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Asymmetry in children's salivary cortisol and alpha-amylase in the context of marital conflict: Links to children's emotional security and adjustment

Kalsea J. Koss,
Institute of Child Development, University of Minnesota

Melissa R.W. George,
University of South Carolina

E. Mark Cummings,
University of Notre Dame

Patrick T. Davies,
University of Rochester

Mona El-Sheikh, and
Auburn University

Dante Cicchetti
University of Minnesota and Mt. Hope Family Center, University of Rochester

Abstract

Recent research supports the promise of examining interactive models of physiological processes on children's adjustment. The present study investigates interactions between children's autonomic nervous system activity and adrenocortical functioning in the context of marital discord; specifically, testing models of concurrent responses proposed by Bauer, Quas, & Boyce (2002) in the prediction of children's behavioral responses to conflict and adjustment. Asymmetry and symmetry in children's salivary alpha-amylase and cortisol were examined in 195 children (*M* age = 8 years) in response to viewing conflict vignettes. Results were partially consistent with an interactive model in the context of high marital discord; asymmetry among higher alpha-amylase and lower cortisol related to higher emotional insecurity and concurrent and subsequent maladjustment. In contrast, patterns of symmetrical responses were related to greater maladjustment for children exposed to lower levels of marital discord, supporting an additive model. Findings support the importance of a multisystem approach to investigating the adaptiveness of children's physiological stress responses, while also highlighting the value of considering physiological responses in the context of family risk.

Keywords

marital conflict; cortisol; salivary alpha-amylase; emotional security; internalizing and externalizing problems

Children's regulatory processes are often supported as important in understanding the negative impact of family functioning on children's development, especially in research

Correspondence should be addressed to Kalsea Koss, Institute of Child Development, University of Minnesota, Minneapolis, MN 55455; kossx022@umn.edu.

examining the influence of marital discord on children's maladjustment (Cummings & Davies, 2010). Children's ability to regulate their emotion and behavior during stressful contexts is critical and difficulties with regulation have been linked to the development of later social, emotional, and behavioral problems (Eisenberg et al., 2001; Shields, Cicchetti, & Ryan, 1994). Individual differences in children's physiological reactivity and regulation are important components in understanding the impact of environmental influences on children. However, less is known about how multiple physiological regulatory systems employed during stressful situations contribute collectively to children's maladjustment.

In the face of marital conflict, children often utilize multiple regulatory strategies to cope with the threatening nature of conflict, including emotional, behavioral, cognitive, and physiological responses (Cummings & Davies, 2010). There is a growing body of research supporting the notion that children's physiological activity and regulation are important indicators of the stress and threat children experience when witnessing marital conflict as well as important mechanisms for regulating their exposure to discord. Research has shown that multiple physiological systems including the parasympathetic and sympathetic branches of the autonomic nervous system (ANS) and the adrenocortical axis are sensitive to environmental influences such as marital conflict (e.g., Davies, Sturge-Apple, Cicchetti, & Cummings, 2007; El-Sheikh, 2005; El-Sheikh et al., 2009). Furthermore, researchers suggest that individual differences in physiological responses to stress may place certain children at greater or lesser risk for developing problem behaviors (e.g., Ellis & Boyce, 2008). Although research has established associations between responses in single stress response systems and children's internalizing and externalizing problems, physiological systems do not operate in isolation and a better understanding of children's adjustment in the context of marital discord entails examining activity across multiple systems. Thus, understanding how multiple systems interact to relate to risk for maladjustment may be necessary for understanding which children are most at risk for the development of problem behavior. The present study focuses on the interaction of two stress-related systems, the ANS, indexed through salivary alpha-amylase (sAA), and the hypothalamic-pituitary-adrenal axis (HPA), indexed through cortisol, in relation to children's emotional and behavioral responses to conflict and later adjustment problems. Implications for coordination among systems for child adjustment may differ depending on the context in which they are employed; thus, the present study also sought to address if the interaction of multiple physiological stress systems is further moderated by level of exposure to marital conflict.

As the first wave of autonomic response, the ANS is associated with the fight or flight response and primes the body to respond to stressful events. Variations in children's ANS responses are related to adjustment difficulties in children. The direction of these relationships may be complex. Among children exposed to family adversity both high and low levels of activity and reactivity of the ANS are associated with problem behavior (El Sheikh & Erath, 2011). For example, Keller and El-Sheikh (2009) found non-linear relations among sAA and externalizing problems, both higher and lower levels were associated with increased externalizing problems longitudinally. Further examination of the complex associations between ANS functioning and child adjustment is warranted. The current study utilizes sAA as a promising surrogate marker for ANS functioning (Bosch, Veerman, de Geus, & Proctor, 2011).

As a second wave of autonomic response to stress, activation of the HPA axis occurs in response to distressing or threatening events. The HPA axis is responsible for mobilizing the body's resources to cope with stress and starts a cascade of events resulting in the secretion of the hormone cortisol. Cortisol is secreted into saliva making it a non-invasive indicator of the HPA axis activity. Researchers have found cortisol production to be sensitive to threat in social situations (e.g., Chen, Cohen, & Miller, 2010). Heightened and dampened responses have been identified as dysregulation of the HPA axis, suggesting an inverted U-shape pattern in relation to adaptation. Both higher and lower cortisol activity and reactivity have been associated with child adjustment difficulties (for a review see Gunnar & Vasquez, 2006).

Research on both ANS and adrenocortical functioning highlights mixed findings in their association for the development of psychopathology. Moreover, while both of these stress-related systems have been identified as critical in understanding variations in child adjustment, little is known about how these systems interact and influence one another. To better understand the role of these systems it may be necessary to understand how these two systems operate concurrently for delineating their effects in the stress response system-maladjustment link. Bauer, Quas, and Boyce (2002) proposed two testable models for understanding the interactive nature of HPA and ANS responses to stress in relation to the development of behavioral problems. Both models assume that a moderate level of arousal in each of the two systems is optimal for children. However, the two models differ in regards to understanding the role of coordination in the activation of each of these systems in contributing to problem behaviors. The *additive model* assumes the ANS and HPA systems contribute independently to children's stress regulation and the sum activation is important for relations to development. Thus, the additive model assumes that responses symmetrical in nature, that is co-activation (high levels in both systems) or co-deactivation (low levels in both systems) of the two systems, is problematic for children and contributes to problem behavior. Alternatively, the *interactive model* suggests that the HPA and ANS serve complimentary roles in responding to stress. According to this model, disassociations or asymmetry in responses (e.g., high levels in one system and low levels in the other system), likely reflect inefficient or poor coordination in physiological systems. Thus, the interactive model proposes asymmetry in responses contributes to children's psychopathology. These models differ in that the former proposes symmetry while the latter proposes asymmetry to be associated with poor functioning and emotional and behavioral difficulties.

Specific to tests of these two models, examining of the patterns of symmetry and asymmetry in children's cortisol and sAA activity and reactivity have resulted in different patterns of coordination among both normative and high risk samples. Some studies support patterns of symmetry among cortisol and sAA basal activity (El-Sheikh, Erath, Buckhalt, Granger, & Mize, 2008) and reactivity (Gordis, Granger, Susman, & Trickett, 2006), asymmetry in basal activity (Vigil, Geary, Granger, & Flinn, 2010) and reactivity (Allwood, Handwerger, Kivlighan, Granger, & Stroud, 2011; Gordis, Granger, Susman, & Trickett, 2008), or no interactive effects between the two systems (Lisonbee, Pendry, Mize, & Gwynn, 2010; Spinrad et al., 2009) in contributing to children's behavior problems. Additionally, research also suggests that relations between symmetry and asymmetry may change over time. Hastings and colleagues (2011) found that symmetrical activation of the ANS (blood pressure) and HPA axis (cortisol) was associated with concurrent increased internalizing problems but that overtime asymmetry involving low ANS reactivity and high HPA reactivity led to more internalizing problems for girls two years later. Furthermore, many studies suggest specific directions of symmetry and asymmetry in relation to children's internalizing and externalizing problems. For example, asymmetry in responses may support specific patterns of findings such as in the context of low cortisol and high sAA levels contributing to risk and child behavior, rather than general patterns of asymmetry (e.g., Fortunato, Dribin, Granger, & Buss, 2008; Vigil et al., 2010).

While the number of investigations examining the interactive role of the ANS and HPA axis has increased, findings across multiple investigations of the interaction of both the ANS and

HPA axis suggest that inconsistencies in relation to the prediction of adjustment persist despite accounting for functioning within both systems. It is likely that additional considerations, such as level of exposure to chronic stress, type of risk, and developmental timing of risk exposure, are necessary for understanding the exact nature of the role of symmetry or asymmetry among stress responses in contributing to problem behavior. Thus, consideration of additional factors may be necessary to disentangle the stress response system-adjustment link. Coordination of systems may organize to fit the environmental context in which they occur (Del Giudice, Ellis, & Shirtcliff, 2011). Thus, the implications of different patterns of symmetry and asymmetry for child adjustment may depend on the degree to which this coordination is adaptive for a child's environment. Subgroups of children may develop different patterns of responses that are adaptive for a given environmental context; what is adaptive for optimal child adjustment may differ for harmonious and adverse family contexts. Research comparing children and adolescents exposed to trauma or maltreatment finds greater asymmetrical patterns of HPA and ANS functioning in children exposed to trauma compared to those who have not experienced trauma (Gordis et al., 2008; Shenk, Noll, Putnam, & Trickett, 2010; Vigil et al., 2010). These findings suggest that the organization of the HPA axis and ANS may be different for children exposed to chronic stress. Understanding a history of exposure to adversity may be necessary for disentangling the impact of coordination among systems on problem behavior. The present study specifically sought to investigate moderation of family adversity, in the form of marital discord, in contributing to the impact of coordination among systems on adjustment problems. Specifically, the interrelations between children's cortisol and sAA in relation to their emotional and behavioral responses to discord and adjustment were explored among varying levels of risk.

In addition to understanding relations with adjustment problems, it is imperative to understand how coordination among physiological responses relates to and may motivate behavioral and emotional coping strategies (Bauer, Quas, & Boyce, 2002). Thus the present study sought to examine how patterns of symmetry and asymmetry relate to children's known emotional and behavioral responses to conflict. Marital conflict threatens children's security about the family motivating them to restore a sense of security through behavioral and emotional strategies that serve to alleviate the immediate threat of and their exposure to conflict (Davies & Cummings, 1994). While these strategies may be adaptive in the short-term, chronic use of dysregulated behavioral responses may undermine adaptive functioning in other settings leading to the development of problem behavior. Children's physiological responses to conflict are also employed to respond to marital conflict (Cummings & Davies, 1996). Inefficient use of physiological systems activated in the face of threat is likely associated with additional indicators of children's insecurity in the marital relationship. In accordance with calls to understand how physiological responses relate to psychological responses to stress, the present study sought to explore how symmetry and asymmetry in children's cortisol and sAA, reflecting the additive and interactive models, are related to known indicators of children's emotional and behavioral responses to marital conflict. Specifically, the role of behavioral and emotional responses to conflict that are associated with increased risk for maladjustment are examined, including children's involvement in conflict, behavioral dysregulation (e.g., acts of aggression during conflict), and increased displays of emotional distress (e.g., anger, fear, sadness).

The current study is an empirical examination of the two hypothesized models outlined in Bauer et al. (2002); that is, the proposed interactive relationships between children's cortisol and sAA levels are examined in the context of marital conflict. Given children's experiences with marital conflict vary greatly, it may be necessary to take into account the level of exposure to marital conflict children experience to examine if relations among cortisol and sAA vary as a function of differing levels of family risk. Thus, the present study examined a three-way interaction of marital conflict, cortisol, and sAA. Children's affective and behavioral responses, indicative of emotional insecurity, were examined in relationship to symmetrical and asymmetrical patterns of children's cortisol and sAA in response to viewing videotaped conflict vignettes. Additionally, children's concurrent childhood and subsequent early adolescent internalizing and externalizing problems were examined in relation to patterns of symmetry and asymmetry. Based on previous research, it was hypothesized that asymmetry in physiological responses to conflict, indexed by children's cortisol and sAA, would be predictive of problem behavior; however, it was also expected that these relations might exist for a subset of children exposed to chronic levels of marital conflict and that a different pattern of responses may be found for children with little exposure to marital conflict. Thus, marital conflict was examined as a moderator of the relations between coordination in the ANS and HPA axis and child adjustment. Given differences in previous research as to the direction of asymmetry (e.g., high cortisol-low sAA or low cortisol-high sAA) in contributing to child adjustment no specific direction of asymmetry in responses was hypothesized.

Method

Participants

Participants were 195 mothers, fathers, and their second-grade child (107 girls, 88 boys, *M* age = 7.99 years, *SD* = .53) taking part in a larger longitudinal study examining the effects of marital and family functioning on child adjustment. Families were recruited from the South Bend, IN and Rochester, NY areas through flyers distributed at schools, churches, and local community events. Eligibility requirements for the study included all three family members living together for a minimum of three years, families had a child in kindergarten at the start of the study, and all family members were English proficient. Families were racially and ethnically representative of the communities in which they reside. Of participants, 77.3% were White, 17.0% were Black or African American, 2.6% Biracial or Multiracial, and 3.1% reported other racial and ethnic backgrounds. Median family annual income range was $40,000 to $54,999 ($n$ = 53) with the full sample ranging from less than $6,000 to more than $100,000. The majority of families reported being married at the current time point (87.6%; *M* years together = 12.80, *SD* = 4.77) and were the biological parents of the study child (94.4% mothers, 86.6% of fathers).

Data for the current study were drawn from a larger longitudinal study; the present study utilized data from when children were in second (T1, n = 195) and seventh grade (T2, n = 176). There was a 91.5% retention rate of families from the start of the larger longitudinal study to the T1 time point in which the data for the present study are drawn (215 of 235 families). Families not participating at T1 did not differ from families retained on any demographic or study variables including parent age, child age and gender, marital conflict, emotional security, or child adjustment at the start of the study. However, retained families had higher income ranges than families not participating ($\chi^2(9) = 31.85$, $p < .01$). The median income range for retained families was $40,000–54,999 (28%) whereas the median income range for non-retained families was $29,000–39,999 (30%). Participants were excluded from the current analyses if children had missing or inadequate amounts of saliva for assay procedures (n = 20). Children with missing or inadequate saliva amounts did not differ from children included in the analyses on demographics, marital conflict, emotional security, or child adjustment. This resulted in a total of 195 children with complete saliva samples for the concurrent T1 analyses.

Of the 195 families whose data were used in the analyses examining concurrent functioning (at T1), 90.2% of families returned to the laboratory setting in early adolescence (T2; *M* age = 12.55 years, *SD* = .56, Median grade = 7, 55.7% female). This resulted in a sample size of

176 families for the analyses examining functioning in early adolescence (T2). There were no differences in families lost to attrition in early adolescence compared to retained families on any demographic or study variables.

Procedure

Marital conflict vignettes—Children were shown a series of seven videotaped clips depicting conflict between two adults (Koss et al., 2011; Shamir, Cummings, Davies, & Goeke-Morey, 2005). Children were asked to pretend that each of the disagreements was taking place between their parents. Vignettes were approximately one minute in length and depicted varying degrees of intensity, destructiveness/constructiveness, and resolution. Disagreements in the clips were centered on family financial or leisure concerns. The series of vignettes included a neutral warm-up story, an unresolved conflict, a resolved conflict, an unresolved child-related conflict, a resolved conflict, an unresolved escalating conflict, and a final resolution to all previous disagreements. Children were assigned one of two sets of videotapes. Ordering of the conflicts was identical across the groups; however, the topic of each disagreement varied between the two stimuli. There were no differences in levels of cortisol, sAA, child adjustment, or emotional security across the two tape sets. All analyses controlled for tape selection.

Saliva collection—Children provided one pre-task and one post-task saliva sample in accordance with the viewing of the marital conflict vignettes. To reduce the number of contaminants present in the saliva samples, children were instructed to rinse their mouths out with water prior to the pre-task sample. To induce saliva production, children chewed Trident sugarless gum. Children were instructed to chew the gum for three minutes to minimize the effects of the initial flavor burst. Stimulated whole mouth samples were collected with the aid of a straw (Granger et al., 2007); pre-task and post-task saliva samples were assayed for both cortisol and sAA. The pre-task sample was collected after the initial arrival and introduction to the laboratory and assent procedures. The saliva collection was initially designed to examine cortisol in response to children viewing the marital conflict vignettes. Research suggests that salivary cortisol peaks 20 to 40 minutes after the occurrence of the stressor (Dickerson & Kemeny, 2004); thus children provided the post-conflict saliva sample 25 minutes after viewing the child-related conflict (fourth of a series of seven vignettes). This resulted in the collection of the saliva sample approximately ten minutes after the conclusion of viewing the last of the seven vignettes. Salivary alpha-amylase reactivity peaks earlier than salivary cortisol; thus the cortisol and sAA levels likely reflect reactivity to viewing different conflict vignettes. Saliva collection occurred in the late afternoon hours (*M* time = 3:54 pm; *SD* = 2 hours 6 minutes) to minimize the effects of the diurnal rhythm of physiological functioning. Time of day was included in all analyses as a covariate to control for differences due to the diurnal rhythms of salivary cortisol and sAA.

Measures

Salivary cortisol—All saliva samples were assayed for salivary cortisol using a highly sensitive immounassay at Salimetrics Inc. (State College, PA). The assay test process utilized 25 μg/dl of saliva and the samples were tested in duplicate. The test had a lower test sensitivity of .007 μg/dl and an upper test sensitivity of 3.0 μg/dl. The average intra-assay coefficient was 4.2% for the current sample.

Salivary alpha-amylase—Saliva samples were assayed by a kinetic reaction assay employing a chromagenic substrate, 2-chloro-p-nitrophenol, linked to maltotriose (Salimetrics Inc., State College, PA). The enzymatic action of the salivary α-amylase on the substrate can be spectrophotometrically measured at 405 nm using a standard laboratory plate reader. The amount of sAA is directly proportional to the increase in absorbance over a two-minute period. The assay procedure utilizes 10 μL of saliva and results are reported in U/mL.

Marital conflict—Mothers and fathers completed the O'Leary Porter Scale (OPS; Porter & O'Leary, 1980). The OPS (9 items) assessed the frequency of overt hostility in the marital relationship. Participants rated the frequency of hostility on a four point likert scale. Scores were summed and averaged across parents to create a parent-composite of marital conflict occurring in the home. The internal reliability for the current sample was $\alpha = .86$.

Emotional security—Mothers and fathers completed the Security in the Marital Subsystem scale (SIMS; Davies, Forman, Rasi, & Stevens, 2002). The SIMS assesses children's behavioral and emotional reactions to witnessing marital conflict. Parents completed the involvement (9 items), behavioral dysregulation (5 items), and emotional reactivity (10 items) subscales. The involvement subscale assessed the degree to which children involve themselves in marital conflict. The behavioral dysregulation subscale measured the use of angry or aggressive reactions to witnessing marital conflict. The emotional reactivity subscale measured the degree to which children responded emotionally (e.g., scared, mad, sad) to marital disputes. Parents rated each response on a five point likert scale ranging from 1 (*not at all like him/her*) to 5 (*a whole lot like him/her*). Scores for each subscale were summed with higher scores indicating more emotional insecurity to witnessing marital conflict. Mother and father summed scores were averaged for each of the subscales to create a parent-composite score for each of the indices children's emotional insecurity. The internal reliability for the current sample were involvement $\alpha = .85$, behavioral dysregulation $\alpha = .70$, and emotional reactivity $\alpha =.82$. Empirical findings and reports of internal consistency in the literature support the use of these subscales of the SIMS (e.g., Cummings, George, McCoy, & Davies, 2012; Cummings, Schermerhorn, Davies, Goeke-Morey, & Cummings, 2006).

Child adjustment—Mothers and fathers completed the internalizing and externalizing problems subscales of the Child Behavior Checklist (CBCL; Achenbach, 1991) at two time points; parents provided concurrent assessments in childhood (T1) and again during early adolescence (T2). The internalizing problems subscale (30 items) reflects children's anxious, withdrawn, and depressive symptomatology. The externalizing problems subscale (33 items) reflects children's aggressive and delinquent behaviors. Parents rated children's behaviors on a three point likert scale. Scores were summed and averaged across parents to create a parent-composite score of internalizing and externalizing problems. The internal reliability coefficients for the current sample were childhood internalizing problems $\alpha = .87$ and externalizing problems $\alpha = .89$ and adolescent internalizing problems $\alpha = .84$ and externalizing problems $\alpha = .93$. Utilizing parent composite scores, 26.0% and 17.7% of children at T1 and 11.5% and 15.1% of early adolescents at T2 were classified as borderline or clinical on the internalizing and externalizing problems scales, respectively.

Results

Descriptive statistics and correlations for all study variables are displayed in Table 1. Physiological functioning was unrelated to children's behavioral and emotional responses to conflict and child adjustment. Time of day of the saliva collection was related to cortisol, but not sAA levels; thus, time of assessment was included as a covariate in all subsequent analyses. The majority of children displayed a decrease (e.g., any difference less than zero) in cortisol (81.0%) and sAA (61.5%) from the pre-task to post-task assessments. Higher levels of marital conflict were correlated with higher levels of children's emotional insecurity indices. Additionally, the emotional security variables were highly correlated. Child adjustment was highly correlated with adjustment in early adolescence. Family income was related to marital conflict and children's emotional security and was included as a covariate in all subsequent analyses. A one-way between subjects analysis of variance was conducted to examine child gender and ethnicity differences among study variables. There were no significant ethnicity differences among any study variables and no significant differences among boys and girls in physiological responses, emotional security, marital conflict, and most child adjustment variables. However, there was a significant difference among boys and girls in T1 externalizing problems. Boys ($M = 10.37$, $SD = 6.22$) had higher levels of parent-report of externalizing problems compared to girls ($M = 8.16$, $SD = 5.67$; $F(1,213) = 7.39$, $p < .01$) at T1.

Regression Analyses

Multiple regression analyses were conducted examining the interaction between children's post-task cortisol, post-task sAA, and marital conflict on children's emotional security and adjustment. Specifically, multiple regression analyses were conducted in the prediction of children's involvement, behavioral dysregulation, and emotional reactivity to marital conflict as well as concurrent childhood and later early adolescence internalizing and externalizing problems. All analyses controlled for child age, gender, conflict stimulus tape, family income, time of day of assessment, and pre-task levels of cortisol and sAA. Pre-task cortisol and sAA levels were included as a covariate in all analyses that included the post-task cortisol and sAA levels to account for individual differences prior to the start of the task. Covariates, the main effects of marital conflict and post conflict task cortisol and sAA in response to viewing the marital conflict videotapes, the three two-way interactions, and the three-way interaction were included. Variables were centered before creating the interaction terms. Slope difference tests (Dawson & Richter, 2006) were examined to probe for where differences may be among significant 3-way interactions.

Due to the skewed nature of cortisol and sAA, the raw data was transformed to approximate a near-normal distribution. In accordance with Tabachnick and Fidell (2007), a square-root transformation was conducted on the moderately skewed sAA data and a natural log transformation was conducted on the heavily skewed cortisol data. Distributions of the cortisol and sAA data approximated a normal distribution after the transformations; thus all analyses in the present study utilize the transformed data.

Children's Emotional Security

Multiple regression results for the three behavioral indicators of emotional security (T1) are displayed in Table 2. There was a significant 3-way interaction for all of the emotional security variables: children's involvement, behavioral dysregulation, and emotional reactivity. For ease of interpretability, Figure 1 depicts one standard deviation above and below the mean for the three-way interaction between post-task cortisol, post-task sAA, and marital conflict. Patterns were fairly consistent across analyses for emotional security indicators showing support for the interactive model, in the form of lower cortisol and higher sAA, among children exposed to higher levels of marital conflict and partial support for the additive model among children exposed to lower marital conflict in the home. Children from high conflict homes with an asymmetrical pattern of cortisol and sAA levels had the highest levels of involvement, behavioral dysregulation, and emotional reactivity to witnessing marital conflict. In particular, asymmetry in the context of lower cortisol and higher sAA levels was predictive of the highest levels of emotional insecurity (see Figure 1). Among children exposed to low levels of marital conflict in the home, the combination of high cortisol and high sAA, indicative of the additive model, was predictive of higher levels of involvement, behavioral dysregulation, and emotional reactivity compared to other children with low conflict exposure. However, the reverse, low cortisol and low sAA, was not predictive of elevated emotional insecurity among the low conflict risk group, providing partial support for an additive model.

Slope difference tests showed significant differences between slopes for children's *involvement* in conflict between 1) high sAA-high cortisol and high sAA-low cortisol (t = −2.95, $p < .01$), 2) high sAA-low cortisol and low sAA-high cortisol (t = −6.14, $p < .001$), and 3) high sAA-high cortisol and low sAA-low cortisol (t = −4.891, $p < .001$). Slope difference test for children's *behavioral dysregulation* showed slope differences between 1) high sAA-low cortisol and low sAA-high cortisol (t = −2.81, $p < .01$), 2) high sAA-low cortisol and high sAA-high cortisol (t = −35.44, $p < .001$), 3) high sAA-high cortisol and low sAA-high cortisol (t = −6.16, $p < .001$), and 4) high sAA-high cortisol and low sAA-low cortisol (t = −2.70, $p < .01$). There was also a trend for a difference between high sAA-low cortisol and low sAA-low cortisol (t = 1.92, p = .056). Lastly, slope differences tests for *emotional reactivity* showed differences in slopes between high sAA-low cortisol and low sAA-high cortisol (t = 4.12, $p < .001$). These slope differences provide further support for differences in symmetry and asymmetry in physiological systems among children exposed to differing levels of risk. In summary, asymmetry among low cortisol-high sAA in the context of high marital conflict was predictive of more emotional insecurity for children. Alternatively, symmetry among high cortisol-high sAA for children exposed to low levels of marital discord was related to higher emotional insecurity characterized by greater involvement in conflict.

Child Adjustment

Concurrent child adjustment—Multiple regression results for internalizing and externalizing problems (T1) are displayed in Table 3. There was a significant 3-way interaction for childhood internalizing problems. Figure 2 depicts the 3-way interaction for one standard deviation above and below the mean for post-task cortisol, post-task sAA, and marital conflict in the prediction of internalizing problems. The pattern for internalizing problems was consistent with the pattern of findings for children's emotional security. Specifically, children from high conflict homes with asymmetry in cortisol and sAA levels in response to viewing the marital conflict vignettes characterized by high sAA in conjunction with low cortisol had the highest levels of internalizing problems providing support for the interactive model. However, children with the asymmetrical pattern characterized by low sAA and high cortisol did not have elevated levels of internalizing problems. Further, in the context of low conflict, children with symmetrical low sAA-low cortisol had elevated internalizing problems; however, the reverse symmetrical pattern of high sAA-high cortisol did not relate to elevated internalizing problems. A significant slope difference test between high sAA-low cortisol and low sAA-low cortisol (t = 3.19, $p < .01$) was found. There were no significant interaction effects for externalizing problems.

Early adolescent adjustment—Results of the regression analyses for adolescent internalizing and externalizing problems (T2) are displayed in Table 3. There was a significant 3-way interaction for internalizing and externalizing problems (see Figure 3). For internalizing problems, children exposed to higher marital conflict had the highest predicted means of adolescent internalizing problems in the context of high sAA-low cortisol, providing partial support for the interactive model. Additionally, there was support for the additive model for children exposed to lower levels of childhood conflict with the most elevated levels of adolescent internalizing problems for low sAA-low cortisol. Slope difference tests support these relations. There were significant slope differences among the 1) high sAA-low cortisol and low sAA-low cortisol (t = 2.68, $p < .01$) and 2) high sAA-low cortisol and high sAA-high cortisol (t = 2.10, $p < .05$).

For externalizing problems, there was support for the additive model among children exposed to lower levels of marital conflict during childhood. Children with higher levels of cortisol and sAA had the highest levels of externalizing problems. Additionally, children exposed to lower levels of marital conflict with low cortisol and low sAA levels had slightly elevated externalizing symptoms when compared to children with asymmetry in this context. There was partial support for the interactive model among children exposed to higher levels of marital conflict in the context of low cortisol and high sAA levels. Slope difference tests provide support for these relations. Specifically, there were significant differences in slopes for 1) high sAA-low cortisol and high sAA-high cortisol ($t = 3.58$, $p < .001$), 2) high sAA-low cortisol and low sAA-low cortisol ($t = 2.94$, $p < .01$), 3) high sAA-low cortisol and low sAA-high cortisol ($t = 2.06$, $p < .05$), and 4) high sAA-high cortisol and low sAA-high cortisol ($t = -2.50$, $p < .05$).

Discussion

The present study sought to examine the interaction between children's physiological responses to marital conflict in relation to children's behavioral and emotional responses to conflict and adjustment. Consistent with hypotheses, patterns of symmetry and asymmetry in physiological responses were associated with children's emotional and behavioral regulation strategies utilized during marital discord and child adjustment. The pattern of findings for different indicators of emotional insecurity and behavioral problems was generally consistent across these different outcomes in the present study. While behavioral dysregulation, involvement, and emotional reactivity represent different forms of behavioral and emotional responses, indicative of emotional insecurity, it is not surprising that similar forms of physiological responses may be associated with a variety of emotional and behavioral responses. Exposure to marital discord may motivate children to utilize a variety of these behavioral responses to alleviate the threat of conflict resulting in similar patterns of findings in association with physiological functioning. Differences were particularly pronounced for children's level of involvement in conflict. Higher responsivity of the ANS was associated with more involvement; however, this association differed depending on coordination of the ANS with the HPA axis. In addition to predicting concurrent responses, the interaction between physiological activity and family risk during childhood was also predictive of behavioral problems spanning into early adolescence. Relations among patterns of physiological responses and problem behavior were moderated by exposure to marital conflict. Exposure to higher levels of marital conflict played an important role in these relationships. The interaction between indices of adrenocortical and ANS functioning alone was not predictive of most behavioral responses without considering the context of risk exposure, that is, the degree of marital conflict that children were exposed to also interacted with physiological functioning to predict child adjustment. Children's physiological responses to stress likely emerge over development as a result of exposure to different environmental stressors in conjunction with biological vulnerabilities. While it is possible specific patterns of coordination of the ANS and HPA axis have a genetic component, the results of the present study suggest that children's response patterns may emerge partly based on experience with chronic environmental stress. These results highlight the need to examine individual differences in patterns of regulatory responses to stress and underscore the importance of understanding the context of risk exposure for examining the interrelatedness of children's regulatory responses.

For children exposed to higher levels of marital conflict, asymmetry in ANS and HPA axis responses was linked to more emotional insecurity, including increased levels of emotional reactivity, behavioral dysregulation, and involvement in marital conflict as well as increased behavior problems. This pattern of responses is consistent with the interactive model proposed by Bauer and colleagues (2002). In particular, support for the interactive model was most pronounced in the context of low cortisol and high sAA levels among children exposed to higher levels of marital conflict. Consistent with previous research, exposure to chronic stress may lead to lower levels of cortisol (Trickett, Noll, Susman, Shenk, & Putnam, 2010). Thus in the face of stress, high risk children may respond with disassociations in physiological systems due to changes in adrenocortical responding that may be adaptive in the face of chronic stress. While the faster-acting ANS response is activated in the face of new stress, the attenuation of the HPA axis for children faced with chronic stress may result in asymmetry in responses. This pattern of findings is consistent with recent research examining the interactive role of cortisol and sAA in adolescents experiencing trauma (Vigil et al., 2010) and provides further support for individual differences in the way in which physiological systems may interact in contributing to psychological risk.

The majority of children had declining levels of cortisol in response to viewing the marital conflict vignettes. Declines in cortisol production in response to conflict paradigms are common (Gunnar, Talge, & Herrera, 2009). It is difficult to interpret the exact nature of this decline without diurnal samples necessary to untangle whether lower cortisol levels were related to a down-regulation of the HPA axis as a result of a higher anticipatory response to arriving in the laboratory setting or an active suppression of the HPA axis during the marital conflict task. The present study would benefit from basal measures of cortisol and sAA collected on a non-laboratory visit day to help determine further whether children experienced a decline due to a return to baseline from a higher anticipatory response to visiting the laboratory setting, an active suppression of the stress response in response to viewing the marital conflict vignettes, or due to the diurnal rhythms of physiological activity. Nevertheless, the laboratory setting was designed to reflect a home living environment and at the time of the current investigation children had experienced multiple sessions in this setting, thus a greater anticipatory response was not expected. Greater declines in cortisol may serve to inhibit the necessary resources to effectively respond to marital conflict and decreases in response to the task may reflect counter-regulation among higher risk children when paired with elevations in the ANS responses. Glucocorticoids are thought to terminate activation of the SNS and greater decreases in cortisol in response to this task may relate to inefficient coordination among the systems.

In contrast to asymmetrical responses among higher exposure to marital conflict, a pattern of symmetrical responses was found to relate to greater maladjustment for children exposed to lower levels of conflict, supporting an additive model. In the context of low levels of conflict, symmetrical responses of higher activation of both the ANS and HPA axis were found to predict higher levels of emotional insecurity relative to other low risk children. Among children exposed to lower levels of marital conflict, symmetrical levels characterized by low sAA and low cortisol, were associated with greater concurrent and subsequent internalizing problems. However, symmetrical responses of high sAA and high cortisol led to the longitudinal prediction of elevations in internalizing and externalizing problems. Previous research supports the notion that lower levels of cortisol are associated with concurrent mental health problems and higher cortisol levels are predictive of increased problem behavior longitudinally (Shirtcliff & Essex, 2008). Among children experiencing less family risk, increased activation of both systems during childhood may serve as a precursor to later problem behavior. Lastly, changing relations among patterns of responses and concurrent and longitudinal relations with adjustment have been identified in the literature (e.g., Hastings et al, 2011).

The findings of the present study may indicate more complex patterns associated with exposure to conflict. Inconsistent support for the additive and interactive models in previous research may be due to a lack of consideration of the level of risk exposure; previous research has utilized both normative and high risk samples without consideration for level of risk. It should be noted that, while elevated emotional insecurity was found in the context of high levels of cortisol and sAA for children with low exposure to marital conflict these behaviors were not equally as highly elevated when compared to those with elevated behavioral responses in the high risk group for concurrent relations indicating this context may be a maladaptive form of responding relative to low risk contexts. However, in the prediction of problem behaviors into early adolescence, high co-activation for children exposed to less marital conflict during childhood was related to similarly high levels of externalizing problems as children with high conflict exposure and asymmetry during childhood. The symmetrical pattern of responses among children with low exposure to marital conflict during childhood was associated with increasingly elevated levels of maladjustment during early adolescence. Thus, high co-activation among low risk children may also serve as a precursor for the development of behavioral problems in adolescence. Research examining histories of marital discord in childhood have been shown to predict problem behaviors in adolescence (Cummings, George, McCoy, & Davies, 2012). Additionally, early RSA, an index of PNS functioning, lead to increases in externalizing problems for boys (El-Sheikh & Hinnant, 2011). Consistent with the notions of hierarchical motility, early experiences with adversity may affect organizations of biological and behavioral systems that carry over into later developmental difficulties as new organizations of functioning evolve during development (Cicchetti & Cohen, 1995). As it relates to a history of exposure to marital conflict, patterns of childhood physiological functioning may lead to the emergence of later adjustment problems. Future research is needed to explore these relations longitudinally to determine if these children with high co-activation in childhood developed dissociations in physiological responses during adolescence.

The current study used measures of overall cortisol and sAA levels in examining the interaction between systems. In response to conflict exposure, future research should examine the interaction in reactivity or changes in levels with more samples to capture differences in initial reactivity and recovery. Additional saliva samples would be valuable to better capture the sequence of reactivity and recovery of the stress response systems in response to social stress tasks. However, given this study is one of the first to examine these relations in exposure to marital conflict, overall post-task levels were examined as a first step in understanding the interactive nature of responses. The present study utilized sAA as a promising indicator of ANS functioning; however, it is important to note that sAA, as a broader indicator of ANS functioning, is influenced by both the sympathetic and parasympathetic branches. Further assessments of research questions with specific indices of both SNS and PNS activity will likely contribute meaningfully to this emerging literature. Additionally, the study procedures were designed to assess children’s cortisol responses. No information on salivary flow rate, which has been found to influence the measurement of sAA, was available. The timing for the assessment of sAA was also not ideal; research on sAA responses shows that levels peak five to ten minutes after exposure to stress. The present study assessment was collected 5–10 minutes after the conclusion of the marital conflict vignettes. It is important to note that the initial peak of sAA was likely not captured in the current study and the cortisol and sAA levels likely correspond to different points during the marital conflict vignettes. However, given the unpredictable nature of conflict, children’s responses likely capture residual ANS responding to the continued task. Consistent with some previous research, one saliva sample has been used to assay both cortisol and sAA; thus similarly delayed samples have been utilized in exploring relations with children adjustment (e.g., Lisonbee, Pendry, Mize, & Gwynn, 2010). Lastly, reliance on parent-report for measures of family risk and child outcomes is an additional study limitation. Parent-report of child behavior may be influenced by their own psychopathology, parenting, or child temperament. However, use of a composite report of mothers and fathers and objective assessments of salivary measures help to mitigate this concern.

The present study contributes to a growing body of research supporting the role of children's physiological responsivity to conflict and its relationship with children's emotional security about the marital relationship and child adjustment (e.g., Davies, Sturge-Apple, Cicchetti, & Cummings, 2008). While the present study highlights the need to examine multiple physiological systems in the context of stress, these finding also continue to provide support for the need to examine physiological responses in relation to other regulatory responses children used in times of stress (e.g., emotional, behavioral strategies) as well as consider the environmental risk factors children face.

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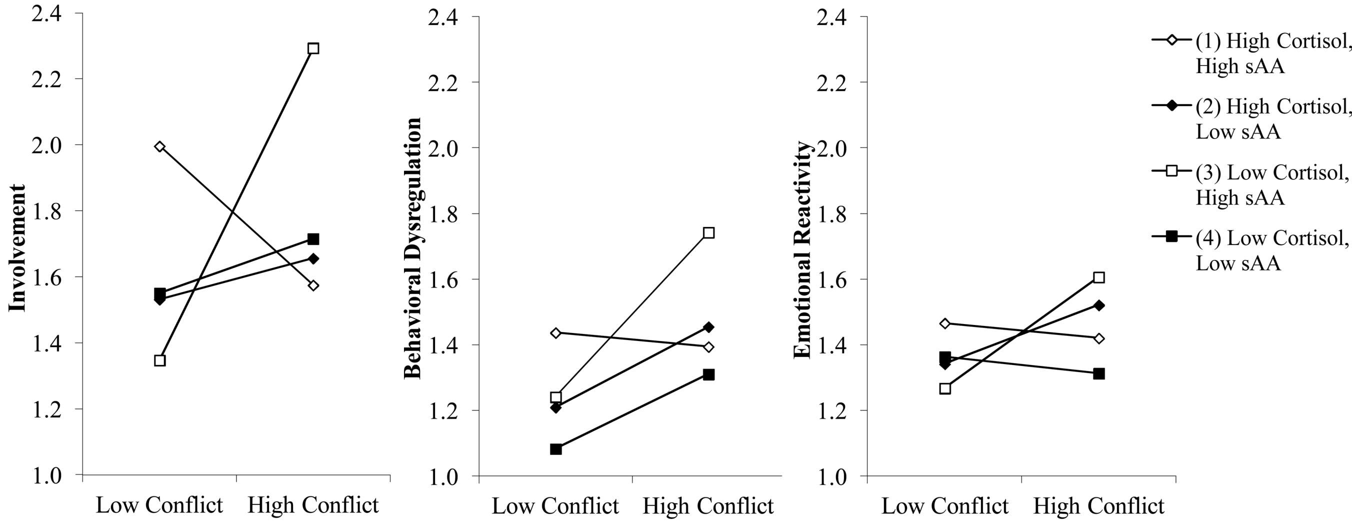

Figure 1.

Three-way interaction for marital conflict and children's cortisol and alpha-amylase levels predicting children's responses to marital disputes including, involvement, behavioral dysregulation, and emotional reactivity. Figures depict 1 SD above and below the sample mean for high and low post-task cortisol, post-task sAA, and marital conflict.

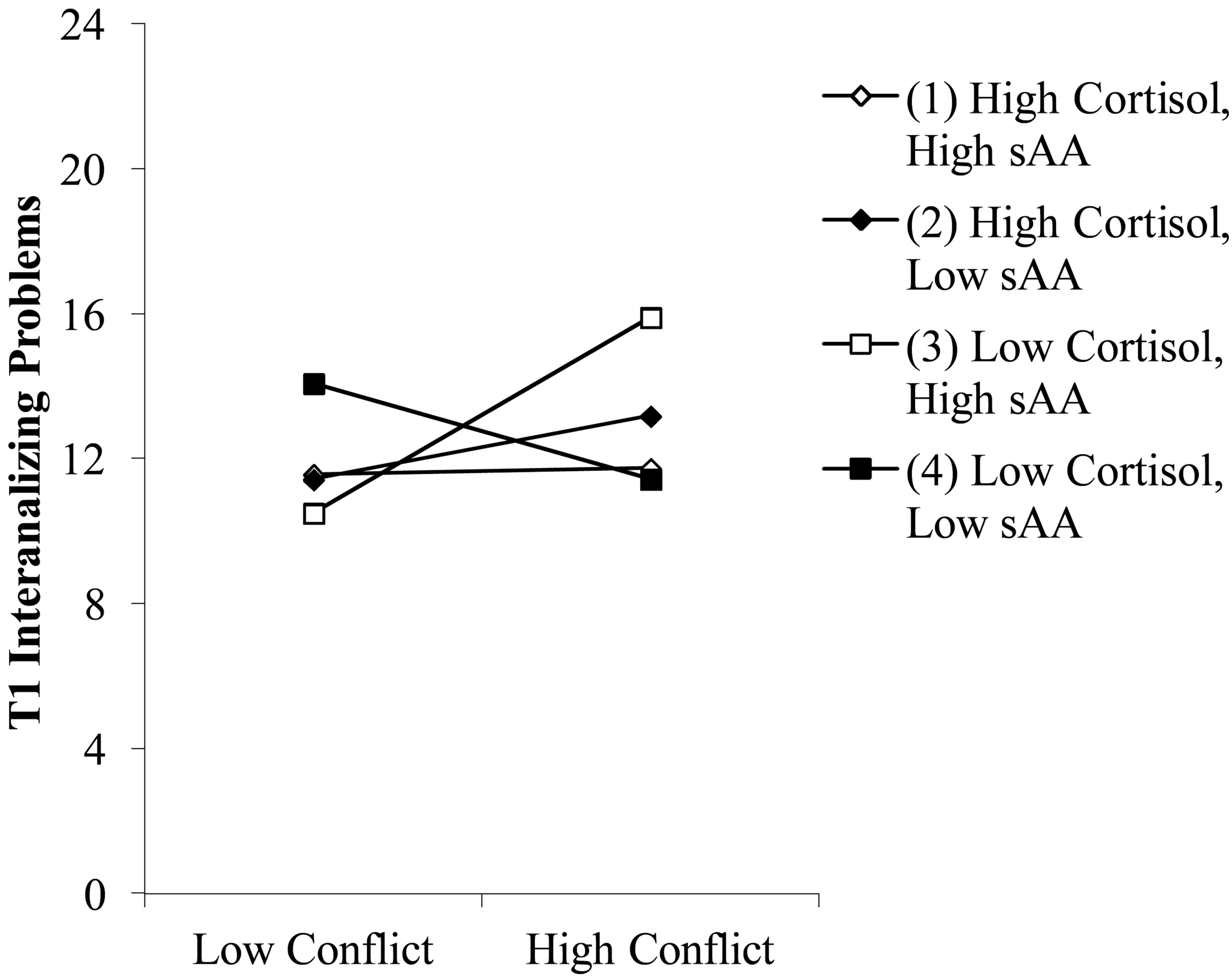

Figure 2.
Three-way interaction for marital conflict and children's cortisol and alpha-amylase levels predicting children's concurrent T1 internalizing problems. Figures depict 1 SD above and below the sample mean for high and low post-task cortisol, post-task sAA, and marital conflict.

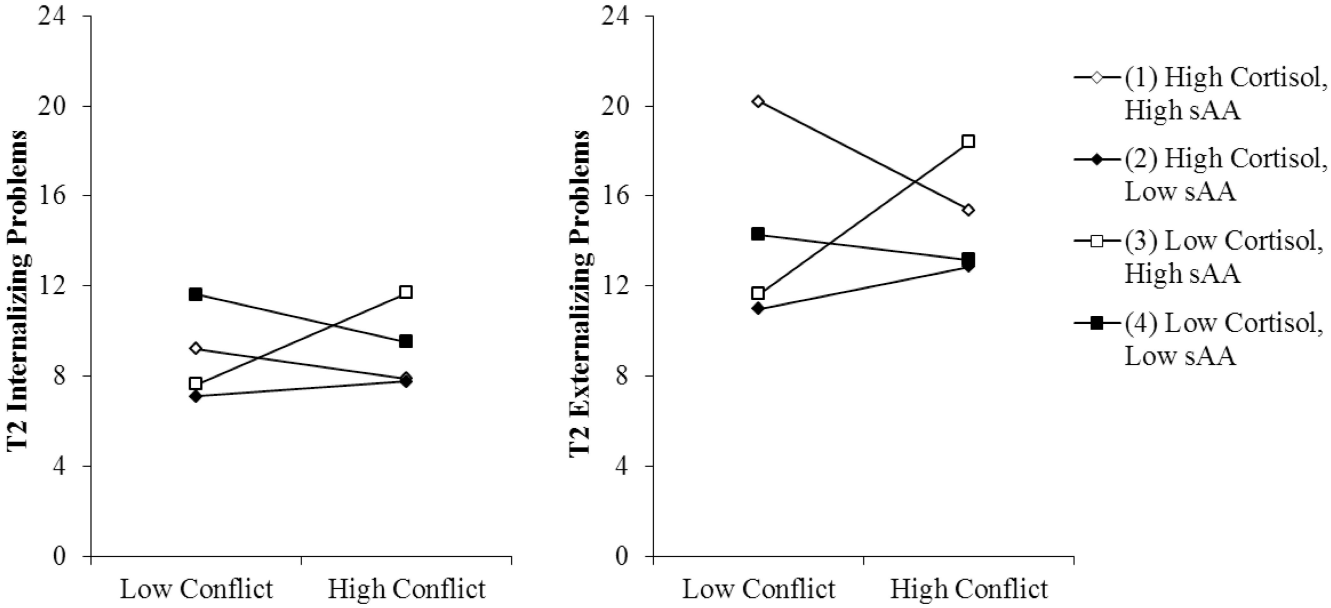

Figure 3.

Three-way interaction for marital conflict and children's cortisol and alpha-amylase levels predicting adolescent's T2 internalizing and externalizing problems. Figures depict 1 SD above and below the sample mean for high and low post-task cortisol, post-task sAA, and marital conflict.

Table 1

Correlations and descriptive statistics

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Pre-Task Cortisol	--												
2. Post Conflict Cortisol	.82**	--											
3. Pre-Task sAA	.09	.04	--										
4. Post Conflict sAA	.07	.05	.84**	--									
5. Marital Conflict	−.03	−.02	.04	.05	--								
6. Involvement	−.07	−.07	.07	.09	.20**	--							
7. Behavioral Dysregulation	−.06	−.01	−.01	.05	.33**	.33**	--						
8. Emotional Reactivity	−.08	−.02	.04	.06	.20**	.31**	.30**	--					
9. Internalizing - T1	−.04	−.04	.06	.00	.12	.17*	.30**	.55**	--				
10. Externalizing - T1	−.06	.04	.13	.09	.12	.15*	.45**	.37**	.64**	--			
11. Internalizing - T2	−.05	−.11	−.07	−.13	.05	.17*	.21*	.33**	.70**	.46**	--		
12. Externalizing - T2	−.01	.04	.09	.12	.22**	.23**	.41**	.29**	.55**	.72**	.61**	--	
13. Saliva Collection Time	−.30**	−.38**	.08	.07	.04	.08	−.11	.01	−.07	−.12	−.04	−.14	--
14. Family Income	.12	.06	−.02	−.03	−.21**	−.16*	−.07	−.20**	−.09	−.11	−.05	−.19*	.04
M	−2.30	−2.66	7.57	7.26	11.87	2.17	1.38	1.49	7.88	8.98	5.57	5.41	3:53pm
SD	.59	.57	2.65	2.73	4.06	.65	.41	.36	5.75	5.89	4.65	5.53	2h 7m

Note. Cortisol and sAA are transformed variables.

* $p < .05$;

** $p < .01$.

Table 2

Multiple Regression for 3-way Interaction predicting Children's Emotional Security

	Involvement	Behavioral Dysregulation	Emotional Reactivity
Covariates			
Pre-task Cortisol	− .07 (.14)	− .11 (.09)	− .09 (.08)
Pre-task sAA	.01 (.03)	− .02 (.02)	.003 (.02)
Assessment Time	.02 (.02)	**− .03 (.02)***	− .004 (.01)
Tape Stimuli	− .15 (.09)	− .02 (.06)	.01 (.05)
Child Gender	.03 (.09)	− .10 (.06)	− .04 (.05)
Child Age	.06 (.09)	.08 (.06)	.04 (.05)
Family Income	− .02 (.02)	.00 (.01)	− .02 (.01)
Main Effects			
Post Conflict Cortisol	− .02 (.15)	.03 (.09)	.05 (.08)
Post Conflict sAA	.03 (.03)	.04 (.02)	.01 (.02)
Marital Conflict	**.03 (.01)***	**.03 (.01)*****	**.01 (.01)***
2-Way Interactions			
Cortisol X sAA	.01 (.03)	− .03 (.02)	− .01 (.02)
Cortisol X Conflict	**− .08 (.02)****	− .03 (.02)	− .01 (.01)
sAA X Conflict	.003 (.004)	.00 (.003)	.002 (.002)
3-Way Interaction			
Cortisol X sAA X Conflict	**− .03 (.01)****	**− .01 (.01)***	**− .01 (.01)***
R^2	.15	.19	.10

Note. Unstandardized coefficients (and standard errors) are reported. Cortisol and sAA levels are transformed variables. Child gender was coded dichotomously with 0 for boys and 1 for girls. Bolded values indicate significance.

* $p < .05$;

** $p < .01$;

*** $p < .001$

Table 3

Multiple Regression for 3-way Interaction Predicting Child Adjustment

	Childhood Adjustment		Early Adolescence Adjustment	
	Internalizing Problems	**Externalizing Problems**	**Internalizing Problems**	**Externalizing Problems**
Covariates				
Pretask Cortisol	− .49 (1.20)	**− 3.26 (1.23)****	.38 (1.01)	− 2.07 (1.24)
Pretask sAA	.20 (.28)	.29 (.29)	− .03 (.23)	− .17 (.28)
Assessment Time	− .28 (.21)	**− .48 (.22)***	− .18 (.18)	**− .54 (.22)***
Tape Stimuli	.00 (.81)	.39 (.84)	.03 (.68)	.43 (.84)
Child Gender	− .85 (.82)	**− 2.42 (.85)****	.59 (.68)	− .19 (.84)
Child Age	.24 (.78)	− .26 (.81)	− .004 (.64)	.20 (.78)
Family Income	− .35 (.21)	− .17 (.21)	− .16 (.17)	− .40 (.21)
Main Effects				
Conflict Cortisol	− .86 (1.28)	2.20 (1.32)	− 1.99 (1.19)	2.07 (1.24)
Conflict sAA	− .03 (.27)	.08 (.28)	.02 (.22)	**.63 (.27)***
Marital Conflict	.14 (.10)	.14 (.10)	.04 (.08)	.08 (.10)
2-Way Interactions				
Cortisol X sAA	− .15 (.26)	.49 (.27)	.34 (.24)	**.77 (.29)****
Cortisol X Conflict	− .05 (.21)	− .41 (.22)	− .13 (.19)	**− .46 (.23)***
sAA X Conflict	**.08 (.04)***	− .02 (.04)	.05 (.03)	.01 (.04)
3-Way Interaction				
Cortisol X sAA X Conflict	**− .19 (.08)***	− .16 (.08)	**− .16 (.07)***	**− .29 (.90)*****
R^2	.09	.16	.12	.21

Note. Unstandardized coefficients (and standard errors) are reported. Cortisol and sAA levels are transformed variables. Child gender was coded dichotomously with 0 for boys and 1 for girls. Bolded values indicate significance. Child and adolescent adjustment were run as separate multiple regression analyses.

* $p < .05$;

** $p < .01$;

*** $p < .001$.