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Marital Conflict, Allostatic Load, and the Development of Children's Fluid Cognitive Performance

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Abstract

Relations between marital conflict, children's respiratory sinus arrhythmia (RSA), and fluid cognitive performance were examined over three years to assess allostatic processes. Participants were 251 children reporting on marital conflict, baseline RSA and RSA reactivity to a lab challenge were recorded, and fluid cognitive performance was measured using the Woodcock-Johnson III. A cross-lagged model showed that higher levels of marital conflict at age 8 predicted weaker RSA-R at age 9 for children with lower baseline RSA. A growth model showed that lower baseline RSA in conjunction with weaker RSA-R predicted the slowest development of fluid cognitive performance. Findings suggest that stress may affect development of physiological systems regulating attention, which are tied to the development of fluid cognitive performance.

Keywords

Marital Conflict; Cognitive Performance; Respiratory Sinus Arrhythmia; Physiological Reactivity; Allostatic Load

Marital conflict encompasses verbal and physical aggression between partners and is a familial stressor that has well established links to poor child outcomes (e.g., Kitzmann, Gaylord, Holt, & Kenny, 2003). Recent directions in this area of research have emphasized the multiple mediating processes that may explain *why* marital conflict is related to less optimal outcomes and the moderating factors that help to identify *who* is especially vulnerable to the harmful effects of marital conflict (Cummings, El-Sheikh, Kouros, & Buckhalt, 2009; El-Sheikh & Erath, 2011). Of relevance, parental marital conflict has been linked with reactivity to stress in multiple physiological systems (Davies, Sturge-Apple, Cicchetti, & Cummings, 2008; El-Sheikh, 2005; Katz, 2007; Saltzman, Holden, & Holahan, 2005) and to cognitive functioning and development (Ghazarian & Buehler, 2010; Kitzmann et al., 2003). Building on the literature, and with a longitudinal sample of children from middle to late childhood, we evaluated (1) marital conflict as a predictor of physiological reactivity indexed by change in respiratory sinus arrhythmia (RSA) from baseline to task (termed RSA reactivity or RSA-R), which in turn was examined as a predictor of fluid cognitive performance, the ability to use working memory and rapid information processing to solve novel problems that are independent of crystallized or explicit knowledge. This model was evaluated with baseline RSA as a moderator; and (2) interactions between marital conflict, baseline RSA, and RSA-R as predictors of initial levels and change over time in fluid cognitive performance.

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We conceptualize our study from an allostatic load perspective (McEwen & Stellar, 1993; Goldstein & McEwen, 2002). The Allostatic Load model was developed to explain how environmental stress influences or shapes the body's responses to stress over time. Shifts in physiological functioning over time are termed allostasis. Repeated activation of physiological stress response systems in reacting to chronic stress is thought to eventually result in burnout and maladaptive physiological functioning, termed allostatic overload. These allostatic shifts, in turn, are related to adjustment and development across multiple domains (Juster, McEwen, & Lupien, 2010; Loman & Gunnar, 2010). We propose that marital conflict serves as an environmental stressor that contributes to decreases in parasympathetic nervous system (PNS) stress reactivity indexed by RSA withdrawal in response to stress, which in turn is related to decrements in fluid cognitive performance. Further, we propose that these allostatic processes are more evident in children with lower baseline RSA, a characteristic that is thought to be broadly related to a number of maladaptive outcomes (Beauchaine, 2001; Hinnant & El-Sheikh, 2009). These propositions address *why* marital conflict may be related to poorer cognitive performance in a probable causal pathway of stress, allostasis, and performance. Additionally, we address *who* is most likely to be influenced by stress through risk and protective factors and hypothesize that higher baseline RSA in conjunction with greater RSA withdrawal will serve as protective factors for fluid cognitive development in contexts of high levels of marital conflict. To provide a framework for our assessment of the proposed models, we review relations between: marital conflict and children's cognitive performance, marital conflict and physiological stress regulation indexed by RSA, as well as RSA and cognitive performance; alternate models linking RSA with marital conflict were also tested and are described later.

Relations between parental marital conflict and children's academic performance are well documented. A meta-analysis on marital conflict and child outcomes by Kitzmann and colleagues (2003) found an effect size of -.45 on academic problems, which is a moderate to a large effect size. Similar results have been found in other studies (e.g., Ghazarian & Buehler, 2010). Notably, studies in this area are generally limited to academic performance as evaluated through school grades. The focus of this present paper, however, is fluid cognitive performance, which entails the use of rapid information processing and working memory in order to identify patterns and relations to solve novel problems (Cattell, 1943). While fluid cognitive performance is related to academic performance (Evans, Floyd, McGrew, & Leforgee, 2001), they are separate constructs. Very few studies have examined links between marital conflict and fluid cognitive performance or assessed allostatic processes in these relations. However, Davies, Woitach, Winter, and Cummings (2008) found that children's sense of security about their parents' marital relationship was negatively related to later attention problems, and attention problems partially mediated the link between marital conflict and academic performance. Building on this sparse literature, we examined baseline RSA and RSA-R as process variables related to the regulation of attention in connecting marital conflict and fluid cognitive performance.

Allostasis due to marital conflict was examined as a potential agent of change in cognitive performance. Although no longitudinal studies to date have evaluated how marital conflict may affect physiological stress response systems that influence fluid cognitive performance, researchers have investigated individual parts of this question. In relating marital conflict to physiological regulation, Davies, Sturge-Apple, et al. (2008) found that children's distress to marital conflict predicted increases in cortisol, a stress hormone produced in response to hypothalamic-pituitary-adrenal activation, in response to conflict. Other cross sectional studies have shown that even brief exposure to psychosocial stress results in increases in cortisol and results in impaired memory recall (Quesada, Wiemers, Schoofs, & Wolf, 2012). It is important to note that the study conducted by Quesada and colleagues was experimental with random assignment to stress conditions and thus provides support for a causal relation between stress and memory. Also relevant to the current study, Evans and Schamberg (2009) found that the negative effects of chronic poverty in childhood on adult working memory were mediated by allostatic load as measured by levels of cortisol and catecholamines. Each of these studies adds some support for links between stress, physiological regulation, and cognitive functioning, but research in this area is sparse and no studies to our knowledge have focused on the PNS as a regulatory system that may mediate and moderate the relations between marital conflict and cognitive development.

The PNS is an important physiological stress system for "first response" reactions to environmental challenge; withdrawal of PNS influence results in increased metabolic output in numerous organs and systems and is implicated in attentional and social engagement processes (Porges, 2007). In children, PNS activity is most commonly assessed through respiratory sinus arrhythmia (RSA) - high frequency heart rate variability that occurs in phase with respiration (Berntson et al., 1997). RSA typically decreases when responding to stress (reflecting withdrawal of PNS influence) (Berntson et al., 1997). In this study, PNS activity is operationalized by measuring RSA. Change in RSA from baseline to stressors is described as RSA reactivity (RSA-R), with weaker RSA-R indicating smaller than average decreases (or even augmentation) in RSA from baseline and stronger RSA-R indicating greater than average decreases (withdrawal) in RSA.

Disordered child-caregiver attachment (Oosterman, Schipper, Fisher, Dozier, & Schuengel, 2010) and harsh or negative parenting (Calkins, Graziano, Berdan, Keane, & Degnan, 2008) have been linked to weaker RSA-R. More specifically, marital conflict has been linked to lower baseline RSA and weaker RSA-R in infancy (Moore, 2010) and weaker RSA-R in childhood (Katz, 2007), although null findings have also been reported (e.g., El-Sheikh, Harger, & Whitson, 2001). Longitudinal studies have offered some explanations as to how environmental stress may result in maladaptive, "burnout" responses to stress in the PNS. Salomon (2005) found that stronger RSA-R was related to decreased baseline RSA three years later. Similarly, El-Sheikh and Hinnant (2011) found that children who witnessed higher levels of marital conflict and who showed stronger RSA-R evidence decreases in baseline RSA over time, which is suggestive of allostatic load effects on basal functioning. Thus, one developmental explanation for allostasis and allostatic load in the PNS is that while strong RSA-R is adaptive in dealing with acute stress in the short term and is associated with positive adjustment in the context of marital conflict (El-Sheikh et al., 2011; El-Sheikh & Whitson, 2006), excessive or chronic stress and RSA withdrawal in response to stress may result in incomplete recovery to baseline levels. Incremental decreases in baseline RSA over time limits the degree to which RSA can be withdrawn when reacting to stress, and thus appears to be related to weaker RSA-R through developmental, allostatic processes that are cyclical.

Alternatively, it is possible that the process works in reverse order from our hypothesis or that both processes operate simultaneously: weaker RSA-R and behaviors associated with blunted RSA-R, such as externalizing behavior (El-Sheikh et al., 2011), may evoke increased levels of marital conflict, which then predicts adjustment. Studies of children diagnosed with oppositional defiant disorder or attention deficit hyperactivity disorder have found supporting results, that children's behaviors predict future parenting behaviors (Burke, Pardini, & Loeber, 2008; Lifford, Harold, & Thapar, 2008). Especially relevant to the current paper, other researchers have found that conduct problems and dysregulated externalizing behaviors were predictive of increased future marital conflict (Schermerhorn, Cummings, DeCarlo, & Davies, 2007) and probability of divorce (Wymbs, Pelham, Molina, Gnagy, Wilson, & Greenhouse, 2008), which strongly suggests that child behaviors may evoke increased problems in marital relationships. Thus, it seems reasonable to evaluate if RSA-R, as a characteristic that is related to emotional dysregulation and externalizing behavior, predicts future marital conflict. We evaluated this alternate hypothesis in conjunction with our primary hypotheses.

Consistent with evidence linking stronger RSA-R to the ability to react to and engage with the environment, RSA-R is related to attention in infancy (Bornstein & Suess, 2000; Porges, Doussard-Roosevelt, Portales, & Suess, 1994; Suess, Porges, & Plude, 1994). In addition, baseline RSA has been related to better fluid cognitive functioning in children (Elmore-Staton, El-Sheikh, & Buckhalt, 2009). Fluid cognitive/executive functioning is generally considered to encompass working memory, attention shifting, inhibition, decision making, and planning (Carlson, 2005). RSA, both baseline and reactivity, may play a significant role in fluid cognitive performance. In support of this supposition, Marcovitch and colleagues (2010) found that children who exhibit moderate RSA-R (as opposed to unusually weak or strong RSA-R) had better performance on a composite measure of executive functioning tasks tapping memory and inhibitory control. Taken together, these findings suggest the possibility of a biosocial developmental cascade wherein repeated exposure to marital conflict may evoke continued RSA-R, which eventually may lead to burnout and weaker RSA withdrawal, which in turn could lead to compromised cognitive performance. Based on the extant literature, this process may be especially evident for children with lower baseline RSA. We also test the opposite direction of effects: that weaker RSA-R predicts increased marital conflict at later time points. Additionally, we evaluate if high levels of marital conflict in combination with lower baseline RSA and/or weaker RSA withdrawal creates risk for compromised fluid cognitive development.

Our primary study hypotheses were that higher levels of marital conflict at age 8 would be associated with weaker RSA-R at age 9 (controlling for prior RSA-R and baseline RSA), and that weaker RSA-R at age 9 would be associated with poorer fluid cognitive functioning at age 10 (controlling for prior marital conflict and prior cognitive functioning), especially for children with lower baseline RSA. We also tested whether lower baseline RSA and/or weaker RSA-R served as risk factors for poorer development of cognitive functioning in the context of high marital conflict in a latent growth model. We used data collected over three years (T1, T2, T3) spanning middle to late childhood to address our research questions and controlled for possible confounding variables, socioeconomic status (SES) and ethnicity.

Method

Participants

At T1, participants were 251 school-recruited children (123 boys, 128 girls; *M* age = 8.23, *SD* = 0.72) and their parents from the Southeastern U.S. These families were the same participants as those in (El-Sheikh et al., 2011). Second or third grade children from two parent homes in which parents had cohabitated for at least two years were eligible for participation. Consistent with community demographics, the sample was comprised of 64% European (EA) and 36% African- American (AA) children. To reduce potential confounds, children were not eligible to participate if they had an ADHD diagnosis, a developmental or learning disability, or a chronic illness. The median family income was in the $35,000 to $50,000 range, and based on Hollingshead criteria (1975), the sample was diverse in relation to socioeconomic status (SES; *M* raw score = 37.38; *SD* = 9.92). Parents were either married (88%) or had been living together for an extended period (*M* = 10 years, *SD* = 5.67). Because the majority of couples were married, we use the term marital conflict in the paper. The majority of children (74%) lived with both biological parents and 26% lived with the mother and step-father or partner. One year later (*M* = 12.84 months, *SD* = 2.06 months lag between T1 and T2), 217 children (105 boys, 112 girls) and their families participated at T2 (86% retention rate; children's *M* age = 9.31, *SD* = .79). At T3, (*M* = 11.34 months after T2; *SD* = 1.62 months). 183 children (88 boys and 95 girls) and their families participated (85%

retention rate from T2; children's *M* age = 10.28, *SD* = 0.99). At T2, four of the 217 returning couples had dissolved their relationship. By T3, another two couples had dissolved their relationship and two mothers declined to answer the question about relationship status. Reasons for attrition included lack of interest in participating and geographic relocation. All available data were used in our analyses.

Procedure

The present study is part of a larger investigation and only procedures and measures pertinent to the current paper are discussed. At each study wave, assent and consent were obtained in our laboratory, and children completed a physiological assessment session during which baseline RSA and RSA-R was derived. Then, children completed a cognitive assessment test and questionnaires via interview with a trained researcher. All measures were obtained during the three assessments.

During RSA data collection the child was seated and electrodes were attached. A 6-min adaptation period occurred, which was followed by a 3-min baseline. Children were presented with the star tracing task (3-min) during which they trace the outline of a star on a sheet of paper; the star was blocked from direct view and only visible through a mirror. The star-tracing task is a well-established laboratory challenge (Matthews, Rakaczky, Stoney, & Manuck, 1987; Matthews, Woodall, & Stoney, 1990) and performance on this task is related to individual differences associated with family risk and child functioning (El-Sheikh et al., 2011). The task also has some face validity as a method of eliciting physiological reactivity while requiring the use of working memory, inhibitory control, and decision-making.

Measures

RSA Data Acquisition and Reduction—RSA was measured following standard guidelines (Bernston, Cacioppo, & Quigley, 1991). Two electrocardiography (ECG) electrodes were placed on the rib cage approximately 10–15 cm below the armpits, and an additional electrode was placed on the center of the chest to ground the signal. A pneumatic bellows belt was placed around the chest to assess changes in respiration. A custom bioamplifier from SA Instruments (San Diego, CA) was used and the signal was digitized with the Snap-Master Data Acquisition System (HEM Corportation, Southfield, MI). To assess ECG, the bioamplifier was set for bandpass filtering with half power cutoff frequencies of .1 and 1,000 Hz and the signal was amplified with a gain of 500. The ECG signal was processed using the Interbeat Interval (IBI) Analysis System from the James Long Company (Caroga Lake, NY). A pressure transducer with a bandpass of DC to 4,000 Hz was used with the pneumatic bellows to reduce phase or time shifts while measuring respiration. An automated algorithm was used to identify R-waves. The R-wave times were converted to IBI's and resampled into equal time intervals.

The rhythmic fluctuations in heart rate that are accompanied by phases of the respiratory cycle were used to calculate RSA (Grossman, Karemaker, & Wieling, 1991). RSA was determined by the peak-to-valley method and units were in seconds (Bernston et al., 1997). RSA was computed by using the difference in IBI readings from inspiration to expiration onset. Baseline RSA was averaged across the 3-min baseline and RSA-R was computed as a change score (obtained by subtracting baseline RSA from RSA during the star tracing task). Thus, negative RSA-R values indicate RSA withdrawal in response to the task while positive RSA-R values indicate increases in RSA in response to the task.

Marital Conflict—Children's reports on the Destructive Marital Conflict Subscale of the Children's Perception of Interparental Conflict Scale (CPIC; Grych, Seid, & Fincham, 1992)

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were derived. The subscale assess perceptions of the frequency, intensity, and lack or resolution of parents' conflict; coefficient alphas ranged between .82 and .87 across waves.

Cognitive performance—Children were administered selected tests from the Woodcock-Johnson Tests of Cognitive Abilities III (WJ III; Woodcock, McGrew, & Mather, 2001), which is a well-normed battery with excellent reliability, validity, and norms across all ages. The battery of tests was designed to fit the Cattell-Horn-Carroll (CHC) theory of cognitive abilities, a hierarchical theory with three strata: Stratum I comprised of more than 60 specific abilities; Stratum II comprised of 8 broad factors; and Stratum III comprised of one general intelligence (g) factor (Carroll, 1993). CHC theory is a contemporary extension and expansion of what was originally termed Gf-Gc theory based on Cattell's (1943) distinction between fluid (Gf) and crystallized (Gc) intelligence. For the current study, factor scores for fluid cognitive performance were derived from four Stratum I scale scores: Visual Matching, which requires rapid visual scanning and circling of matching numbers; Numbers Reversed, where numbers have to be recalled in reverse order; Auditory Working Memory, where a series of numbers mixed with words are presented, and the words must be recalled first in correct order followed by the numbers in correct order; and Decision Speed, where a series of pictures must be scanned quickly to identify those depicting related concepts. Fluid cognitive performance thus reflects the ability to process information quickly based on both visual and conceptual features, engaging automatic executive functioning. Comparability of test scores over time is a challenge for longitudinal research and the WJ III provides vertically-equated IRT-scaled scores (W scores). These scores reflect an individual's deviation from a criterion score and are thus equitable over time (Rasch, 1960); that is, a score of 500 at age 9 means the same thing as a score of 500 at age 10.

Plan of Analysis

First, we constructed a measurement model to create factor scores from the four fluid cognitive performance scale scores. To address our first research question we fit a cross-lagged panel model to examine the effects of marital conflict on children's RSA-R to the lab challenge, and children's fluid cognitive performance. At each time point we had three observed variables, one for marital conflict, one for RSA-R, and one for the fluid cognitive performance factor score. Each of the three variables at one time point predicts the same variable at the next time point. These estimates illustrate the stability of constructs over ages 8 to 10. In addition, marital conflict, at each time point predicts both RSA-R and fluid cognitive performance at subsequent time points, and RSA-R at each time point predicts fluid cognitive performance at subsequent time points. We also tested the alternate, supplementary hypothesis that RSA-R predicts future marital conflict and fluid cognitive performance. These results illustrate the cross-lagged effects of these constructs over three time periods, one year apart. To test the hypothesis of moderation by baseline RSA, we conducted multiple-group analyses at high and low levels of baseline RSA using a median split and evaluated the regression paths for invariance across the groups according to suggested best practices (Muthen & Muthen, 1998–2010).

Next, a latent growth model was used to assess our second research question of which children were most likely to show compromised development in cognitive performance. Interaction terms between marital conflict and baseline RSA, and RSA-R were created and used to predict the latent intercept and slope of fluid cognitive performance. Factor loadings for the latent intercept and slope variables were set so that the intercept represented initial levels of cognitive performance and the slope represented change over time from the initial levels (Curran, Bauer, & Willoughby, 2004). To facilitate interpretation, all variables in the latent growth model were mean centered and all interactions were plotted using continuous variables at low (−1 *SD*) and high (+1 *SD*) levels of the moderating variables (Whisman & McClelland, 2005).

Missing data were not imputed, rather, available data from all 251 participants were used in analyses by using full information maximum likelihood (FIML) estimation with robust standard errors, which is one of the best methods for dealing with missing data (Acock, 2005). The proportion of data present to estimate each relationship ranged from 70% to 100%. Differences were not found on demographic, predictor, or outcome variables between respondents who were missing data and those who were not. Model fit for the developmental panel and growth model were assessed by RMSEA < .08, a χ^2/df ratio < 5 (Wheaton, Muthen, Alwin, & Summers, 1977), and a CFI > .90 (Bollen, 1989) indicating adequate fit.

Results

Measurement Model

We assessed the measurement model for fluid cognitive performance by building three latent variables representing fluid cognitive performance at each time point. Each latent variable had four indicators from the Woodcock Johnson scales: Visual Matching (VM), Numbers Reversed (NR), Auditory Working Memory (AWM), and Decision Speed (DS). We allowed for several considerations based on the structure of the WJ-III and the repeated measures nature of the data. The best fitting model most consistent with the WJ-III's Stratum II factor scores allowed for some of the residual variances of the indicators to covary. Specifically, VM and NR, NR and AWM, and VM and DS were allowed to covary within time points because each pair composes a Stratum II factor score. Correlations between these pairs, however, were constrained to be equal across time points (e.g., the covariance between VM and NR were set to be equivalent at Time 1, 2, and 3). Additionally, each indicator was allowed to covary with its counterparts at other time points but, again, these correlations were constrained to be equal (e.g., VM at Time 1 was allowed to covary with VM at Times 2 and 3 but each correlation was set to be equivalent at Times 1, 2, and 3). We felt that this model allowed for a parsimonious solution while also taking into account the theoretical and empirical structure of the WJ-III. Model fit was adequate; RMSEA = .09, χ^2/df = 3.01, CFI = .91. Table 1 displays the factor loadings for the measurement model.

Preliminary analyses

Descriptive statistics and correlations among study variables are presented in Table 2. Repeated measures were generally correlated within domains. RSA-R at age 8 was positively related to RSA-R at age 9 but not age 10. Additionally, baseline RSA was negatively related to RSA-R within time points, meaning that children with higher baseline RSA show greater RSA withdrawal to the stress task. SES was positively related to fluid cognitive performance at age 8. Finally, European American ethnicity was associated with lower baseline RSA at ages 8 and 9, higher SES, and higher fluid cognitive performance scores at all time points.

Developmental Cross-lagged Model

Figures 1 illustrates the cross-lagged model for the effects of marital conflict on RSA-R and fluid cognitive performance over time for children with lower and higher baseline RSA. The model fit the data adequately (RMSEA = .06; χ^2/df =1.82; CFI = .71). Autoregressive effects of marital conflict over time were significant and equivalent for both groups. Autoregressive effects of RSA-R from age 8 to 9 were significant for children with higher baseline RSA but not children with lower baseline RSA while effects from age 9 to 10 were

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significant for children with lower baseline RSA but not for children with higher baseline RSA. All autoregressive effects for fluid cognitive performance were significant for children with lower baseline RSA while fluid cognitive performance at age 8 was related to performance at age 9. The autoregressive effect for fluid cognitive performance was not significant from age 9 to 10 for children with higher baseline RSA.

Regarding our primary hypotheses, marital conflict at age 8 was positively related to RSA-R at age 9 for children with lower baseline RSA, meaning that children who experienced higher levels of marital conflict showed weaker RSA withdrawal one year later, while there was no relation for children with higher baseline RSA. Marital conflict and RSA-R were not directly related to fluid cognitive performance at any of the later time points for either group of children. Our alternate hypothesis, that RSA-R may predict future marital conflict, was not supported at any of time points.

Latent Growth Model

Unconditional growth—The unconditional model fit the data adequately (RMSEA = .09; χ^2/df =3.12; CFI = .95). Fluid cognitive performance increased significantly over time at an average of 14.7 points per year. Initial levels of fluid cognitive performance were positively correlated with the slope, $r = .31$, $p = .05$, indicating that children with higher initial levels of fluid cognitive performance show greater increases in performance over time. There was limited variability in initial levels of fluid cognitive performance, $\sigma^2 = 12.66$, $p = .32$, but significant variability in the slope, $\sigma^2 = 8.97$, $p = .01$, indicating that children showed different rates of change over time.

Conditional growth—Data for the conditional growth model are presented in Table 3. Non-nested fit indices, the Bayesian information criterion (BIC) and the Akaike information criterion (AIC) comparing the unconditional and conditional growth models indicated that adding predictors to the models improved model fit. BIC and AIC in the unconditional model was 281.2 and 287.6, respectively. For the conditional model the BIC and AIC was 237.7 and 241.3, respectively. European American children had higher initial levels of fluid cognitive performance, as did children from higher SES families. RSA-R was positively related to initial levels of fluid cognitive performance, but this relation was qualified by a significant interaction between baseline RSA and RSA-R on both the intercept and slope (Figure 2). The hypothesized three-way interaction between marital conflict, baseline RSA, and RSA-R was not significant but the two-way interaction between baseline RSA and RSA-R indicated that children with lower baseline RSA and stronger RSA-R (greater withdrawal) had the lowest initial levels of fluid cognitive performance but showed increases over time in fluid cognitive performance that were similar to most other children. Although all slopes were significantly different from zero, children with lower baseline RSA and weaker RSA-R showed a noticeably shallower slope (represented by triangles in the figure). The scale on the figure makes comparisons at any one time point difficult, but at age 10 the predicted difference between children with lower baseline RSA and weaker RSA-R and most other children is approximately five points, or almost one standard deviation. In total, the predictors accounted for 39% of the variance in initial levels of fluid cognitive performance and 7% of the variance in its slope; the significant interaction accounted for 19% of the variance in the intercept and 6% of the variance in the slope. It should be noted, however, that the amount of variance accounted for in initial levels of fluid cognitive performance may be overestimated due to its limited variability.

Discussion

Consistent with an allostatic load perspective (Juster et al., 2010; McEwen & Stellar, 1993), we examined marital conflict, baseline RSA, and RSA-R as predictors of fluid cognitive performance in cross-lagged and latent growth models during middle to late childhood. We expected that (1) Cross-lagged models of allostatic load would show that marital conflict, as one significant source of environmental stress, would be related to poorer physiological regulation as indicated by weaker RSA-R, and that weaker RSA-R would be related to poorer fluid cognitive performance, especially for children with lower baseline RSA; and (2) Latent growth models would show that high levels of marital conflict in combination with lower baseline RSA and/or weaker RSA-R would predict poorer development of children's fluid cognitive performance.

Although many studies have found robust relations between martial conflict and children's academic performance (Kitzmann et al., 2003), only a few studies have investigated the variables that may explain these relations (e.g., Ghazarian & Buehler, 2010) or evaluated marital conflict in relation to cognitive versus academic performance. In contrast to studies linking marital conflict to academic performance, we did not find associations between marital conflict and fluid cognitive function. There are many potential explanations for our null effects. It is possible that marital conflict more directly affects academic performance by disrupting children's study schedules and opportunities to solidify crystallized intelligence while it may affect fluid intelligence indirectly through physiological systems responsible for the regulation of attention and problem solving. Building on the sparse literature in this area, the cross-lagged allostatic load models partially supported our hypotheses and indicated that even after controlling for autoregressive effects, higher levels of marital conflict at age 8 predicted weaker RSA-R one year later for children with lower, but not higher, baseline RSA. The alternate model evaluating evocative effects of RSA-R on future marital conflict was not supported. Weaker RSA-R at age 9 did not predict fluid cognitive performance at age 10 for children with high or low baseline RSA. Although speculative, the pathway from marital conflict to fluid cognitive performance may be indirect, and operate through allostatic processes on physiological and neurological systems of self-regulation. While RSA-R did not predict individual differences in *levels* of fluid cognitive performance at age 9 or 10 (at either high or low levels of baseline RSA), individual differences in change over time in fluid cognitive performance were predicted, which offered some support for our second hypothesis. The latent growth model assessing development of fluid cognitive performance was predicted by the interaction between baseline RSA and RSA-R but the three-way interaction including marital conflict was not significant. The most notable findings were for children with lower baseline RSA and weaker RSA-R; these children exhibited notably shallower slopes of change in fluid cognitive performance across time. Thus, in future research it is important to consider how environmental stressors contribute to allostatic shifts in basal levels of RSA as well as basal levels of other physiological regulatory systems.

By evaluating the results of the cross-lagged and latent growth models together, we found some support for the allostatic load model. High levels of environmental stress predicted compromised stress response system function (weak RSA withdrawal for children with lower baseline RSA). This combination of lower baseline RSA and weak RSA-R predicted poorer developmental trajectories of fluid cognitive performance. In future studies it may be useful to investigate relations between environmental stress, physiological regulation, and cognitive function with more specific cognitive measures. For example, speed of mental processing, working memory, and fluid intelligence have been found to operate in a developmental cascade such that individual differences in speed affect growth of working memory and working memory growth affects broader aspects of fluid intelligence (Fry and Hale, 1996; Kail, 2007).

Neuropsychological studies shed light on how stressors contribute to allostatic load in the brain and how disrupted brain development translates into suboptimal cognitive, emotional, and behavioral development (Bremner & Vermetten, 2001; Mead, Beauchaine, & Shannon, 2010; Teicher et al., 2003). The prefrontal cortex is involved in parasympathetic withdrawal in contexts involving attention shifting, working memory, and problem solving and has an extended developmental period that is highly sensitive to stress (Mead et al., 2010). A likely pathway of developmental cascades involves environmental stress affecting development of the prefrontal cortex, which is at least partially responsible for RSA withdrawal during fluid cognitive performance. For example, adolescents who experienced high levels of early life stress, operationalized through adoption due to early caregiver maltreatment and neglect, showed longer response times during a measure of cognitive inhibitory control of prepotent responding and greater activation in the anterior cingulate, inferior prefrontal cortex, and striatum, areas of the brain tied to performance on cognitive control measures (Mueller et al., 2010). Morphological differences between control children and maltreated children also exist; maltreated children exhibit smaller prefrontal cortex volumes and less white matter (De Bellis et al., 1999; 2002). We did not measure any aspect of central nervous system functioning in this study and integrating such measures with peripheral nervous system measures is an important direction for future research.

Some strengths of the study include the non-overlapping assessment methods; children reported on marital conflict, PNS functioning (baseline RSA and RSA-R) was collected through standardized procedures and cognitive performance was assessed via neurocognitive measures administered by trained researchers. We used recommended statistical practices to test our hypotheses in cross-lagged developmental and latent growth models and found support for the allostatic load perspective.

Several limitations of this study should be noted. First, findings are based on a community sample in which children exhibited cognitive performance within a normative range and, generally speaking, were from families with normative levels of marital conflict. Samples drawn from families with more extreme levels of marital conflict may have yielded different patterns of findings. Second, we evaluated allostatic changes in one branch of the ANS and used one laboratory task; it is possible that some children did not find the task to be taxing or that our aggregate of RSA across time obscured individual differences in change over time during the task, either of which would contribute to measurement error. Third, although completion of the star-tracing task certainly involves some use of working memory (child is tracing the star using a mirror image as a guide), processing speed (being able to quickly adjust action to feedback from the mirror image), and cognitive efficiency and thus has some face validity, it also taps some aspects of higher order cognition (error detection and correction, inhibitory control). In future studies it might be advisable to more closely match the task in which physiological functioning is recorded to the dependent variables of interest. Finally, allostatic shifts in physiological functioning may unfold over a significant period of time and certain periods of development, such as the transition to adolescence, may be especially sensitive to environmental cues and allostatic shifts (Romeo, 2010; Steinberg, 2007). Although we found evidence for allostatic load on the development of cognitive performance in middle and late childhood, further research focused on especially sensitive periods of development is clearly needed.

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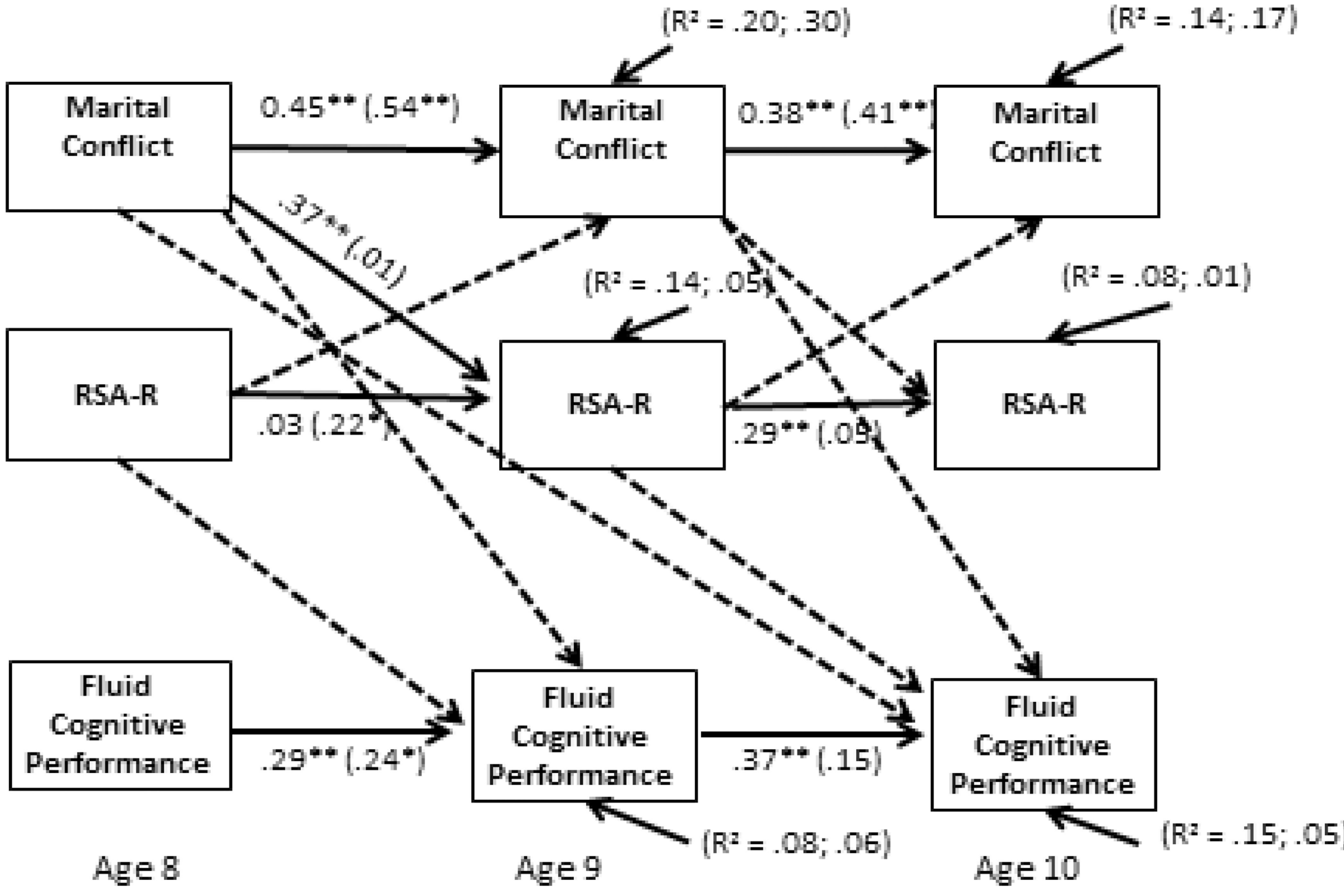

Figure 1.
Cross-Lagged Model for Fluid Cognitive Performance at Low and High Levels of Baseline RSA. Estimates are standardized regression coefficients. Coefficients for children with low baseline RSA are given first (without parentheses) and coefficients for children with high baseline RSA are given second (within parentheses). Similarly, R^2 values for children with low baseline RSA are given first, followed by values for children with high baseline RSA. Non-significant paths for both groups (low and high baseline RSA) are illustrated with a dotted line.

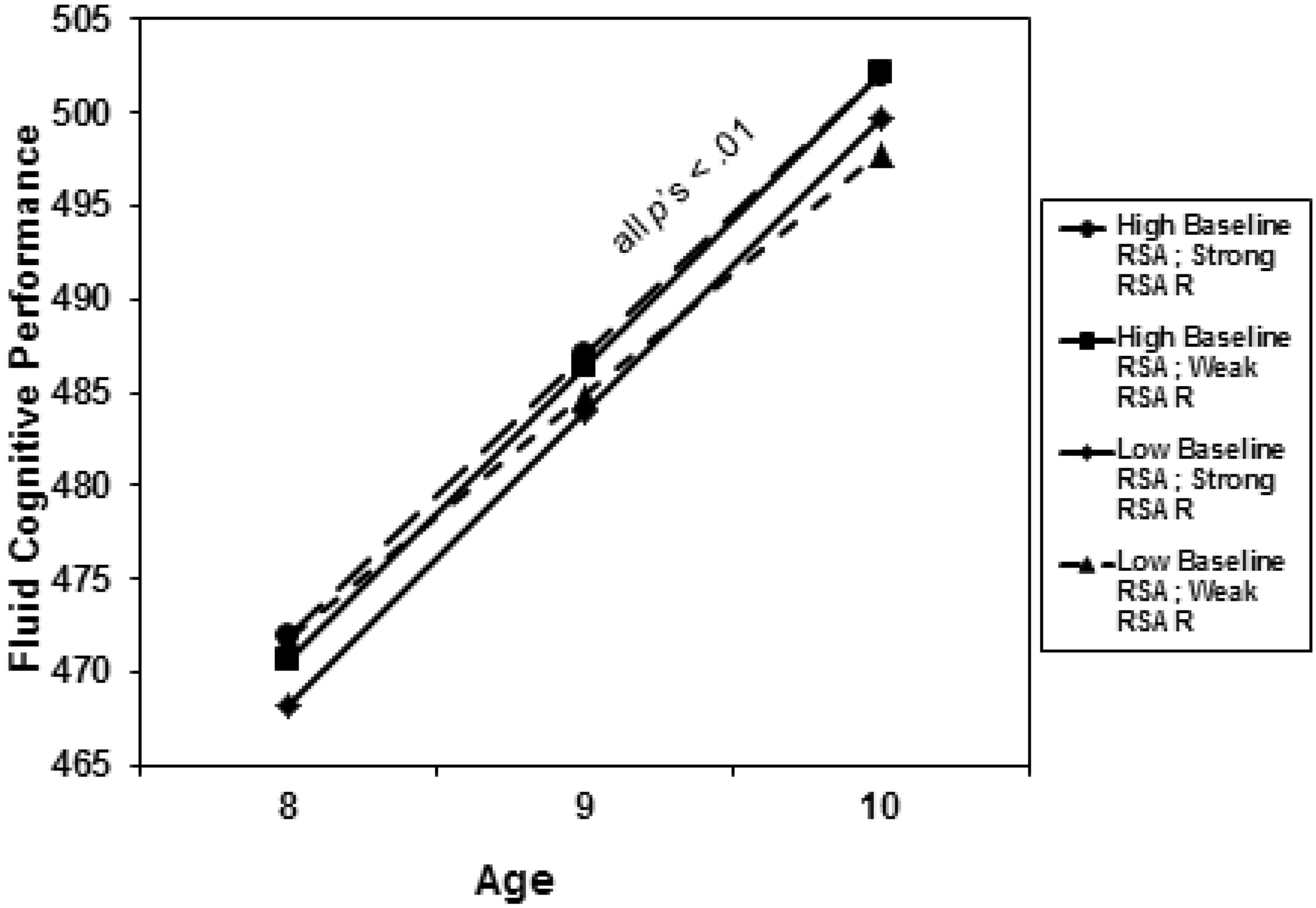

Figure 2.
Latent Growth Model of Cognitive Performance Predicted by the Interaction Between Baseline RSA and RSA-R.

Table 1

Standardized Factor Loadings for WJ-III Scales on Latent Measures of Fluid Cognitive Performance

	Age 8 Fluid Cognitive Performance	Age 9 Fluid Cognitive Performance	Age 10 Fluid Cognitive Performance
Visual matching	.50	.46	.52
Numbers reversed	.43	.42	.52
Auditory working memory	.67	.63	.68
Decision speed	.61	.57	.62

Table 2

Means, Standard Deviations, and Correlations Among Study Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Marital conflict 8	-													
2. Marital conflict 9	.48**	-												
3. Marital conflict 10	.30**	.38**	-											
4. Baseline RSA 8	−.02	−.02	−.03	-										
5. Baseline RSA 9	−.05	−.05	−.04	.63**	-									
6. Baseline RSA 10	.01	−.05	−.01	.56**	.65**	-								
7. RSA reactivity 8	.01	.02	.05	−.50**	−.14	−.11	-							
8. RSA reactivity 9	.12	.01	−.05	−.22**	−.43**	−.26**	.21**	-						
9. RSA reactivity 10	−.01	−.01	.04	.01	−.04	−.41**	−.04	.15*	-					
10. Fluid cognition 8	−.05	−.04	−.11	−.01	.09	−.05	−.02	−.15*	−.01	-				
11. Fluid cognition 9	.02	−.01	−.04	−.03	−.04	−.01	.06	.08	−.09	.26**	-			
12. Fluid cognition 10	.02	−.01	−.01	.02	−.01	−.08	.02	−.06	.03	.36**	.28**	-		
13. SES	−.04	−.09	−.12	−.08	−.08	−.16*	−.03	−.04	.04	.13*	.06	.09	-	
14. Ethnicity	−.05	−.03	−.10	−.28**	−.16*	−.11	.12	.05	−.10	.16*	.21**	.17*	.21**	-
M	.78	.57	.69	.15	.17	.16	−.03	−.03	−.03	470.85	491.94	501.78	37.38	.65
SD	.77	.70	.82	.08	.08	.09	.05	.06	.05	9.78	8.34	7.79	9.91	.48

Note. Ethnicity is coded as 1 for European Americans and 0 for African Americans.

* $p < .05$;

** $p < .01$.

Table 3

Latent Growth Model Results for Prediction of Fluid Cognitive Performance From Ages 8 to 10.

	Intercept			Slope		
	B	**SE**	β	**B**	**SE**	β
Fluid cognitive performance	479.59	.58		14.68	.35	
SES	.10	.05	.21*	−.02	.04	−.07
Ethnicity	2.74	1.23	.27*	−.07	.79	−.01
Marital conflict	−.69	.92	−.12	.29	.59	.07
Baseline RSA	−2.22	8.82	−.04	4.27	5.63	.10
RSA reactivity	25.53	14.85	.28*	−5.45	9.50	−.08
MC×RSAB	.15	11.54	.01	−5.37	7.35	−.09
MC×RSAR	−10.29	17.80	−.11	1.95	11.73	.03
RSAB×RSAR	−466.07	121.38	−.58**	151.01	77.69	.26*
MC×RSAB×RSAR	66.86	193.42	.06	−55.39	123.59	−.07

Note. Ethnicity is coded as 1 for European Americans and 0 for African Americans.

* $p < .05$;

** $p < .01$.