salivary analytes

Across a single day, three saliva samples were collected from each child at the initial assessment. The children were instructed to refrain from food and drink (except water) prior to sample donation (see Granger et al., 2012). Whole, un-stimulated, saliva was collected by passive drool (Granger et al., 2007). The first sample was taken at approximately 0900, the second 15 min later, and the third 30 min later. Between sample collections, participants completed a variety of questionnaires. Immediately after collection, specimens were frozen and stored at −80 °C until assay. On the day of assay, samples were centrifuged at 3000 rpm for 15 min to remove mucins. Following Granger et al. (2007), samples were assayed for sAA using a commercially available assay kit for the kinetic measurement of sAA activity without modification to the manufacturers recommended protocol (Salimetrics, State College PA). The coefficient of variation is less than 10% for both intra- and inter-assay. Samples were also assayed for salivary cortisol using a commercially available enzyme immunoassay (Salimetrics, State College, PA). The assay had a range of sensitivity from 0.007 to 3.0 μg/dl. Average intra- and inter-assay coefficients of variation were less than 5% and 10%. Latent measures of cortisol and sAA were modeled as latent variables with three corresponding sample collections as indicators (Chen et al., 2014; Out et al., 2013; Shirtcliff, Granger, Booth, & Johnson, 2005; Taylor et al., 2012). Descriptive statistics for sAA and salivary cortisol are reported in Table 1.

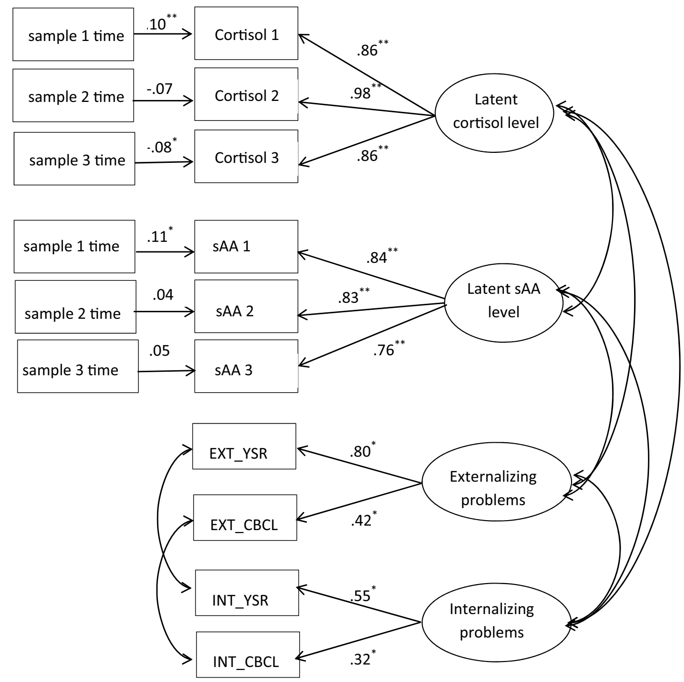

Fig. 1. Measurement model and results for latent variable cortisol, sAA and behavior problems.
Note. Circles represent latent variables and rectangles represent observed variables; EXT_CBCL = externalizing problems from parent-reported Child Behavior Checklist (CBCL); EXT_YSR = externalizing problems from Youth Self-Report (YSR); INT_CBCL = internalizing problems from parent-reported Child Behavior Checklist (CBCL); INT_YSR = internalizing problems from Youth Self-Report (YSR); sAA = saliva alpha-amylase; standardized coefficients are reported; $^{*}p < .05$, $^{**}p < .01$.

3.5. Pubertal stage, body mass index, household income and ethnicity

The children self-reported the stage of their genital, pubic hair, and breast development (Morris & Udry, 1980). They were presented with drawings illustrating Tanner's five stages of pubertal development and were instructed to choose the drawing closest to their own stage of development. The stages of pubic hair and breast (girls) or genital stage (boys) were averaged to yield an overall score of puberty stage for each participant. The children's height and weight were measured and body mass index (BMI) was determined (dividing weight (kg) by the square of the height (m^2)). Caregivers reported demographic information including income and ethnicity of the children. See Table 1 for means and standard deviations.

3.6. Statistical analysis

All analyses were conducted in Mplus 7 (Muthén & Muthén, 1998-2012) using maximum likelihood estimation with robust standard errors. There were two parts of analysis. First, we tested the measurement model for externalizing and internalizing problems, latent cortisol level and latent sAA level (see Fig. 1). The latent variables of externalizing and internalizing problems were assessed by the corresponding subscales of the CBCL and the YSR. Errors from the same reporter sources (e.g., errors from parent-reported externalizing and internalizing problems) were freely correlated to account for common method. Univariate outliers for cortisol and sAA at each time point were defined as three standard deviations away from the mean (Tabachnick & Fidell, 2012). There was one outlier in each of the three cortisol samples, and five, six and four outliers in each of the sAA samples. Outliers were treated as missing values. Full information maximum likelihood (FIML) was employed to handle missing data. That is, cases with missing data would be kept in the model estimation so that other information from these cases could be utilized. Six cases had missing data on all three morning saliva samples and were excluded from analysis because no information was available from these cases to construct latent levels of cortisol and sAA. Latent levels of cortisol and sAA were formed with the corresponding analytes assayed from the three samples as manifest indicators, and these indicators were regressed on the corresponding saliva collection time to tease out the variance of the indicators that was attributable to the time of sample collection. The measurement model was evaluated with χ^2 test, the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA) (Hu & Bentler, 1998; Kline, 2011). The model fits the data well if the χ^2 test is not significant, the CFI has a value above .90 and the RMSEA has a value below .05.

The second part of the analysis was to test whether and how harsh discipline interacts with latent cortisol and latent sAA to predict externalizing and

Table 1
Means (standard deviation) of all variables in the model.

		Boys (N=213)	Girls (N=212)	Overall (N=425)
Externalizing problems (T score)	CBCL	54.50 (10.56)	52.66 (11.25)	53.58 (10.94)
	YSR	51.73 (10.71)	50.91 (10.55)	51.32 (10.63)
Internalizing problems (T score)	CBCL	53.34 (10.74)	51.86 (10.78)	52.60 (10.77)
	YSR	56.71 (9.93)	53.28 (10.47)	54.99 (10.33)
Harsh discipline		4.21 (5.60)	4.97 (5.69)	4.59 (5.65)
Cortisol (μg/dl)	Sample 1	.17 (.20)	.20 (.19)	.18 (.19)
	Sample 2	.19 (.16)	.21 (.21)	.20 (.18)
	Sample 3	.17 (.13)	.19 (.22)	.18 (.18)
Salivary alpha-amylase (U/ml)	Sample 1	72.24 (59.71)	75.63 (57.61)	73.93 (58.63)
	Sample 2	84.23 (71.49)	88.79 (65.87)	86.51 (68.69)
	Sample 3	90.26 (79.43)	86.96 (67.30)	88.59 (73.48)
Saliva collection time (hour)	Sample 1	9.31 (.32)	9.29 (.37)	9.30 (.34)
	Sample 2	9.57 (.32)	9.55 (.37)	9.56 (.35)
	Sample 3	9.82 (.32)	9.81 (.38)	9.82 (.35)
Pubertal stage		3.06 (1.01)	3.47 (.93)	3.27 (.99)
BMI		20.97 (5.15)	22.75 (6.27)	21.86 (5.80)
Income		3271.37 (3550.91)	2724.14 (2734.12)	2994.56 (3173.39)
Ethnicity	African-American	79.81%	80.66%	80.24%

Note. CBCL, Child Behavior Checklist; YSR, Youth Self-Report; BMI, Body mass index.

internalizing problems. The latent variables of externalizing and internalizing problems, the latent levels of cortisol and latent sAA were constructed in the same way as in the measurement model. Cases with missing data on harsh discipline were excluded in the analysis (N = 15) because the multiplicative terms for interactions with latent variables can only be produced with non-missing data. We tested a model with the main effects, all two-way interactive effects and the three-way interactive effect of latent cortisol, latent sAA and harsh discipline as predictors and with externalizing and internalizing problems as outcomes (see Fig. 2). To account for the moderate correlation between externalizing and internalizing problems, the residual variance of the externalizing and internalizing problems was freely correlated. The model adjusted for pubertal stage, BMI, income and ethnicity. Continuous predictors were centered to facilitate interpretation. Given the potential sex differences in the physiology-behavior association (Netherton, Goodyer, Tamplin, & Herbert, 2004), the model in Fig. 2 were estimated with a multi-group approach (i.e., two groups: boys and girls). That is, the measurement models and the effects of covariates were all constrained to be equal across sex,

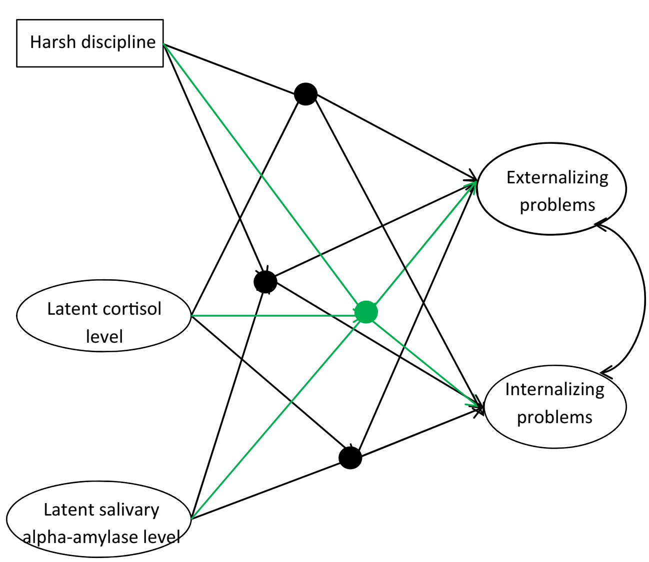

Fig. 2. Individual and interactive effects of harsh discipline, latent basal cortisol, and latent basal salivary alpha-amylase on externalizing and internalizing problems. Model adjusted for income, BMI, puberty stage and ethnicity.
Note. Circles represent latent variables, rectangles represent observed variables and dots represent interaction involving latent variables. Indicators that were used to construct the latent variables are omitted in this figure. Green lines and dot represent the three-way interaction on externalizing and internalizing problems, the interest of the current study.

whereas all the main effects, two-way interactions and three way interaction on behavior problems were freely estimated across sex. Note that all the estimations were done only in one model. In order to get a parsimonious model (i.e., reduced model), we constrained all the non-significant main effects or interactive effects in both boys and girls to be equal across sex. A Wald test was used to examine whether the parameters that were freely estimated were significantly different across sex in the reduced model. The model had interaction terms including latent variables, thus conventional model fit indices such as CFI and RMSEA were not available.

If the three-way interaction was significant for either externalizing or internalizing problems, it was probed by two steps combining the traditional pick-a-point approach (Aiken & West, 1991; Cohen, Cohen, West, & Aiken, 2003; Jaccard & Turrisi, 2003) and the Johnson-Neyman technique (J-N technique; Hayes & Matthes, 2009; Johnson & Fay, 1950; Johnson & Neyman, 1936). First, following the pick-a-point approach, we chose high (mean +1SD) and low (mean −1SD) values of the latent sAA, and for each of them, we utilized the J-N technique to examine how latent cortisol moderated the relationship between harsh discipline and externalizing (or internalizing) problems by plotting the regions of significance. Regions of significance here referred to the value range of latent cortisol in which the harsh discipline had significant effects on behavior problems (Hayes & Matthes, 2009). We could, in theory, find such significant regions of latent cortisol for *every* value of latent sAA. However, to simplify the process and illustrate the general pattern, we chose high (mean +1SD) and low (mean -1SD) values of the latent sAA for such plotting. Therefore, for the low latent sAA level, we plotted a line with the slopes of harsh discipline on behavior problems for every value of latent cortisol, testing whether each slope was significant by referring to its 95% confidence interval, and examining the trend of the slopes. The same was done for high latent sAA level. Second, to further ease the interpretation, we plotted the relationship between harsh discipline and externalizing (or internalizing) problems for four factorial combinations of high (mean +1SD) and low (mean −1SD) latent levels of cortisol and sAA. If the slope is significantly different from zero, it means that for this particular combination of moderators there is a significant association between harsh discipline and externalizing (or internalizing) problems (Aiken & West, 1991; Jaccard, Wan, & Turrisi, 1990).

4. Results

4.1. Descriptive statistics and measurement model

Bivariate correlations among all variables are reported in Table 2. All indicators of cortisol were correlated at high levels and all indicators of sAA were correlated at moderate to high levels. Externalizing and internalizing problems were correlated at a moderate to high level within each report source (r = .56 for parent-report and r = .60 for self-report). Self-reported and parent-reported externalizing problems were significantly correlated at a low to moderate level (r = .34), and internalizing problems across report sources were significantly correlated but at a low level (r = .17).

Table 2
Correlations among all variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. EXT_CBCL	1														
2. EXT_YSR	.34**	1													
3. INT_CBCL	.56**	.17**	1												
4. INT_YSR	.13*	.60**	.17**	1											
5. Cortisol 1	−.08	−.00	−.04	.04	1										
6. Cortisol 2	−.08	.02	.01	.08	.81**	1									
7. Cortisol 3	−.04	.03	.04	.13*	.54**	.78**	1								
8. sAA 1	−.08	−.07	−.00	−.01	.03	.04	.10*	1							
9. sAA 2	−.05	−.06	−.00	.01	.04	.03	.06	.67**	1						
10. sAA 3	−.04	−.07	−.04	.01	.02	.03	.09	.57**	.68**	1					
11. Harsh discipline	.13**	.35**	.12	.29**	.03	.01	.03	−.04	−.07	−.07	1				
12. Pubertal stage	−.06	.07	−.05	−.03	.08	.08	.07	.15**	.08	−.01	.07	1			
13. BMI	.04	.08	.12*	.05	−.00	−.01	.02	.04	−.03	−.13**	.03	.23**	1		
14. Income	−.20**	−.22**	−.16**	−.19**	−.07	−.11*	−.08	−.02	−.01	−.02	.00	−.13*	−.11	1	
15. Ethnicity	.07	.09	.11*	.08	−.01	−.01	−.02	.06	.02	.12*	.01	.11*	.07	−.26**	1

Note. EXT_CBCL, externalizing problems from parent-reported Child Behavior Checklist (CBCL); EXT_YSR, externalizing problems from Youth Self-Report (YSR); INT_CBCL, internalizing problems from parent-reported Child Behavior Checklist (CBCL); INT_YSR, internalizing problems from Youth Self-Report (YSR); BMI, body mass index; Ethnicity: 1 = African-American, 0 = non-African-American.

* $p < .05$.

** $p < .01$.

The measurement model for latent cortisol, latent sAA, externalizing and internalizing problems converged to an admissible solution and fit the data well as indicated by the model fit indices ($\chi^2_{(55)} = 68.78$, $p = .10$; CFI = .99; RMSEA = .024). As seen in Fig. 1, all factor loadings were above .3 and most of them were above .8.

4.2. Interaction of harsh discipline, latent cortisol and latent salivary alpha-amylase on behavior problems: a multi-group model

We tested the individual and interactive effects of harsh discipline, latent cortisol, and latent sAA on externalizing and internalizing problems with a multi-group model. We further simplified the model by constraining all non-significant main effects or interactive effects in both boys and girls to be equal across sex. The reduced model converged to an admissible solution. In the reduced model, only the main effect of latent cortisol and the three-way interaction on both externalizing and internalizing problems, and the main effect of latent sAA on externalizing problems were freely estimated across sex (see Table 3), all other parameters were constrained to be equal across sex. The Wald z test showed that the aforementioned five parameters were indeed significantly different across sex (Wald $z = 12.335$, df = 5, $p = .03$). Overall, the model explained 19.04% and 65.56% of the variance of boys' externalizing problems and internalizing problems, and explained 14.04% and 57.41% of the variance of girls' externalizing problems and internalizing problems.

The main effects of harsh discipline on both externalizing and internalizing problems were significant for boys and girls, with higher levels of harsh discipline associated with higher levels of externalizing and internalizing problems. The three-way interaction was significant for externalizing and internalizing problems among boys but not girls (see Table 3). Furthermore, the main effect of latent cortisol and latent sAA were both inversely associated with boys' externalizing problems but not internalizing problems. In contrast, only the main effect of latent cortisol was significantly associated with girls' internalizing problems.

To examine the three-way interaction on boys' behavior problems, we first plotted the significant regions of latent cortisol for the impact of harsh discipline on externalizing problems by high versus low latent levels of sAA (see Fig. 3). For low latent sAA level, when latent cortisol was smaller than the value of −0.1 (the mean of latent cortisol level is zero), the slopes of harsh discipline on externalizing problems were not significant, as the 95% confidence interval enclosed the value zero; when latent cortisol was above −0.1, the slopes of harsh discipline on externalizing problems were significant (see panel a of Fig. 3). For high latent sAA level, harsh discipline was associated with externalizing problems when

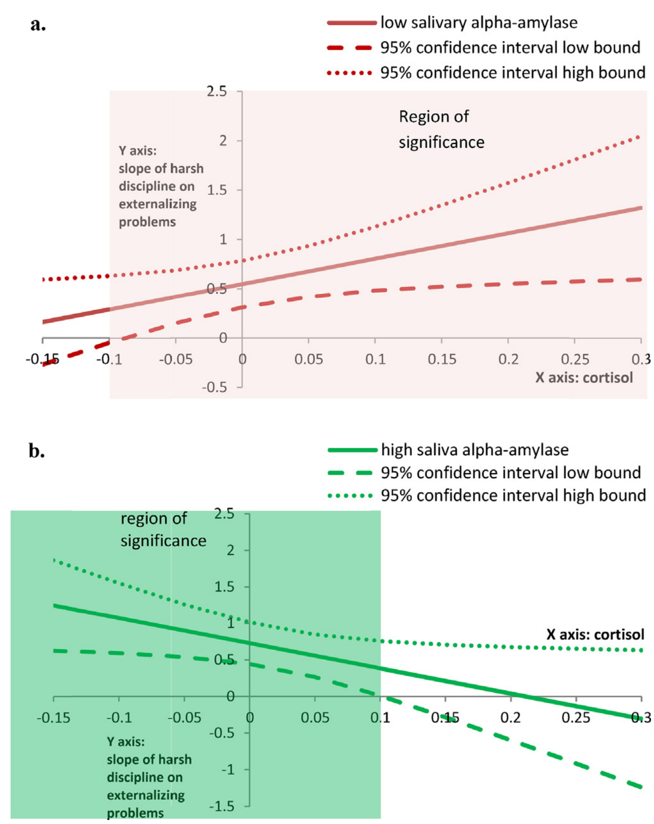

Fig. 3. Latent basal cortisol regions of significance for slopes of harsh discipline on boys' externalizing problems by **low** (panel a) and **high** levels of latent basal salivary alpha-amylase (panel b).
When low latent basal sAA is coupled with latent basal cortisol above the value of −.01 (mean = 0), the slopes of harsh discipline on externalizing problems are significant as the confidence intervals do not enclose the value of zero; when high latent basal sAA is coupled with latent basal cortisol below the value of .10 (mean = 0), the slopes of harsh discipline on externalizing problems are significant as the confidence intervals do not enclose the value of zero. Regions of significance are marked by shadow.

Table 3
Individual and interactive effects of harsh discipline, latent basal cortisol and latent basal alpha-amylase on levels of externalizing and internalizing problems in a multi-group structural equation model.

	B (SE)		*P*	
Outcome variable: latent externalizing problems				
Effects constrained to be equal across sex				
Ethnicity	−.02 (1.40)		.89	
Pubertal stage	−.06 (.59)		.92	
BMI	.11 (.09)		.23	
Income	−.79** (.16)		.00	
Harsh discipline	.64** (.09)		.00	
Latent basal cortisol × latent basal sAA	−6.34 (8.53)		.46	
Harsh discipline × latent basal sAA	.17 (.19)		.37	
Harsh discipline × latent basal cortisol	−.43 (.85)		.61	
Effects freely estimated for boys and girls	*Girls*	*Boys*	*Girls*	*Boys*
Latent basal cortisol	2.68 (4.46)	−8.12* (4.17)	.55	.05
Latent basal sAA	−.15 (1.27)	−2.28* (.99)	.91	.02
Harsh discipline × latent basal sAA × latent basal cortisol	3.00 (2.69)	−5.57** (2.14)	.27	.009
Outcome variable: latent internalizing problems				
Effects constrained to be equal across sex				
Ethnicity	.65 (1.36)		.63	
Pubertal stage	−1.06* (.49)		.03	
BMI	.18* (.08)		.02	
Income	−.69** (.17)		.00	
Harsh discipline	.54** (.08)		.00	
Latent basal sAA	.27 (.94)		.77	
Latent basal cortisol × latent basal sAA	.22 (6.24)		.97	
Harsh discipline × latent basal sAA	.21 (.19)		.26	
Harsh discipline × latent basal cortisol	−.24 (.48)		.61	
Effects freely estimated for boys and girls	*Girls*	*Boys*	*Girls*	*Boys*
Latent basal cortisol	7.53* (2.7)	−.01 (3.69)	.006	.997
Harsh discipline × latent basal sAA × latent basal cortisol	1.37 (1.89)	−5.11** (1.64)	.47	.002

Note. B, unstandardized coefficients; SE, standard error; Ethnicity: 1 = African-American, 0 = non-African-American.
* $p < 0.05$.
** $p < 0.01$.

latent cortisol was below the value of .10, as the 95% confidence intervals did not enclose the value of zero (see panel b of Fig. 3). The pattern for internalizing problems mirrored that for externalizing problems: when low latent level of sAA was coupled with latent cortisol level above the value of −.05, or when high latent level of sAA was coupled with latent cortisol level below the value of .125, harsh discipline was positively associated with internalizing problems (see panel a and b of Fig. 4).

The impact of harsh discipline on boys' externalizing and internalizing problems by the four factorial combinations of high and low latent cortisol and sAA are plotted in Fig. 5, harsh discipline had a positive effect on externalizing and internalizing problems but only when asymmetrical profiles of latent cortisol and latent sAA were observed, that is, low latent cortisol coupled with high latent sAA, or high latent cortisol couple with low latent sAA. Harsh discipline had a null impact on both externalizing and internalizing problems when symmetrical profiles of latent cortisol and sAA were observed, that is, concurrently high or concurrently low levels of latent cortisol and sAA, as indicated by the flat lines in Fig. 5. Boys with asymmetrical profiles had the highest levels in both externalizing and internalizing problems when experiencing high levels of harsh discipline.

5. Discussion

The study is the first (to the best of our knowledge) to document significant interactive effects among harsh discipline, ANS arousal, and HPA activity, on externalizing and internalizing problems in youth. More specifically, when cortisol and sAA displayed asymmetrical profiles (i.e. low-high or high-low), harsh discipline had an impact on both externalizing and internalizing problems; but when cortisol and sAA were symmetrical (i.e., low-low or high-high), harsh discipline had a null impact on externalizing and internalizing problems. Unexpectedly, this pattern was evident for boys but not girls. That is, boys with asymmetrical HPA activity and ANS arousal had the highest levels of externalizing and internalizing problems when experiencing high levels of harsh discipline and had the lowest levels of externalizing and internalizing problems when experiencing low levels of harsh discipline. Our findings underscore the importance of the multi-system approach to index individual differences in environmentally sensitivity biological processes (e.g., Bauer et al., 2002; Gordis et al., 2006) and can be interpreted as consistent with the main tenets of the *differential susceptibility* model (Belsky & Pluess, 2009).

Children with asymmetrical profiles of ANS arousal and HPA activity differed in their levels of behavior problems if placed in drastically different caregiving circumstances. It is tempting to speculate that asymmetry in ANS arousal and HPA activity indicates an openness or plasticity to influence by social forces. Of course, a firm conclusion is premature, but such an interpretation, in general, is consistent with the assumptions of the differential susceptibility model (Belsky & Pluess, 2009). The model postulates that individuals who are most adversely affected by various stressors in life may be the very same ones who reap the most benefit from environmental support, including the absence of adversity. Thus, in theory, individuals who express asymmetrical profiles of ANS arousal and HPA activity may be the most at risk, but also following the logic of the differential susceptibility model, they may be most likely to benefit from intervention efforts aimed to change their adverse circumstances. If the observations noted here proved reliable, their implications could be far reaching as a potential mechanism for explaining why not all individuals raised in such adverse family circumstances express behavior problems

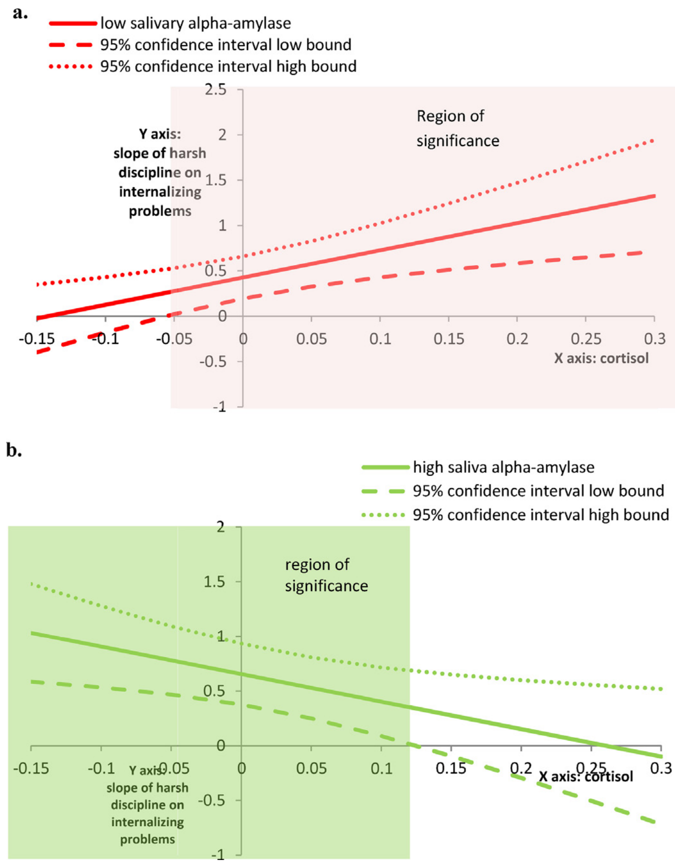

Fig. 4. Latent basal cortisol regions of significance for slopes of harsh discipline on boys' internalizing problems by **low** (panel a) and **high** levels of latent basal salivary alpha-amylase (panel b).

When low latent basal sAA is coupled with latent basal cortisol level above the value of −.05 (mean = 0), the slopes of harsh discipline on externalizing problems are significant as the confidence intervals do not enclose the value of zero; when high latent basal sAA is coupled with latent basal cortisol below the value of .125 (mean = 0), the slopes of harsh discipline on externalizing problems are significant as the confidence intervals do not enclose the value of zero. Regions of significance are marked by the shadow.

later in life. Future studies aimed to repeat these findings and test this possibility seem well worthwhile.

It is equally interesting that the combined effects of harsh parenting and asymmetry in ANS arousal and HPA activity were observed on total problem behavior (*both* externalizing and internalizing) than either externalizing or internalizing problem behavior specifically. As noted above, children's exposure to these negative parenting behaviors early in life is associated with later adjustment problems including higher rates of aggressive behavior (Gershoff, 2002) but also anxiety and depression (McLoyd et al., 2007; Rodriguez, 2003; Wang & Kenny, 2014). The profound impact of comorbidity of externalizing and internalizing problems in children's lives is well documented (Kessler & Wang, 2008). Children with comorbid behavior problems have an earlier-onset and more serious and chronic problems (Oland & Shaw, 2005; Youngstrom, Findling, & Calabrese, 2003), worse developmental outcomes such as risky behavior, substance abuse and adult criminality (Fanti & Henrich, 2010; Keiley, Lofthouse, Bates, Dodge, & Pettit, 2003; Nottelmann & Jensen, 1995) and high usage rates of psychiatric services (Costello et al., 1996; Kovacs, Paulauskas, Gatsonis, & Richards, 1988). In the present study, as in many previous reports, externalizing and internalizing problems were associated modestly or strongly. If asymmetry in ANS arousal and HPA activity could be construed as translating environmental adversity into differential risk for comorbidity this possibility could have important research implications.

Unlike what we observed for boys, the impact of harsh discipline on behavior problems appeared to exert an impact on girls' behavior problems relatively independent of their ANS arousal or HPA activity. No interactive effects were revealed for either externalizing or internalizing behavior problems. It is possible that harsh discipline has a more direct impact on girls' behavior problems. Alternatively, the impact of harsh discipline on girls' behavior problems could be moderated by other biological or social mechanisms that were not examined here. Indeed, contemporary theory suggests that females' responses to adversity may be more marked by a pattern of biological responses related to "tending-and-befriending" (Taylor et al., 2000) rather than the classic physiological responses associated with the males' "fight-or-flight" response. Using an evolutionary perspective, Taylor et al. (2000) argued that females' quieting and caring for offspring (i.e., tending) and affiliating with social networks (i.e., befriending) may

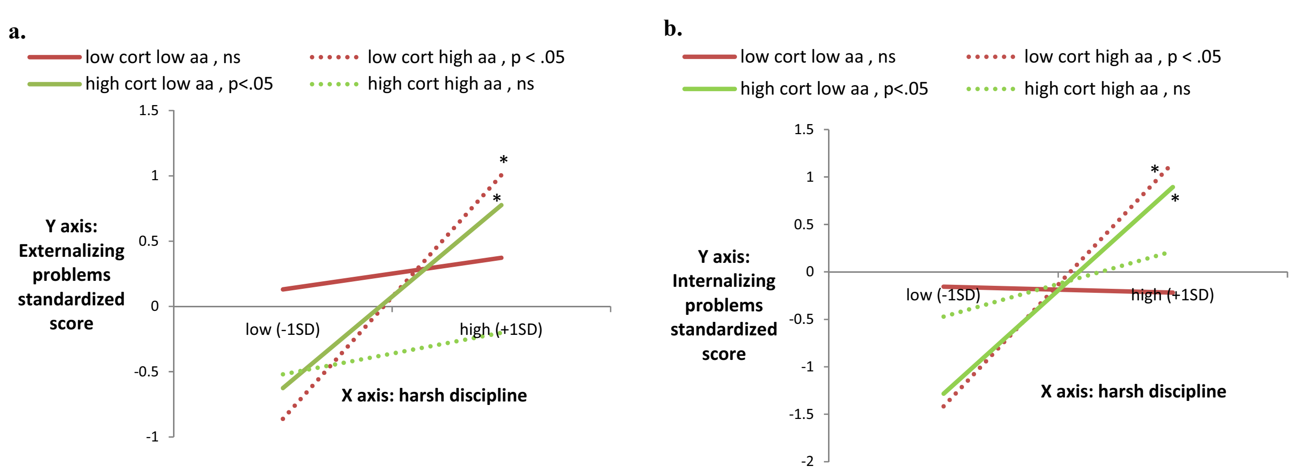

Fig. 5. Effects of harsh discipline on standardized scores of boys' externalizing (panel a) and internalizing problems (panel b) by factorial combination of high versus low latent basal cortisol and salivary alpha-amylase.

Harsh discipline has significant impacts on externalizing and internalizing problems for asymmetrical profiles of latent basal cortisol and sAA (marked by asterisk), that is, when low latent basal sAA is coupled with high latent basal cortisol (green line) or when high latent basal sAA is coupled with low latent basal cortisol (red dashed line). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

be more effective for addressing threats. Correspondingly, biobehavioral mechanisms implicated in caregiving-attachment, such as oxytocin, opioids and dopaminergic pathways are more likely to be underpinning this "tending-and-befriending" pattern (Taylor, 2006). Thus, activity of the ANS and HPA may not necessarily be the important biobehavioral mechanisms involved in moderating the association between harsh discipline and girls' behavior problems. At a minimum, our findings highlight the importance of considering the possibility of sex differences in the mechanisms thought to underlie individual differences in biological susceptibility.

This study has several advantages but also some limitations. First, we only assessed cortisol and sAA levels on a single day. The stability of the latent variables constructed from multiple samples within one day may be different than if multiple day measurements were employed. Second, the participants in this study were drawn from a very narrow age span ranging only from age 11 to 12, and most were of African-American descent. Thus, the conclusions drawn may not readily generalize to youth in different developmental stages and of other ethnic/racial backgrounds. Last, the differential susceptibility model is typically tested with environment features ranging from positive to negative. The absence of harsh parenting behavior does not equate to socially appropriate parenting behavior and discipline. Future research on this topic would be well served to study the spectrum of both positive-socially appropriate and negative-harsh parenting behavior. These relative limitations should be balanced with the strengths and significance of the study. We used a sophisticated measurement model to get less biased assessments for our predictors and outcomes. For example, externalizing and internalizing problems were constructed with measures from both self-reported and parent-reported sources which allowed us to model the common method bias; cortisol and sAA were modeled with a latent variable approach in order to tease out the variance attributable to momentary change and saliva collection time. Furthermore, the relatively large sample size affords more statistical power than most studies to date and enabled us to satisfactorily test and interpret this complex three-way interaction.

6. Concluding comment

This study highlights a potentially important role of the coordinated effects of the ANS and HPA as a mechanism in the linkage of environmental adversity and children's behavior problems. Findings, if replicated and robust, have potentials to advance our understanding of risk and resilience in face of adversity to new limits. They also suggest that in future studies more theoretical and empirical attention should be given to potential sex differences in our models of differential susceptibility.

Disclosure statement

In the interest of full disclosure, DAG is founder and Chief Scientific and Strategy Advisor at Salimetrics LLC. DAG's relationships with these entities are managed by the policies of the Conflict of Interest Committee at the Johns Hopkins University School of Medicine and the Office of Research Integrity and Assurance at Arizona State University.

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References

Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA school-age forms & profiles*. Burlington, VT: University of Vermont, Research Center for Children, Youth, & Families.

Adam, E. K. (2006). Transactions among adolescent trait and state emotion and diurnal and momentary cortisol activity in naturalistic settings. *Psychoneuroendocrinology*, *31*(5), 664–679. http://dx.doi.org/10.1016/j.psyneuen.2006.01.010

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions*. Thousand Oaks, CA: Sage.

Bauer, A. M., Quas, J. A., & Boyce, W. T. (2002). Associations between physiological reactivity and children's behavior: Advantages of a multisystem approach. *Journal of Developmental and Behavioral Pediatrics*, *23*(2), 102–113. http://dx.doi.org/10.1016/j.psyneuen.2006.05.010

Belsky, J., & Pluess, M. (2009). Beyond diathesis stress: Differential susceptibility to environmental influences. *Psychological Bulletin*, *135*(6), 885–908. http://dx.doi.org/10.1037/a0017376

Booth, A., Granger, D. A., & Shirtcliff, E. A. (2008). Gender- and age-related differences in the association between social relationship quality and trait-levels of salivary cortisol. *Journal of Research on Adolescence*, *18*, 239–260. http://dx.doi.org/10.1111/j. 1532-7795.2008.00559.x

Cannon, W. B. (1914). The interrelations of emotions as suggested by recent physiological researches. *American Journal of Psychology*, *25*, 256–282.

Chen, F. R., Raine, A., Soyfer, L., & Granger, D. A. (2014). Interaction of adrenocortical activity and autonomic arousal on children's externalizing and internalizing problems. *Journal of Abnormal Child Psychology*, http://dx.doi.org/10.1007/s10802-014-9900-y

Chrousos, G. P., & Gold, P. W. (1992). The concepts of stress system disorders: Overview of behavioral and physical homeostasis. *JAMA*, *267*, 1244–1252.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences* (3rd ed.). Mahwah, NJ: Erlbaum.

Costello, E., Angold, A., Burns, B., Stangl, D., Tweed, D., Erkanli, A., et al. (1996). The Great Smoky Mountains Study of youth: Goals, design, methods, and the prevalence of DSM III-R disorders. *Archives of General Psychiatry*, *53*(12), 1129–1136. http://dx.doi.org/10.1001/archpsyc.1996.01830120067012

Csorba, J., Rozsa, S., Vetro, A., Gadoros, J., Makra, J., Somogyi, E., et al. (2001). Family and school-related stresses in depressed Hungarian children. *European Psychiatry*, *16*(1), 18–26. http://dx.doi.org/10.1016/S0924-9338(00)00531-9

El-Sheikh, M., Erath, S. A., Buckhalt, J. A., Granger, D. A., & Mize, J. (2008). Cortisol and children's adjustment: The moderating role of sympathetic nervous system activity. *Journal of Abnormal Psychology*, *36*, 601–611. http://dx.doi.org/10.1007/s10802-007-9204-6

Fanti, K. A., & Henrich, C. C. (2010). Trajectories of pure and co-occurring internalizing and externalizing problems from age 2 to age 12: Findings from the National Institute of Child Health and Human Development Study of Early Child Care. *Developmental Psychology*, *46*(5), 1159–1175. http://dx.doi.org/10.1037/a0020659

Folkow, B. (1985). Stress and blood pressure in adrenergic blood pressure regulation. In W. H. Birkenhager, B. Folkow, & H. A. J. Struykeer (Eds.), *Current Clinical Practice Series* (pp. 87–93). Amsterdam: Excerpta Medica.

Gerra, G., Zaimovic, A., Mascetti, G. G., Gardini, S., Zambelli, U., Timpano, M., et al. (2001). Neuroendocrine responses to experimentally-induced psychological stress in healthy humans. *Psychoneuroendocrinology*, *26*, 91–107. http://dx.doi.org/10.1016/S0306-4530(00)00046-9

Gershoff, E. T. (2002). Corporal punishment by parents and associated child behaviors and experiences: A meta-analytic and theoretical review. *Psychological Bulletin*, *128*, 539–579. http://dx.doi.org/10.1037/0033-2909.128.4.539

Gershoff, E. T., Lansford, J. E., Sexton, H. R., Davis-Kean, P. E., & Sameroff, A. J. (2012). Longitudinal links between spanking and children's externalizing behaviors in a national sample of White, Black, Hispanic, and Asian American families. *Child Development*, *83*, 838–843. http://dx.doi.org/10.1111/j. 1467-8624.2011.01732.x

Gordis, E. B., Granger, D. A., Susman, E. J., & Trickett, P. K. (2006). Asymmetry between salivary cortisol and α-amylase reactivity to stress: Relation to aggressive behavior in adolescents. *Psychoneuroendocrinology*, *31*, 976–987. http://dx.doi.org/10.1016/j.psyneuen.2006.05.010

Granger, D. A., Fortunato, C. K., Beltzer, E. K., Virag, M., Bright, M. A., & Out, D. (2012). Focus on methodology: Salivary bioscience and research on adolescence: An integrated perspective. *Journal of Adolescence*, *35*, 1081–1095. http://dx.doi.org/10.1016/j.adolescence.2012.01.005

Granger, D. A., Hibel, L. C., Fortunato, C. K., & Kapelewski, C. H. (2009). Medication effects on salivary cortisol: Tactics and strategy to minimize impact in behavioral and developmental science. *Psychoneuroendocrinology*, *34*, 1437–1448.

Granger, D. A., Kivlighan, K. T., El-Sheikh, M., Gordis, E. B., & Stroud, L. R. (2007). Salivary alpha-amylase in biobehavioral research: Recent developments and applications. *Annals of the New York Academy of Sciences*, *1098*, 122–144. http://dx.doi.org/10.1196/annals.1384.008

Hayes, A. F., & Matthes, J. (2009). Computational procedures for probing interactions in OLS and logistic regression: SPSS and SAS implementations. *Behavior Research Methods*, *41*, 924–936. http://dx.doi.org/10.3758/BRM.41.3.924

Hellhammer, D. H., Kirschbaum, C., & Belkien, L. (1987). Measurement of salivary cortisol under psychological stimulation. In J. N. Hingtgen, D. H. Hellhammer, & G. Huppmann (Eds.), *Advanced Methods in Psychobiology* (pp. 281–289). Toronto: Hogrefe.

Henry, J. P. (1993). Biological basis of the stress response. *Physiology*, *8*, 69–73.

Hu, L., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods*, *3*, 424–453.

Jaccard, J., & Turrisi, R. (2003). *Interaction effects in multiple regression* (2nd ed.). Thousand Oaks, CA: Sage.

Jaccard, J., Wan, C. K., & Turrisi, R. (1990). The detection and interpretation of interaction effects between continuous variables in multiple regression. *Multivariate Behavioral Research*, *25*, 467–478. http://dx.doi.org/10.1207/s15327906mbr2504_4

Johnson, P. O., & Fay, L. C. (1950). The Johnson–Neyman technique, its theory and application. *Psychometrika*, *15*, 349–367. http://dx.doi.org/10.1007/BF02288864

Johnson, P. O., & Neyman, J. (1936). Tests of certain linear hypotheses and their application to some educational problems. *Statistical Research Memoirs*, *1*, 57–93.

Keiley, M. K., Lofthouse, N., Bates, J. E., Dodge, K. A., & Pettit, G. S. (2003). Differential risks of covarying and pure components in mother and teacher reports of externalizing and internalizing behavior across ages 5 to 14. *Journal of Abnormal Child Psychology*, *31*, 267–283. http://dx.doi.org/10.1023/A:1023277413027

Kenny, D. A., & Zautra, A. (2001). Trait-state models for longitudinal data. In L. M. Collins, & A. G. Sayer (Eds.), *New methods for the analysis of change* (pp. 243–263). Washington, DC: American Psychological Association.

Kessler, R. C., & Wang, P. S. (2008). The descriptive epidemiology of commonly occurring mental disorders in the United States. *Annual Review of Public Health*, *29*, 115–129. http://dx.doi.org/10.1146/annurev.publhealth.29.020907.090847

Kirschbaum, C., & Hellhammer, D. H. (1994). Salivary cortisol in psychoneuroendocrine research: Recent developments and applications. *Psychoneuroendocrinology*, *19*, 313–333. http://dx.doi.org/10.1016/0306-4530(94)90013-2

Kline, R. B. (2011). *Principles and practice of structural equation modeling* (3rd ed.). New York: Guilford Press.

Kovacs, M., Paulauskas, S., Gatsonis, C., & Richards, C. (1988). Depressive disorders in childhood: III. A longitudinal study of comorbidity with and risk for conduct disorders. *Journal of Affective Disorders*, *15*, 205–217. http://dx.doi.org/10.1016/0165-0327(88)90018-3

Liu, J., Richmond, T. S., Raine, A., Cheney, R., Brodkin, E. S., Gur, R. C., et al. (2013). The Healthy Brains and Behavior Study: Objectives, design, recruitment, and population coverage. *International Journal of Methods in Psychiatric Research*, *22*(3), 204–216. http://dx.doi.org/10.1002/mpr.1394

Lovallo, W. R., & Thomas, T. L. (2000). Stress hormones in psychophysiological research: Emotional, behavioral, and cognitive implications. In J. T. Cacioppo, L. G. Tassinary, & G. G. Bernston (Eds.), *Handbook of psychophysiology* (2nd ed., pp. 342–367). New York: Cambridge University Press.

Lundberg, U., & Frankenhaeuser, M. (1980). Pituitary-adrenal and sympathetic-adrenal correlates of distress and effort. *Journal of Psychosomatic Research*, *24*, 125–130. http://dx.doi.org/10.1016/0022-3999(80)90033-1

McLoyd, V. C., Kaplan, R., Hardaway, C. R., & Wood, D. (2007). Does endorsement of physical discipline matter? Assessing moderating influences on the maternal and child psychological correlates of physical discipline in African American Families. *Journal of Family Psychology*, *21*(2), 165–175. http://dx.doi.org/10.1037/0893-3200.21.2.165

Monroe, S. M., & Simons, A. D. (1991). Diathesis-stress theories in the context of life stress research: Implications for the depressive disorders. *Psychological Bulletin*, *110*, 406–425. http://dx.doi.org/10.1037/0033-2909.110.3.406

Morris, N. M., & Udry, J. R. (1980). Validation of a self-administrated instrument to assess stage of adolescent development. *Journal of Youth and Adolescence*, *9*(3), 271-280. doi: 10.1007/BF02088471.

Muthén, L. K., & Muthén, B. O. (1998-2012). *Mplus user's guide* (7th ed.). Los Angeles, CA: Muthén & Muthén.

Nater, U. M., & Rohleder, N. (2009). Salivary alpha-amylase as a noninvasive biomarker for the sympathetic nervous system: Current state of research. *Psychoneuroendocrinology*, *34*(4), 486–496. http://dx.doi.org/10.1016/j.psyneuen.2009.01.014

Netherton, C., Goodyer, I., Tamplin, A., & Herbert, J. (2004). Salivary cortisol and dehydroepiandrosterone in relation to puberty and gender. *Psychoneuroendocrinology*, *29*, 125–140.

Nottelmann, E., & Jensen, P. (1995). Comorbidity of disorders in children and adolescents: Developmental perspectives. *Advances in Clinical Child Psychology*, *17*, 109–155.

Oland, A. A., & Shaw, D. S. (2005). Pure versus co-occurring externalizing and internalizing symptoms in children: The potential role of socio-developmental milestones. *Clinical Child and Family Psychology Review*, *8*(4), 247–270. http://dx.doi.org/10.1007/s10567-005-8808-z

Out, D., Bakermans-Kranenburg, M., Granger, D. A., Cobbaert, C. M., & van IJzendoorn, M. H. (2011). State and trait variance in salivary alpha-amylase: A behavior genetic study. *Biological Psychology*, *88*, 147–154. http://dx.doi.org/10.1016/j.biopsycho.2011.07.008

Out, D., Granger, D. A., Sephton, S. E., & Segerstrom, S. C. (2013). Disentangling sources of individual differences in diurnal salivary alpha-amylase: Reliability, stability and sensitivity to context. *Psychoneuroendocrinology*, *38*(3), 367. http://dx.doi.org/10.1016/j.psyneuen.2012.06.013

Peters, M. L., Godaert, G. L., Ballieux, R. E., van Vliet, M., Willemsen, J. J., Sweep, F. C. G. J., et al. (1998). Cardiovascular and endocrine responses to experimental stress: Effects of mental effort and controllability. *Psychoneuroendocrinology*, *23*, 1–17. http://dx.doi.org/10.1016/S0306-4530(97)00082-6

Raine, A. (2005). The interaction of biological and social measures in the explanation of antisocial and violent behavior. In D. Stoff, & E. Susman (Eds.), *Developmental psychobiology of aggression* (pp. 13–42). New York: Cambridge University Press.

Reid, J. B., Patterson, G. R., & Snyder, J. (2002). *Antisocial behavior in children and adolescents: A developmental analysis and the Oregon model for intervention*. Washington, DC: American Psychological Association.

Rodriguez, C. M. (2003). Parental discipline and abuse potential affects on child depression, anxiety, and attributions. *Journal of Marriage and Family*, *65*(4), 809–817. http://dx.doi.org/10.1111/j. 1741-3737.2003.00809.x

Sapolsky, R. M., Romero, L. M., & Munck, A. U. (2000). How do glucocorticoids influence stress response? Integrating permissive, suppressive, stimulatory, and preparative actions. *Endocrine Reviews*, *21*(1), 55–89. http://dx.doi.org/10.1210/edrv.21.1.0389

Schommer, N. C., Hellhammer, D. H., & Kirschbaum, C. (2003). Dissociation between reactivity of the hypothalamus-pituitary-adrenal and the sympathetic-adrenal-medullary system to repeated psychosocial stress. *Psychosomatic Medicine*, *65*, 450–460. http://dx.doi.org/10.1097/01.PSY.0000035721.12441.17

Shirtcliff, E. A., Granger, D. A., Booth, A., & Johnson, D. (2005). Low salivary cortisol levels and externalizing behavior problems in youth. *Development and Psychopathology*, *17*, 167–184. http://dx.doi.org/10.1017/S0954579405050091

Steely, A. C., & Rohner, R. P. (2006). Relations among corporal punishment, perceived parental acceptance, and psychological adjustment in Jamaican youths. *Cross-Cultural Research*, *40*(3), 268–286. http://dx.doi.org/10.1177/1069397105284397

Strauss, M. A. (1979). Measuring intrafamily conflict and violence: The Conflict Tactics Scales. *Journal of Marriage and the Family*, *41*, 75–88.

Strauss, M. A., Hamby, S. L., Finkelhor, D., Moore, D. W., & Runyan, D. (1998). Identification of child maltreatment with the parent-child Conflict Tactics Scales: Development and psychometric data for a national sample of American parents. *Child Abuse and Neglect*, *22*(4), 249–270. http://dx.doi.org/10.1016/S0145-2134(97)00174-9

Tabachnick, B. G., & Fidell, L. S. (2012). *Using multivariate statistics* (6th ed.). Boston: Pearson Education, Inc.

Taylor, S. E. (2006). Tend and befriend: Biobehaviorl bases of affiliation under stress. *Current Directions in Psychological Science*, *15*(6), 273–277. http://dx.doi.org/10.1111/j.1467-8721.2006.00451.x

Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. A. R., & Updegraff, J. A. (2000). Biobehavioral responses to stress in females: Tend-and-befriend, not fight-or-flight. *Psychological Review*, *107*(3), 411–429. http://dx.doi.org/10.1037/0033-295X.107.3.411

Taylor, Z. E., Spinrad, T. L., VanSchyndel, S. K., Eisenberg, N., Huynh, J., Sulik, M. J., et al. (2012). Sociodemographic risk, parenting, and effortful control: Relations to salivary alpha-amylase and cortisol in early childhood. *Developmental Psychobiology*, *55*(8), 869–880. http://dx.doi.org/10.1002/dev.21079

Toth, S. L., & Cicchetti, D. (2013). A developmental psychopathology perspective on child harsh discipline. *Child Harsh Discipline*, *18*(3), 135–139.

Wang, M., & Kenny, S. (2014). Longitudinal links between fathers' and mothers' harsh verbal discipline and adolescents' conduct problems and depressive symptoms. *Child Development*, *85*(3), 908–923. http://dx.doi.org/10.1111/cdev.12143

Youngstrom, E., Findling, R., & Calabrese, J. (2003). Who are the comorbid adolescents? Agreement between psychiatric diagnosis, youth, parent, and teacher report. *Journal of Abnormal Child Psychology*, *31*(3), 231–245, 0.1023/A:1023244512119.