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Biological Sensitivity to Context Moderates the Effects of the Early Teacher-Child Relationship on the Development of Mental Health by Adolescence

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Abstract

The moderating effects of biological sensitivity to context (physiological and behavioral stress reactivity) on the association between the early teacher-child relationship and the development of adolescent mental health problems were examined in a community sample of 96 children. Grade 1 measures of biological sensitivity to context included physiological (i.e., slope of mean arterial pressure across a 20-30 min stress protocol) and behavioral (i.e., temperamental inhibition/disinhibition) markers. Grade 1 measures of the teacher-child relationship included positive (i.e., closeness) and negative (i.e., conflict) qualities. Mental health symptoms were assessed at Grades 1 and 7. Results of a multiple regression analysis indicated substantial association of the teacher-child relationship with the development of adolescent mental health symptoms, especially for more reactive children. In addition to teacher-child relationship main effects, all four reactivity $\times$ teacher-child relationship interaction terms were statistically significant when controlling for Grade 1 symptom severity, suggesting that *both* physiological *and* behavioral reactivity moderate the association of *both* adverse *and* supportive aspects of the teacher-child relationship with Grade 7 symptom severity over and above Grade 1 severity. There were important differences depending on which stress reactivity measure was considered. The importance of these findings for recent theoretical arguments regarding biological sensitivity to context and differential susceptibility is discussed.

Keywords

temperament; autonomic reactivity; teacher-child relationship; biological sensitivity to context; differential susceptibility

Introduction

Children's differential susceptibility to rearing experiences – the idea that individuals with particular characteristics are more responsive to both adverse and supportive contextual influences – has attracted increasing research interest (Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2007; Boyce & Ellis, 2005; Ellis & Boyce, 2008; Ellis, Essex, & Boyce, 2005; Pluess & Belsky, 2009). Most supporting empirical work has focused on the

developmental effects of early rearing experiences with parents, prior to primary school entry, and the moderating influences of children's biological sensitivity to context, operationalized as *either* physiological *or* behavioral responses to environmental adversities. Previous findings generally suggest that children who are more physiologically or behaviorally reactive exhibit more internalizing and externalizing symptoms and poorer adaptive outcomes when in adverse, or unsupportive, contexts (Colder, Lengua, Fite, Mott, & Bush, 2006; Feldman, Greenbaum, & Yirmiya, 1999; Kochanska, Aksan, & Joy, 2007) and lower symptom levels and more positive outcomes when in supportive contexts (Blair, 2002; Crockenberg, 1981; Denham et al., 2000; Feldman et al., 1999; Klein Velderman, Bakermans-Kranenburg, Juffer, & Van Ijzendoorn, 2006). However, little is known about the joint influences of child physiological and behavioral reactivity, along with school-age, non-parental rearing experiences, on the development of mental health by adolescence.

From an evolutionary perspective, the success of different behavioral strategies is contingent upon the physical, economic, and socio-emotional demands of each individual's environmental context (Crawford & Anderson, 1989), and thus strategies that promote success in some contexts may lead to failure in others. The Biological Sensitivity to Context (BSC) model (Boyce & Ellis, 2005) posits that variation in susceptibility to environmental influence—instantiated through reactivity of the stress response systems—has been maintained by natural selection because this variation promotes success and failure in different social contexts. Within the BSC model, greater early stress exposure up-regulates general stress reactivity and increases an individual's capacity and tendency to detect and respond to environmental danger. Conversely, exposure to a highly nurturing context during childhood is also thought to up-regulate stress reactivity, thus increasing the individual's ability to benefit from additional social resources and support. By contrast, exposure to childhood environments that are not extreme in either direction down-regulates stress reactivity, buffering individuals against the chronic stressors encountered in a world that is neither highly threatening nor consistently safe (Boyce & Ellis, 2005).

Central to the BSC model is the assumption that individuals with particular qualities are likely to be not only more susceptible to adversity, but also more sensitive to enriching experiences. Supporting this position, physiological markers of heightened stress reactivity (Boyce et al., 1995b; Boyce et al., 2006), including genetic markers often considered indicative of vulnerability to environmental risk (Belsky et al., 2009), have also been associated with adaptive outcomes under supportive conditions. Thus, heightened stress reactivity likely reflects an increased neurobiologically mediated sensitivity to context (i.e., *biological sensitivity to context*). Importantly, such sensitivity increases the potential for developing negative health outcomes under conditions of adversity and positive outcomes under conditions of support and nurturance (Boyce et al., 1995b; Boyce & Ellis, 2005; Ellis et al., 2005).

While not presupposing that stress reactivity is a conditional evolutionary adaptation, Belsky and colleagues (Belsky et al., 2007; Belsky et al., 2009; Pluess & Belsky, 2009) have, like BSC theory, argued that some individuals may be differentially susceptible to both supportive and adverse environmental influences, “for better *and* for worse” (Belsky et al., 2007). Unlike diathesis-stress models, which treat reactivity as a risk factor for negative outcomes, both BSC and Belsky's and colleagues' work suggest that consideration of differential susceptibility to adverse and supportive contextual influences may more fully explain why some highly reactive children develop problems when other similarly reactive children fail to do so or even thrive (Belsky & Pluess, 2009; Ellis & Boyce, 2008).

Biological Sensitivity to Child Rearing

Biological sensitivity to context in children may dispose them to be sensitive to both the harmful effects of adverse contextual factors and the benefits of supportive contextual characteristics (Calkins, Blandon, Williford, & Keane, 2007; Lengua, Bush, Long, Kovacs, & Trancik, 2008; Obradovic, Bush, Stamperdahl, Adler, & Boyce, 2010; Pauli-Pott, Mertesacker, & Beckmann, 2004; Pluess & Belsky, 2009). This research has focused primarily on early parenting and has examined differential susceptibility across various types of samples and using various measurement strategies and conceptual frameworks. On the one hand, negative parenting behaviors (e.g., maternal hostility, power assertion, psychological control) have been associated with a range of poor outcomes among children with temperaments characterized by negative emotionality, typically operationalized as difficult temperament, irritability, proneness to frustration/anger, impulsivity, fearfulness, or inhibition (Kochanska et al., 2007; Lengua, 2008; Lengua, Wolchik, Sandler, & West, 2000; Leve, Kim, & Pears, 2005; Morris et al., 2002; Van Zeijl et al., 2007). On the other hand, positive parenting behaviors (e.g., maternal sensitivity, positive discipline, secure parent-child relationships) have been linked to better outcomes among children who show more negative emotions (Gilissen, Bakermans-Kranenburg, Van Ijzendoorn, & van der Veer, 2008; Mesman et al., 2009; Van Zeijl et al., 2007; Velderman, Bakermans-Kranenburg, Juffer, & Van Ijzendoorn, 2006). Evidence of differential susceptibility to parental behaviors also includes two recent analyses from the NICHD Study of Early Child Care, which found that – compared to other study participants – children who had been temperamentally difficult infants showed the worst outcomes if they experienced poor parenting and the best outcomes if parenting was excellent (Bradley & Corwyn, 2008; Stright, Gallagher, & Kelley, 2008). Further, evidence from animal models suggests that highly reactive individuals are more sensitive to both the negative consequences of suboptimal parenting and the benefits of highly nurturant care-giving (e.g., (Suomi, 1997).

We previously demonstrated that reactive children are more sensitive to early parental behavior across multiple measures of reactivity (Boyce et al., 2006). Unlike much research in this area that focuses on maternal parenting, our prior analyses focused on the interaction of father involvement during infancy with children's physiological and behavioral reactivity at age 7 years. We found that low father involvement, combined with high reactive mean arterial pressure (MAP), high reactive salivary cortisol, or low temperamental inhibition/high disinhibition, contributed to later high symptom severity (i.e., combined internalizing and externalizing) at age 9, while strong father involvement for reactive children buffered against high symptom levels. Further, a three-way interaction indicated that the children most at risk for high symptom levels were those with high MAP who experienced low paternal involvement and high maternal depression symptoms during infancy. Thus, the most reactive children – whether indexed by physiological or behavioral reactivity – were most susceptible to the effects of both adverse and supportive early parenting.

In addition to parenting, a few investigations have considered early child care as a context to which reactive children may be sensitive. Most notable is a recent study by Pluess and Belsky (2009). Using data from the NICHD Study of Early Child Care, they found that childcare quality – as indexed by caregiver sensitivity – interacted with infant temperament to predict children's behavior problems and social competence. Specifically, when caregiver sensitivity was low, children who had been temperamentally difficult infants exhibited low levels of social competence at 54 months and high levels of behavior problems at 54 months and in kindergarten; conversely, when caregiver sensitivity was high, children who had been temperamentally difficult infants later exhibited high levels of social competence and low levels of behavior problems; and finally, caregiver sensitivity had no effect on outcomes for children who were not temperamentally difficult during infancy. Considering these findings alongside those of Bradley and Corwyn (2008) and Stright et al. (2008), Belsky and Pluess

(2009) conclude that “infants with difficult temperaments appear more affected by the quality of care they experience – both in and out of the home – than do other young children” (p. 401). Several smaller studies also suggest that reactive children may be sensitive to extra-familial caregiving. Being in child care for 30 or more hours a week (Crockenberg & Leerkes, 2005) and in greater numbers of care arrangements (De Schipper, Tavecchio, Van Ijzendoorn, & Van Zeijl, 2004) have been associated with elevated levels of internalizing symptoms among temperamentally reactive young children. In addition, young children high in temperamental social fear exhibited low levels of peer competence when childcare quality was low and high levels of peer competence when childcare quality was high (Volling & Feagans, 1995).

The research summarized above suggests important ways that children's experiences of parenting and child care may interact with their stress reactivity to influence child outcomes. However, work on biological sensitivity to context has received little attention in studies of children's experiences with teachers following the transition to primary school (Myers & Pianta, 2008). Nevertheless, a vast literature has demonstrated that the quality of the relationship between child and teacher is important to numerous childhood outcomes (Baker, Grant, & Morlock, 2008; Birch & Ladd, 1997; Burchinal, Peisner-Feinberg, Pianta, & Howes, 2002; Curby, Rimm-Kaufman, & Ponitz, 2009; Ladd & Burgess, 2001; Myers & Pianta, 2008; Pianta & Stuhlman, 2004). Longitudinal studies have linked the teacher-child relationship in the early school years with children's academic and socio-emotional functioning in later elementary and even middle school years (Brendgen, Wanner, & Vitaro, 2006; Hamre & Pianta, 2001; Pianta, Steinberg, & Rollins, 1995). Generally, greater conflict and (sometimes) less closeness in the teacher-child relationship have been associated with externalizing problems, whereas less teacher-child closeness has been connected in some studies to internalizing problems (Birch & Ladd, 1998; Buyse, Verschueren, Doumen, Van Damme, & Maes, 2008; Henricsson & Rydell, 2004; Pianta & Stuhlman, 2004). In our own prior work (Silver, Measelle, Armstrong, & Essex, 2005), we used a person-centered approach and found that higher levels of teacher-child conflict in kindergarten increased the odds of being in “chronically high” and “low but increasing” (versus “stably low”) externalizing groups.

Although the possible combined effects of teacher-child-relationship quality and children's stress reactivity on child outcomes have received very little attention, there is some evidence indicating that the teacher-child relationship (Brendgen et al., 2006; Meehan, Hughes, & Cavell, 2003), and more broadly, observations of teacher supportiveness and the classroom environment (Gazelle, 2006; Hamre & Pianta, 2005), can have the largest impact on children who are most at risk for negative outcomes. For example, Hamre and Pianta (2001) found that conflict in the kindergarten teacher-child relationship was associated with the highest levels of later disciplinary infractions at school, especially among children with behavior problems in kindergarten. Ladd and Burgess (2001) found that – in addition to teacher-child conflict and closeness functioning as general risk and protective factors (respectively) across kindergarten and grade 1 – teacher-child conflict increased the likelihood of maladjustment primarily among aggressive children. Other studies have focused on the influences of teacher-child closeness. For example, Baker (2006) (Baker, 2006) found that elementary school children with high degrees of emotional/behavioral problems who experienced a close relationship with a teacher evidenced significantly higher levels of positive school outcomes (academic, classroom adjustment, social skills) than children with comparable levels of emotional/behavioral problems who experienced a lack of closeness with their teachers. Our own work (Silver et al., 2005) demonstrated that teacher-child closeness was most beneficial for children with externalizing problems. In regression terms, children who had the highest externalizing intercepts across the early school years experienced the largest decreases in externalizing slope when teacher-child

closeness was high in kindergarten; that is, for children with externalizing problems, high closeness with teachers was associated with the largest declines in externalizing over time, while low closeness was associated with the growth of externalizing.

Taken together, the extensive evidence of the role that early teacher-child relationships can play in children's development, combined with findings on highly reactive children's sensitivity to parental and non-parental contexts, suggest that the levels of conflict and closeness in the teacher-child relationship in the early school years may also have significant influences on the developmental outcomes of reactive children. However, no studies have addressed this important question.

Present Study

We prospectively examined the influences of the teacher-child relationship at Grade 1 (age 7) on the development of child mental health symptoms by Grade 7 (age 13), and the potential moderating effects of child biological sensitivity to context at Grade 1. We chose to focus on the Grade 1 teacher-child relationship primarily because it parallels previous studies and captures the child's early experiences during the transition to primary school before relations with teachers have been well-established. Grade 7 was selected for assessing outcomes primarily because, in addition to representing the early adolescent period when mental health problems begin to increase, it corresponds to the transition to middle school (more than 80% of children in the present study changed schools), with accompanying changes in teachers and the broader school climate and structure. To address questions regarding differential susceptibility to both adverse and supportive school experiences, the levels of conflict and closeness in the teacher-child relationship were considered. Based on the previous research summarized above, adversity in the teacher-child relationship was conceptualized as either a relationship characterized by high levels of conflict or a suboptimal relationship characterized by a lack of closeness; a supportive relationship was conceptualized as either a relationship characterized by high levels of closeness or a relationship without conflict. To address questions regarding possible differences in the moderating influences of physiological and behavioral reactivity, one measure was considered from each domain to assure that the variable to subject ratio was adequate for the relatively small sample size ($N = 96$) of the present study. For the physiological reactivity domain, we focused on the autonomic nervous system (ANS) since it has received more attention than the hypothalamic-pituitary-adrenal system in studies of differential susceptibility (Belsky & Pluess, 2009); and within the ANS, mean arterial pressure (MAP) was chosen because it is an integrated measure of that system. For the behavioral reactivity domain, temperamental inhibition/disinhibition was selected for its coverage of the most commonly studied temperamental characteristics (reviewed above) in previous research on differential susceptibility (Belsky & Pluess, 2009). Consistent with BSC and differential-susceptibility models, we hypothesized that children who were more reactive would develop the most severe Grade 7 mental health symptoms if they had adverse experiences with their Grade 1 teachers, and the fewest mental health symptoms if they had more supportive experiences with their Grade 1 teachers. Grade 7 symptom levels in children low in reactivity were expected to be similar, regardless of Grade 1 teacher-child relational quality. Potential differences by child sex were also explored.

Method

Participants

A sub-sample of 120 children and their parents and teachers was recruited from the Wisconsin Study of Families and Work (WSFW) in 1998 when children were in grade 1 (7 years of age). Using scores on the MacArthur Health and Behavior Questionnaire (HBQ)

(Boyce et al., 2002; Essex et al., 2002) from mother- and teacher-report one year prior (in kindergarten), children were selected with the goal of a sub-sample divided roughly evenly between children high and low in reported mental health symptoms and, among symptomatic children, between those high on internalizing, externalizing, or both. The WFSW, from which the sub-sample was drawn, comprises 570 pregnant women and their partners who were recruited from prenatal clinics in and around Madison and Milwaukee, Wisconsin, to participate in a study of maternity leave and health outcomes. Eligible female participants were over the age of 18, in the second trimester of pregnancy, living with the baby's biological father, and either employed or a full-time homemaker (see (Hyde, Klein, Essex, & Clark, 1995) for details). Of those eligible, 75% agreed to participate. Demographics were collected during the second trimester of pregnancy, and data for the present study were obtained at Grades 1 and 7. In Grade 7, 113 (94%) of the 120 sub-sample participants continued in the study; of these 113, 96 had complete data on the measures of interest and were included in the present analyses. The 17 participants with incomplete data were missing Grade 1 teacher-report ($n = 4$), MAP ($n = 6$), Grade 7 teacher-report ($n = 8$), and/or Grade 7 mother-report ($n = 1$) data.

At recruitment, the 96 mothers ranged in age from 22-41 years ($Mdn = 29$). Three percent of mothers had less than a high school education, 12% were high school graduates or equivalent, 28% had some post-secondary education or training, 38% were college graduates, and 18% had post-baccalaureate schooling and/or degree; fathers' education levels were comparable. Nearly all couples were married (97%); 43% were first-time parents; and 9% were ethnic minorities. Family incomes ranged from less than \$10,000 to \$120,000 ($Mdn = \$50,000$). There were no statistically significant differences between these demographic characteristics of the 96 families and the remainder of the 570 original families. There was a significant difference in the percentage of girls in the 96 families compared to that in the remainder (61% versus 50%, respectively; $\chi^2 = 4.49$, $df = 1$, $p = .034$). Possible differences in the level of mental health symptoms at Grade 1 and Grade 7 between the 96 and the remaining participants of the original 570 children were also examined. No significant differences in mental health symptoms were observed at either grade between these groups.

Measures

Teacher-child relationship—During the spring of Grade 1, teachers completed a phone interview that included rating conflict and closeness in their relationship with the child using a version of the Student-Teacher Relationship Scale [STRS; (Pianta, 1996; Pianta et al., 1995)]. STRS items are rated on a 5-point scale (1 = Definitely does not apply, 5 = Definitely applies). In the present study, scores for conflict (e.g., “When [this child] arrives in a bad mood, you know the two of you are in for a long and difficult day”) and closeness (e.g., “You share an affectionate, warm relationship with [this child]”) were constructed as the mean of the 5 items in each area that were included in the MacArthur HBQ (Boyce et al., 2002; Essex et al., 2002). Internal consistency was good for both scales ($\alpha = .87$ for conflict and .83 for closeness).

Physiological reactivity—A four-hour assessment was conducted by a trained female research assistant (advanced undergraduate or baccalaureate) in the summer following grade 1 to acquire physiological and behavioral data. Approximately halfway through the home visit, children's autonomic reactivity was tested using a 20-30 minute protocol completed in a van stationed outside the family's home (Alkon et al., 2003; Boyce et al., 2001). Children were monitored using thoracic and precordial electrodes and a Dinamap cardiac monitor (Model 1846 SX by Critikon, Inc.) Physiological response parameters employed in the protocol included mean arterial pressure (MAP), measured with the Dinamap monitor at the

point of maximal oscillatory amplitude (Park & Menard, 1987), which provided a single integrated measure of autonomic reactivity. The research assistant administered a session that included four mildly stressful standardized challenges in the following sequence: 1) social task, i.e., a structured child interview modified from the Gesell School Readiness Screening Test (Carlson, 1985); 2) cognitive task, i.e., digit span recitation from the Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983); 3) physical task, i.e., 2-3 drops of concentrated lemon juice placed on the child's tongue; and 4) emotional task, i.e., two video segments (Eisenberg et al., 1988) chosen to elicit mild fear (a train-chase scene from the film *Stand By Me*) and sadness (a paternal death scene from the film *The Champ*). The set of challenge tasks was preceded and followed by the research assistant reading aloud from relaxing, age-appropriate picture books for 2 min, and a 1-min quiet rest period occurred between the cognitive and physical tasks.

Given that this protocol occurred in the middle of an intensive, four-hour assessment, we anticipated that conventional change (Δ) scores might not adequately represent the dynamics of autonomic response within this study context. In situations where achieving resting values is difficult, more predictive reactivity measures might be derived from a multidimensional response profile, encompassing measures such as maximal response intensity, response variability, or the up- or down-regulatory slope of measures over time (Boyce, Alkon, Tschann, Chesney, & Alpert, 1995a). In our data, change scores for MAP indeed showed minimal shifts from resting to task levels, and inspection of raw data suggested that neurobiological reactivity would be best operationalized as the slope of task measures over the course of the four challenge epochs. Positive MAP slope scores denoted increasing autonomic activation over the 20-30 minute protocol.

Behavioral reactivity—Children's behavioral reactivity was assessed with home administration of the Temperament Assessment Battery for Children (Child-TAB; (Goldsmith, Lemery, & Essex, 1998)), a videotaped observational measure that extends the Preschool Laboratory Temperament Assessment Battery (Goldsmith, Reilly, Lemery, Longley, & Prescott, 1993) to middle childhood and comprises a series of standardized emotion- and behavior-eliciting episodes. Children's predispositions to inhibited versus disinhibited behavior under conditions of novelty and social stress were assessed while meeting a stranger – a classic elicitor of inhibition/disinhibition among infants (Rheingold & Eckerman, 1973), children and adults (Kirschbaum, Pirke, & Hellhammer, 1993) – and during administration of the Berkeley Puppet Interview (Measelle, Ablow, Cowan, & Cowan, 1998).

Consistent with prior practice (Goldsmith & Campos, 1990; Pfeifer, Goldsmith, Davidson, & Rickman, 2002), research assistants not present during the home assessment independently rated the latencies, durations, frequencies, and intensities of facial, vocal, and bodily behaviors, with a mean inter-rater reliability of .93. Multiple discrete variables were scored in each episode, across each of 3-5 intervals, including: latency to verbal response, voice tone, amount of speech production, spontaneous conversation, and approach vs. withdrawal behavior. Individual scores were averaged across the intervals, creating a set of intercorrelated scores that were averaged to form an overall Inhibition/Disinhibition composite ($\alpha = .75$). The Inhibition/Disinhibition score was substantially correlated with Temperament Assessment Battery for Children ratings of activity level ($p = -.044, p < .001$) and behavioral control ($p = 0.42, p < .001$). Thus, children with high scores on Inhibition/Disinhibition were quiet, socially reticent, and behaviorally inhibited, whereas children with low scores exhibited bold, undercontrolled, and disinhibited behavior.

Children's mental health symptoms—Mothers, teachers, and children were questioned using instruments designed in parallel to assess children's mental health

symptoms in grades 1 and 7. Mothers and teachers completed the MacArthur Health and Behavior Questionnaire (Boyce et al., 2002; Essex et al., 2002) in Grade 1 and a slightly revised, age-appropriate version of the HBQ in Grade 7. The HBQ shows strong psychometric properties in discriminating groups of children with and without signs of psychopathology (Essex, Klein, Slattery, Goldsmith, & Kalin, 2010; Lemery-Chalfant et al., 2007; Luby et al., 2002). Children were administered the mental health symptom scales (Abelow et al., 1999; Arseneault, Kim-Cohen, Taylor, Caspi, & Moffit, 2005) of the Berkeley Puppet Interview (BPI; Measelle et al., 1998) in Grade 1. For Grade 7, the interview was modified to an age-appropriate questionnaire format in which the child was asked to choose which of two opposing statements was most like them (e.g., “I’m not a sad kid” vs. “I am a sad kid”) and then mark whether that statement was sort of, mostly, or really like them, thus paralleling the item format and coding system of the BPI. For each reporter, scores were computed for internalizing (i.e., mean of subscales for depression, generalized anxiety, and separation anxiety) and externalizing (i.e., mean of subscales for oppositional defiance, conduct problems, inattention, impulsivity, overt aggression, and relational aggression).

Separately for internalizing and externalizing symptoms, multi-informant scores were computed using the PCA-based approach outlined by Kraemer and colleagues (2003), which by carefully selecting reporters who view the child from different perspectives (e.g., child self-view vs. adult view) and in different contexts (e.g., home vs. school) can be used to measure a core characteristic (e.g., behavioral symptoms) that is free of systematic error associated with reporters' different perspectives and contexts. The resulting first component of each PCA (designated the core Internalizing Symptoms score, I, and the core Externalizing Symptoms score, E) represented the variance in reported symptoms shared among the three reports (see (Kraemer et al., 2003) for details). The factor loadings for each informant were consistently above .50, and alpha coefficients for both scales exceeded .80.

To address the frequent epidemiological co-morbidity of childhood internalizing and externalizing symptoms (e.g., in the current study, I and E scores were correlated at $\rho = .49$ in grade 1, $.61$ in grade 7, $ps < .001$), we distinguished the overall, total severity of behavioral symptoms – Symptom Severity, computed as the average of the standardized core scores for Internalizing and Externalizing Symptoms, i.e., $((I + E)/2)$ – from what differentiates them – Symptom Directionality, computed as the half difference of the standardized core scores, i.e., $((I - E)/2)$ (Essex, Klein, Cho, & Kraemer, 2003). A positive Directionality score indicates a preponderance of Externalizing (vs. Internalizing) symptoms, and a negative score indicates the reverse. Importantly, Severity and Directionality scores are independent as calculated and thus can be analyzed separately without incurring additional Type I error.

Data Analyses

Data analysis strategies were selected to be sensitive to the relatively small sample size ($N = 96$) and the limited range and nonparametric character of some of the variables. First, Spearman rank-order correlations were used to assess whether or not differential susceptibility was empirically demonstrated based on criteria suggested by Belsky and colleagues (Belsky et al., 2007; Belsky et al., 2009). Of particular interest was (a) whether or not the environmental factors (i.e., teacher-child conflict and closeness) predicted the outcomes (i.e., Grade 7 symptom severity and directionality); and (b) for demonstrating differential susceptibility, whether the susceptibility factors (i.e., the two biological sensitivity to context measures) were independent of both the environmental influences and the outcomes. Because teacher-child conflict and closeness did not predict Grade 7 symptom directionality ($\rho = .16$ and $\rho = -.04$, respectively; $ps = ns$), the outcome of symptom directionality was not considered further. Second, for Grade 7 symptom severity, a multiple linear regression model was computed, with each independent variable centered at its mean

(Kraemer & Blasey, 2004). Here, we were especially interested in identifying significant interactions of the susceptibility factors and the environmental influences in predicting the outcome. The first step (Model 1) included teacher-child closeness and conflict, the two biological sensitivity to context measures, and the four pair-wise multiplicative interactions of teacher-child closeness and conflict with each reactivity measure. In a second step (Model 2), Grade 1 Severity was added to investigate the influences of the predictors on Grade 7 severity over and above the level of symptom severity at Grade 1. Third, where significant interactions were found, interactive effects were probed using Aiken and West's approach (Aiken & West, 1991) and Cohen and Cohen's technique of plotting interactions using one standard deviation above and below the mean for each component variable (Cohen & Cohen, 1983). Here, for demonstrating differential susceptibility, graphs of significant interactions were inspected for cross-over effects, and tests of simple slopes assessed whether the slope for the susceptible subgroup was significantly different from zero and significantly steeper than that of the non-susceptible subgroup. Finally, to explore potential sex differences, child sex and the interactions of child sex with each predictor were considered. Because child sex was associated only with symptom directionality and no significant interactive effects were found, it was not considered further.

Results

Descriptive Statistics

Descriptive statistics are presented in Table 1. Examination of frequency distributions indicated substantial individual variation for all variables. Closer examination of the biological sensitivity to context variables indicated group level down-regulatory change in MAP over the course of the reactivity protocol, with scores ranging from $-.91$ to $+.98$; the standardized score for Inhibition/Disinhibition ranged from -1.57 to $+1.93$. Closer examination of the two teacher-child relationship variables showed that they covered all or most of the 1-to-5 scale range (range for teacher-child conflict = 1 to 5; teacher-child closeness = 2 to 5), although there were less than 20% of the children above the mid-point of the range for each variable. In addition, to characterize the nature and severity of mental health symptoms, children were divided into those below vs. at or above 1 SD of the mean of the Grade 7 symptom severity score. Using mother-report HBQ cut-points previously established with Diagnostic Interview Schedule for Children Version-IV (DISC-IV) diagnoses (Shaffer, Fisher, Lucas, & NIMH DISC Editorial Board, 1998) in a study of similar-aged children (Lemery-Chalfant et al., 2007), chi-square analyses revealed that children with Grade 7 severity scores at least 1 SD above the mean were significantly more likely than those with lower severity scores to exceed the cut-point for at least one DISC diagnosis ($\chi^2(1) = 32.67, p < .001$). Specifically, of the children in the "high severity" group, 62% (8/13) exceeded the cut-point for a DISC-based diagnosis of an internalizing disorder only ($n = 1$), externalizing disorder only ($n = 3$), or both internalizing and externalizing disorders ($n = 4$) compared with only 6% (5/91) of the remaining children who exceeded the DISC-based diagnostic cut-point for either an internalizing ($n = 3$) or externalizing ($n = 2$) disorder, but not both.

Bivariate Associations

Correlations among all variables are shown in Table 1. The physiological and behavioral stress reactivity measures were independent (i.e., correlations were statistically non-significant); and there was a small, but statistically significant, negative correlation of teacher-child conflict and closeness. Of particular importance for demonstrating differential susceptibility were the correlations of the susceptibility factors (the two biological sensitivity to context measures) with the environmental predictors (teacher-child conflict and closeness) and the outcome (Grade 7 symptom severity). Consistent with evidence for

differential susceptibility, the two reactivity measures were independent of teacher-child conflict and closeness, and Grade 7 symptom severity, with one exception. There was a statistically significant, modest association of child inhibition/disinhibition with teacher-child conflict ($\rho = -.33$).

Influences of Early Teacher-Child Relationship and Biological Sensitivity to Context on Adolescent Symptom Severity

Results of the multiple linear regression for Grade 7 symptom severity are shown in Table 2. The R^2 for Model 1 was statistically significant ($p < .001$) and explained a substantial 34% of the variance in symptom severity; the addition of Grade 1 symptom severity in Model 2 increased the explained variance to 53%. The main effects of teacher-child conflict and closeness were statistically significant in Model 1, but were reduced to non-significance in predicting the residual of Grade 7 symptom severity after the substantial effect of Grade 1 symptom severity was accounted for in Model 2. This, together with the stronger correlations of teacher-child conflict and closeness with Grade 1 Severity (Table 1), suggests that, on average, children with more conflictual and less close relationships with their Grade 1 teachers also evidenced more severe symptoms at that time, which persisted to Grade 7. There was also a statistically significant main effect of MAP slope in Model 1, which was reduced to marginal significance in Model 2, suggesting that, on average, children who were more autonomically reactive evidenced more severe symptoms at Grade 7. There was no significant main effect of temperamental inhibition/disinhibition.

Of most importance for establishing differential susceptibility were the interactions of teacher-child conflict and closeness with the two biological sensitivity to context measures. Except for the statistically marginal interaction of teacher-child conflict $\times$ MAP slope ($p = .099$), the interactions were significant in Model 1. Notably, however, all four interaction terms were also statistically significant (all $ps < .02$) in Model 2, showing that they were associated with more severe Grade 7 symptoms over and above the level of Grade 1 symptoms.

The interactions of MAP slope with teacher-child conflict and closeness are shown in Figure 1. Neither interaction shows a true cross-over effect where the highly reactive children differ from the low reactive children under supportive as well as adverse conditions. As hypothesized, children with high MAP reactivity evidenced the highest Grade 7 severity scores, over and above their Grade 1 severity scores, under adverse conditions – that is, if they experienced high levels of conflict ($\beta = 0.33$, $t = 2.59$, $p = .011$) or low levels of closeness ($\beta = -0.33$, $t = -2.66$, $p = .009$) with their Grade 1 teachers. However, under more supportive conditions – that is, if they experienced high levels of teacher closeness or low levels of teacher conflict – children with high MAP reactivity evidenced low Grade 7 severity scores that were comparable to those of the low reactivity children. In contrast, children with low MAP reactivity evidenced similarly low Grade 7 severity scores regardless of the levels of teacher-child conflict ($\beta = -0.09$, $t = -0.66$, $p = .511$) and closeness ($\beta = 0.13$, $t = 1.01$, $p = .317$) at Grade 1.

The interactions of temperamental inhibition/disinhibition with teacher-child conflict and closeness are shown in Figure 2. Both reflect cross-over interactions, but importantly, the children who are differentially susceptible vary in temperament (i.e., inhibited vs. disinhibited) depending on which dimension of the teacher-child relationship is considered in defining more adverse vs supportive conditions. Highly inhibited children evidenced the highest Grade 7 severity scores, over and above Grade 1 severity scores, if they experienced high levels of conflict with their Grade 1 teachers, and the lowest Grade 7 severity scores if they experienced low levels of teacher conflict ($\beta = 0.31$, $t = 2.04$, $p = .044$); highly disinhibited children evidenced average Grade 7 severity scores regardless of the levels of

teacher-child conflict ($\beta = -0.07$, $t = -0.71$, $p = .482$) at Grade 1. In contrast, highly disinhibited children evidenced the highest Grade 7 severity scores if they experienced low levels of closeness with their Grade 1 teachers, and the lowest Grade 7 severity scores if they experienced high levels of teacher closeness ($\beta = -0.30$, $t = -2.13$, $p = .036$); highly inhibited children evidenced average Grade 7 severity scores regardless of the levels of teacher-child closeness ($\beta = 0.09$, $t = 1.00$, $p = .321$) at Grade 1.

Discussion

This study tested the proposition that individuals with particular physiological and/or behavioral characteristics are more responsive to both adverse and supportive contextual influences. Past research has focused predominantly on the moderating influences of *either* physiological *or* behavioral reactivity on the associations of *either* adverse *or* supportive child-rearing experiences prior to primary school entry with a range of short-term developmental outcomes (see (Belsky & Pluess, 2009) for review). We extended past research to examine the joint influences of *both* physiological and behavioral reactivity on the associations of *both* adverse and supportive aspects of the teacher-child relationship during the transition to primary school with the development of mental health symptoms six years later in early adolescence.

Overall, results highlighted the substantial association of the Grade 1 teacher-child relationship with the development of children's mental health symptoms in Grade 7, especially for more reactive children; multiple regression analyses explained 34% of the variance in Grade 7 symptom severity prior to the inclusion of Grade 1 severity, and 53% when it was included. Teacher-child relationship and child autonomic reactivity significantly predicted later mental health symptoms as main effects. Specifically, high levels of teacher-child conflict, low levels of teacher-child closeness, and greater MAP slopes in Grade 1 significantly predicted greater symptom severity in Grade 7. These main effects were reduced to non-significance (MAP slope remained marginally significant) when Grade 1 symptom severity was controlled for. This, in combination with the stronger association of the teacher-child relationship with Grade 1 compared with Grade 7 symptom severity suggests that, on average, the teacher-child relationship was primarily associated with concurrent Grade 1 child mental health symptoms, which persisted to Grade 7. Most salient to the goals of the present study, all four biological sensitivity to context $\times$ teacher-child relationship interaction terms were statistically significant when Grade 1 symptom severity was controlled for, suggesting that *both* physiological *and* behavioral reactivity moderated the associations of *both* adverse *and* supportive aspects of the teacher-child relationship with Grade 7 symptom severity over and above Grade 1 severity.

Closer examination of the interactions revealed two distinct patterns. First, there was a general (i.e., non-specific) moderating effect of children's biological sensitivity to context on the association of an early adverse teacher-child relationship with the development of children's later mental health symptoms. Across both physiological and behavioral reactivity domains, highly reactive children who experienced high levels of conflict or a lack of closeness with their Grade 1 teachers developed the highest levels of mental health symptoms by Grade 7. These findings extend previous research showing that "vulnerable" children, defined by *either* physiological *or* behavioral reactivity, are disproportionately affected by adverse early child-rearing environments (Colder et al., 2006; Feldman et al., 1999; Kochanska et al., 2007). Notably, teacher-child conflict and closeness were only modestly correlated and thus, represent somewhat distinct environmental conditions. This suggests that, especially for children who are more reactive, it does not take actual conflict with the Grade 1 teacher to increase the probability of developing more severe mental health

symptoms by Grade 7, but that lack of a close relationship with the teacher is equally adverse.

Second, important differences emerged depending on which reactivity measure was considered as a main effect and as a moderator of the influence of teacher-child conflict vs. closeness on the development of adolescent mental health. Results for physiological reactivity suggest that, on average, highly autonomically reactive children develop more severe mental health symptoms by Grade 7. Further, although such children are more susceptible to the adverse qualities of their relationship with their teacher (as noted above), they are no more susceptible than low autonomically reactive children to the supportive qualities of the relationship. As articulated by Belsky et al (2007), this form of interaction suggests a “dual risk” model in which the highly autonomically reactive children (i.e., risk #1) show disproportionately high symptoms under conditions of high conflict or low closeness with their teachers (i.e., risk #2) but do not show disproportionately low levels of symptoms under conditions of high closeness or low conflict with their teachers. In previous work (Boyce et al., 2006), we found this same pattern for early father involvement, where highly autonomically reactive children evidenced the most severe symptoms under conditions of low father involvement but were no more susceptible than low reactive children to high father involvement. However, in earlier work (Boyce et al., 1995b), we found cross-over effects in which cardiovascular and immune reactivity were associated with the highest rates of respiratory illnesses under conditions of adversity in the home or child care center, but the lowest rates under conditions of low adversity and support. It is possible that these cross-over effects were observed because physiological reactivity measures were used to predict a physiological outcome, and more generally, that true cross-over effects might be easiest to detect when both the reactivity and outcome measures are either physiological or behavioral. Further, as noted in Obradovic et al (2010) (Obradovic et al., 2010) and Boyce and Ellis (2005), whether interactions signifying dual risk or differential susceptibility emerge from a given study may depend in part on the particular segment of the social environmental spectrum, from beneficial to pathological, the sample and measures have captured. The present study was based on a relatively small sample of children, with only a few who experienced extremely high conflict or low closeness with their teachers. Further, the particular measures of conflict and closeness used in the present study might not have captured the full range of those relationship qualities. Thus, although simple dual risk-type interactions were found, a larger sample comprised of more children with high levels of conflict and low levels of closeness with their teachers, and a broader “window” on the range of teacher-child relationship qualities, might reveal differential susceptibility effects for highly autonomically reactive children.

In contrast to the results for physiological reactivity, results for behavioral reactivity provided clear evidence for differential susceptibility to both adverse and supportive contexts. As discussed above, these cross-over effects were found when considering reactivity and outcomes measures that are both behavioral. Interestingly, however, the moderating effects of inhibition/disinhibition varied by which dimension (i.e., conflict or closeness) of the teacher-child relationship was considered. Specifically, behaviorally inhibited children developed the most severe mental health symptoms by Grade 7 under conditions of high Grade 1 teacher conflict, but the lowest levels of symptoms under conditions of low teacher conflict; and, there were no differences in symptom severity according to levels of teacher-child closeness. Rather, it was highly *disinhibited* children who developed the most severe mental health symptoms under conditions of low teacher closeness, and the lowest levels of symptoms under conditions of high teacher closeness; and symptom severity did not differ according to levels of teacher-child conflict. These results are consistent with our previous studies. Specifically, in a study of early father involvement (which might be considered parallel to teacher-child closeness), we showed

that, only for disinhibited (vs. inhibited) children, low father involvement was associated with high symptoms, whereas high father involvement was associated with low symptoms, and, there was no effect of father involvement for inhibited children (Boyce et al., 2006). In addition, in a study of the development of externalizing behaviors, children with prior externalizing problems (which are often associated with, but not the same as, disinhibited behaviors) evidenced the greatest decreases in externalizing behaviors if they had a close relationship with their kindergarten teacher (Silver et al., 2005).

Importantly, in contrast to the findings for autonomic reactivity and consistent with the relatively small negative correlation of teacher-child conflict and closeness, the findings for behavioral reactivity suggest that adverse environments characterized by high levels of teacher-child conflict are not the same as sub-optimal relationships characterized by a lack of closeness; and more supportive environments characterized by high levels of teacher-child closeness are not the same as those characterized by a lack of conflict. Rather, it appears that children of differing temperaments are differentially susceptible to the two dimensions of the teacher-child relationship. Inhibited children -- those who are socially reticent and fearful of situations perceived to be threatening -- may be especially sensitive to the level of tension and conflict they experience with their teacher. On the other hand, disinhibited children -- those who are bold and under-controlled -- may be especially sensitive to the level of support and close connectedness they have with their teacher. In broad terms, these findings are consistent with the vast “goodness of fit” literature showing that children of different temperaments fit best in different types of settings (Keogh, 1986). However, the findings also elaborate this perspective to suggest that (a) the salient dimensions of social environments differ by child temperament, and (b) such dimensions are most salient because they are those to which the child is most attuned and responsive.

More generally, when considered together, the present findings extend current thinking on differential susceptibility to suggest that context sensitivity is not a monolithic category – i.e., there are identifiable groups of context sensitive, “orchid” children, as proposed by Boyce and Ellis (2005). Although numerous diverse studies provide converging evidence for differential susceptibility (reviewed in Belsky & Pluess, 2009), the range of reactivity measures, contexts, and outcomes included in these studies have resulted in many inconsistencies in findings and few replications. Further, because few studies have included multiple domains of reactivity, contexts, and outcomes, the question remains whether differential susceptibility reflects a more global, trait-like characteristic or is more specific to the reactivity, context, and outcome being considered. Although it is plausible that some individuals are simply more susceptible in general to the beneficial effects of supportive environments as well as the harmful effects of adverse environments, it is also possible that context sensitivity is specific to different environmental features and that the salience of those features varies according to the stress reactivity system and functional outcome of interest. Although the present study cannot fully address this question, the findings suggest that there might be more than one type of biologically sensitive child.

What remains unclear and unanswerable within the constraints of the sample size of the current study is whether the effects of the teacher-child relationship are attributable to characteristics of that relationship per se or whether the early teacher-child relationship is a proxy for other social relational risk factors, including peer relations, earlier family relations or more distal characteristics such as socioeconomic status (SES), or perhaps later and more proximal relationships with peers or teachers. Although numerous studies have shown associations among the teacher-child relationship, peer relations, family relations, and SES (Howes, 2000; Ladd, Birch, & Buhs, 1999; Miech, Essex, & Goldsmith, 2001; NICHD Early Child Care Research Network, 2004), few have considered the joint influences of multiple relationships. There is some evidence that the teacher-child relationship exerts

independent effects over and above parenting (Meehan et al., 2003). Further, in previous work we have shown that the inclusion of peer, family, and SES variables did not account for the associations of the teacher-child relationship with the development of children's externalizing problems across the elementary school years (Silver, Armstrong, & Essex, in press; Silver et al., 2005). This suggests that the early teacher-child relationship plays an important and distinct role in children's development, over and above that played by the peer and family contexts.

It should also be noted that predispositions to internalizing versus externalizing symptoms in Grade 7, assessed by symptom directionality, were not associated with the earlier teacher-child relationship. Although previous studies have shown that the teacher-child relationship is associated with externalizing (Hughes, Cavell, & Jackson, 1999; Silver et al., in press; Silver et al., 2005) and, to a lesser degree, internalizing (Hamre & Pianta, 2001) problems, most studies have not considered both forms of problems even though their comorbidity during childhood is often quite high (Lilienfeld, 2003). When comorbidity is dealt with, as we have shown here and in our previous work (Boyce et al., 2006; Essex et al., 2006), symptom directionality is associated primarily with children's sex. It is well established that by early adolescence, internalizing forms of mental health problems are reported more frequently among girls and externalizing forms more frequently among boys (Zahn-Waxler, Shirtcliff, & Marceau, 2008). Thus, although the severity of mental health symptoms may be influenced by environmental and neurobiological risk, bias toward internalizing or externalizing forms may be primarily the product of biological sex and/or socially constrained gender roles (Essex et al., 2003; Essex et al., 2006). In other words, symptom directionality may be engendered by complex processes involving sexual dimorphisms in biological circuitry and social conventions regarding acceptable expressions of psychological distress.

Taken together, these results highlight that, in general, children's biological sensitivity to context exerts a significant moderating effect on the association of the early teacher-child relationship with the severity of later mental health symptoms. Further, results suggest that, only in the context of an adverse teacher-child relationship, physiological reactivity may act primarily as a risk factor for the development of mental health symptoms by adolescence. However, behavioral reactivity may act alternately as *either* a risk or protective factor depending upon the qualities of the early teacher-child relationship. Such interpretation implies that temperamental forms of reactivity may reflect most strongly an underlying susceptibility to both the adverse and supportive aspects of this particular early social context as it influences the development of mental health problems by adolescence.

Limitations

The study has several limitations. The possibility of a sampling bias within this population, and the nonrepresentativeness of this sample of the larger U.S. population, must be kept in mind in interpreting the findings. This sample represents largely middle-class, white, and, at least at the outset, intact families in a Midwestern state. In addition, the sample is relatively small, especially given the number of variables included in the major analyses. The ratio of subjects to variables also limits investigation of potentially important additional variables. For example, future studies should investigate the effects of both the parasympathetic and sympathetic components of the ANS system as well as other temperamental characteristics. It is also important to investigate the effects of the HPA system and ways in which all stress reactivity domains might jointly exert their moderating influences to explain children's differential susceptibility to experience. Finally, future studies should investigate positive as well as negative developmental outcomes.

Conclusions

Despite these limitations, this study extends previous research on differential susceptibility in important ways. First, it goes beyond consideration of early family relationships and young children to consider a key non-familial relationship for children after the transition to primary school. Second, it includes both physiological and behavioral markers of biological sensitivity to context. Third, it systematically addresses key questions of differential susceptibility by including both adverse and supportive environmental conditions, and by considering the criteria suggested by Belsky et al (2007) that provide clear evidence of differential susceptibility. Importantly, the findings hold educational implications. Especially because the sample size was relatively small for the number of variables considered, it is important that the findings are replicated by other studies. Nevertheless, the strength of the findings suggests that the early teacher-child relationship may exert a powerful influence – for better and for worse – on the development of children's mental health by adolescence, especially for those who are highly reactive.

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Figure 1.
Grade 1 Teacher-Child Conflict $\times$ MAP Slope interaction and Teacher-Child Closeness $\times$ MAP Slope interaction predicting Grade 7 Symptom Severity (controlling on Grade 1 Symptom Severity).

Figure 2.
Grade 1 Teacher-Child Conflict $\times$ Inhibition/Disinhibition interaction and Teacher-Child Closeness $\times$ Inhibition/Disinhibition interaction predicting Grade 7 Symptom Severity (controlling on Grade 1 Symptom Severity).

Table 1
Means, Standard Deviations, and Spearman Correlations of Variables

	Mean (SD)	1	2	3	4	5
<u>Grade 1</u>						
1. Teacher-Child Conflict	1.43 (.73)	–				
2. Teacher-Child Closeness	4.24 (.69)	-.22*	–			
3. MAP Slope	-0.07 (.58)	.13	-.10	–		
4. Inhibition/Disinhibition	-0.05 (.71)	-.33**	-.16	-.03	–	
5. Symptom Severity	0.03 (.95)	.61**	-.28**	.15	-.22*	–
<u>Grade 7</u>						
6. Symptom Severity	-0.05 (.55)	.37**	-.19	.13	-.09	.61**

Note. $N = 96$.

*
 $p \leq .05$.

**
 $p \leq .01$.

Table 2
Regression Models Predicting Grade 7 Symptom Severity from Grade 1 Factors

	Model 1				Model 2			
	<i>B</i> (<i>SE</i>)	β	<i>t</i>	<i>p</i>	<i>B</i> (<i>SE</i>)	β	<i>t</i>	<i>p</i>
Teacher-Child Conflict	0.46 (0.10)	0.51	4.60	.000	0.12 (0.10)	0.14	1.19	.239
Teacher-Child Closeness	-0.22 (0.10)	-0.24	-2.20	.030	-0.10 (0.09)	-0.11	-1.20	.235
MAP Slope	0.18 (0.08)	0.19	2.10	.038	0.13 (0.07)	0.14	1.83	.070
Inhibition/Disinhibition	-0.04 (0.10)	-0.04	-0.37	.714	0.02 (0.09)	0.02	0.20	.843
Conflict $\times$ MAP	0.15 (0.09)	0.15	1.67	.099	0.21 (0.08)	0.21	2.67	.009
Conflict $\times$ Inhibition/Disinhibition	0.21 (0.09)	0.22	2.20	.030	0.19 (0.08)	0.21	2.40	.018
Closeness $\times$ MAP	-0.22 (0.11)	-0.19	-2.12	.037	-0.23 (0.09)	-0.20	-2.57	.012
Closeness $\times$ Inhibition/Disinhibition	0.23 (0.09)	0.25	2.56	.012	0.19 (0.08)	0.21	2.51	.014
Symptom Severity (Grade 1)					0.62 (0.10)	0.62	5.89	.000

Note. *N* = 96.