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Neuropsychological and interpersonal antecedents of youth depression

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Abstract

This research examined neuropsychological and interpersonal factors that jointly confer vulnerability to youth depression. We proposed that (1) a reduced posterior right hemisphere bias during the processing of facial expressions contributes to subsequent depressive symptoms in youth, and (2) maladaptive responses to interpersonal stress account for this association. Drawing from theory and research indicating sex differences in rates of hemispheric development, we also investigated sex differences in the associations among a reduced posterior right hemisphere bias, maladaptive responses to interpersonal stress, and depressive symptoms. Hypotheses were examined in a longitudinal study of 95 4th – 8th graders (*M* age = 12.33, *SD* = 1.10). Results supported the notion that a reduced posterior right hemisphere bias confers vulnerability to depressive symptoms over time in a sex-specific fashion, and implicate maladaptive stress responses as an explanatory mechanism.

Psychobiological theory and research suggest that atypical patterns of regional brain activity, including irregularities in both anterior and posterior regions, play a role in depression (e.g., Davidson, 1988; Heller, Etienne, & Miller, 1995; Heller & Nitschke, 1997; Henriques & Davidson, 1991). In posterior regions, research specifically links decreased right hemisphere activity to depression (for a review, see Heller & Nitschke, 1997). However, little research has investigated potential mechanisms accounting for this link, particularly in youth. The present research examined the hypothesis that a reduced posterior right hemisphere bias during the processing of facial expressions reflects difficulty in the identification and evaluation of emotional information; this difficulty is presumed to interfere with adaptive responses to stress, thereby conferring vulnerability to depression. Additionally, drawing from theory and research suggesting sex differences in rates of hemispheric maturation (for reviews, see Heller, 1993; Levy & Heller, 1992), the links among a reduced posterior right hemisphere bias, maladaptive stress responses, and depressive symptoms were expected to differ in boys and girls.

Posterior Right Hemisphere Activity and Depression

The association between reduced posterior right hemisphere activity and depression has been established in adults using behavioral (Banich, Stolar, Heller, & Goldman, 1990; Bruder et al., 1995; Kucharska-Pietura & David, 2003) and electrophysiological (Bruder et

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al., 1997; Deldin, Keller, Gergen, & Miller, 2000; Henriques & Davidson, 1997; Kayser et al., 2000) methods. Notably, recent research documents a similar link in youth. One study involving the offspring of depressed parents (a combined youth and young adult sample) revealed reduced posterior right hemisphere activity, as measured using electrophysiological recordings, independent of their prior experience of depressive symptoms (Bruder et al., 2005). A second study demonstrated an association between a reduced posterior right hemisphere bias during the processing of facial expressions and concurrent depressive symptoms in youth (Flynn & Rudolph, 2007). However, research in this area has tended to be descriptive, with little investigation about the processes that may account for this link.

Using behavioral (Borod, Koff, Lorch, & Nicholas, 1986), electrophysiological (Kayser et al., 2000), and functional magnetic resonance imaging (Killgore & Yurgelun-Todd, 2007) methods, research suggests that posterior right hemisphere functioning is involved in the processing of emotional information. Specifically, the posterior right hemisphere has been implicated in the perception, identification, and evaluation of emotional information conveyed through facial expressions (Borod et al., 1986; Kayser et al., 2000; Killgore & Yurgelun-Todd, 2007). Further, a reduced posterior right hemisphere bias during the processing of facial expressions is associated with deficits in youths' self-reported emotional clarity (i.e., the ability to understand one's emotions; Flynn & Rudolph, 2008), deficits in emotional awareness (i.e., the ability to recognize and describe emotions in oneself and others; Lane, Kivley, Du Bois, Shamasundara, & Schwartz, 1995), and alexithymia (i.e., a diminished ability to identify and communicate emotions; Berenbaum & Prince, 1994).

Youth who have difficulty processing emotions are likely to be at particular risk under conditions of stress as they may need to allocate more internal resources toward information processing, thereby precluding the active formulation of goal-directed coping responses (Gohm & Clore, 2000, 2002). Consequently, reduced posterior right hemisphere functioning may disrupt the regulation of arousal, and undermine efforts to cope effectively with stress. In particular, we anticipated that youth with a reduced posterior right hemisphere bias would display fewer effortful coping strategies (i.e., purposeful efforts to resolve or adapt to stressors), such as problem solving, emotion regulation, or positive thinking, and more involuntary, dysregulated reactions, such as rumination (i.e., persistent cognitive focus on the problem), emotional numbing (i.e., not having any feelings), or cognitive interference (i.e., having one's mind go blank). Consistent with this hypothesis, research in youth indicates that a reduced posterior right hemisphere bias during the processing of facial expressions is associated with fewer efforts to adapt to stressful events (e.g., accepting the event or thinking about it in positive terms), as well as a greater tendency to involuntarily disengage from stressors by disconnecting oneself from concomitant emotions, thoughts, and behaviors (e.g., avoiding people and places associated with the event) (Flynn & Rudolph, 2007).

In turn, the tendency to enact maladaptive stress responses may diminish youths' sense of mastery and undermine effective regulation of emotions, leading to negative affect, low self-worth, and other symptoms of depression. How youth respond to *interpersonal* stress may be of particular relevance in that failure to cope effectively with social problems likely interferes with the development and maintenance of supportive relationships that can buffer

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youth from depression. Indeed, maladaptive interpersonal stress responses, in the form of diminished engagement coping and heightened involuntary engagement and disengagement, have been linked to youth depression (Connor-Smith, Compas, Wadsworth, Thomsen, & Saltzman, 2000; Flynn & Rudolph, 2007; Langrock, Compas, Keller, Merchant, & Copeland, 2002; Wadsworth, Rieckmann, Benson, & Compas, 2004). Moreover, the experience of interpersonal stress is a strong predictor of youth depression (for a review, see Rudolph, Flynn, & Abaied, 2008). Thus, we hypothesized that a reduced posterior right hemisphere bias would interfere with the enactment of adaptive responses to interpersonal stress, thereby increasing vulnerability to depressive symptoms.

Sex Differences in Hemispheric Maturation

The contribution of a reduced right posterior hemisphere bias to stress responses and depressive symptoms may differ for boys and girls. Theory and research suggest that sex differences in hemispheric maturation exist throughout early to middle childhood (for reviews, see Heller, 1993; Levy & Heller, 1992). Biological differences are thought to influence the organization and development of the brain such that the right hemisphere matures at a faster rate in boys than in girls (Geschwind & Galaburda, 1985; Kimura, 1999). Indeed, several studies demonstrate that boys outperform girls on right-hemisphere dominant information-processing tasks, such as those involving visual-spatial reasoning and memory, throughout childhood (Ehrlich, Levine, & Goldin-Meadow, 2006; Grossi, Orsini, Monetti, & De Michele, 1979; Levine, Huttenlocher, Taylor, & Langrock, 1999; Orsini, Shiappa, & Grossi, 1981). For instance, boys demonstrate greater proficiency assembling objects (McGuinness & Morley, 1991) and performing tasks requiring mental transformations of spatial designs (Johnson & Meade, 1987; Levine et al., 1999). The slower maturation of the right hemisphere in girls may lead to a consequent left-hemisphere advantage during information processing, such that they develop and rely on left-hemisphere driven information-processing strategies (e.g., verbal and linguistic skills) (Cioffi & Kandel, 1979; Levy & Heller, 1992; Shucard, Shucard, Cummins, & Campos, 1981). Consequently, boys may be conditioned to rely more heavily on right hemisphere functioning whereas girls may be conditioned to rely more heavily on left hemisphere functioning during information processing. This history of hemispheric preference may persist beyond the complete maturation of both hemispheres such that boys have a greater tendency to employ right-hemisphere driven visual-spatial strategies whereas girls have a greater tendency to employ left-hemisphere driven verbal strategies.

Given these sex-linked developmental differences, a reduced right hemisphere bias during the processing of facial expressions may differentially predict developmental outcomes in boys and girls. Specifically, a reduced right hemisphere bias may directly impair boys' ability to process emotional information and to formulate goal-directed cognition and behavior, thereby interfering with adaptive stress responses and heightening risk for depression. In contrast, a reduced right hemisphere bias may not directly impair girls' self-regulatory capabilities because they may be able to compensate for this disruption through reliance on left hemisphere-driven information-processing strategies. Instead, the consequences of a reduced right hemisphere bias may only become apparent when girls' alternative information processing capabilities become overwhelmed. In particular, we

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hypothesized that a reduced right hemisphere bias would contribute to girls' maladaptive interpersonal stress responses and depressive symptoms only under conditions of heightened interpersonal stress.

Overview of the Present Study

The goal of this research was to examine sex differences in the contribution of a reduced posterior right hemisphere bias to maladaptive interpersonal stress responses and depressive symptoms in youth. Relative posterior right hemisphere activity was measured using the Chimeric Faces Task (CFT; Levy, Heller, Banich, & Burton, 1983), a free-vision task that prompts participants to make emotional judgments about facial expressions. Performance on the CFT yields perceptual asymmetry scores indicating relative right versus left hemisphere activity. These perceptual asymmetry scores provide an index of hemispheric specialization, as right hemisphere biases consistently emerge during the processing of emotional and spatial information whereas left hemisphere biases consistently emerge during the processing of linguistic information (Levy et al., 1983). Using a longitudinal design, this study investigated the following hypotheses: (a) a reduced posterior right hemisphere bias would confer vulnerability to depressive symptoms over time in boys (regardless of their stress level) and in girls (under conditions of heightened stress), and (b) maladaptive interpersonal stress responses, in the form of less engagement coping (e.g., problem solving, cognitive restructuring) and more involuntary engagement and disengagement responses (e.g., rumination, emotional numbing), would account for these effects.

Method

Participants

Participants were 4^{th} – 8^{th} graders involved in a longitudinal study examining depression during the transition to adolescence. The CFT was administered at Wave 1 to 108 of 167 youth (administration of this task was discontinued part way through the study due to time constraints). Youth who did versus did not complete the CFT did not differ significantly in terms of sex, $\chi^2(1; N = 167) = 3.31$, *ns*, age, $t(165) = 1.64$, *ns*, ethnicity [white versus minority; $\chi^2(1; N = 167) = .13$, *ns*], income $t(160) = .31$, *ns*, or Wave 1 Children's Depression Inventory scores (CDI; Kovacs, 1981), $t(165) = .62$, *ns*. Of the 108 youth, 95 (88%) had complete data at Wave 1 (W_1) and Wave 2 (W_2); these youth comprised the present sample. Participants ranged in age from 9 to 14 years (49 boys, 46 girls; *M* age = 12.33, *SD* = 1.10). Youth were somewhat diverse in ethnicity (76.8% White, 12.6% African-American, 10.6% other) and represented a broad range of socioeconomic backgrounds (total annual family income was below $30,000 for 14% of the sample and above $75,000 for 16% of the sample).

Procedures

Youth and their primary female caregivers attended two laboratory visits, spaced approximately one year apart. Caregivers provided written consent and youth provided written assent for participation at both waves. At W_1, youth completed the CFT and the CDI. At W_2, youth and caregivers were independently administered the Youth Life Stress

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Interview. Youth completed the Responses to Stress Questionnaire, and again completed the CDI. Table 1 presents descriptive information on all of the measures.

Measures

Chimeric Faces Task (CFT; Levy et al., 1983)—The CFT is a free-vision task consisting of 18 pairs of vertically arranged chimeric faces. The pairs of faces were printed and individually displayed; youth provided written responses. Each pair includes one face with a smile on the right side and one face with a smile on the left side; the second half of each face has a neutral expression. Youth choose which of the two faces looks happier. Responses are scored based on youths' preference for the smile in the left visuospatial field (indicating right hemisphere activity; scored as −1) versus the right visuospatial field (indicating left hemisphere activity; scored as +1). If youth are unable to select a face, an "undecided" response can be given (scored as 0). A mean perceptual asymmetry score, indicating the relative level of right versus left hemisphere activity, is then computed by summing the individual scores and dividing by the total number of items. A perceptual asymmetry score is not calculated if more than half of the responses are "undecided." *Higher* scores on the measure reflect a *reduced* right hemisphere bias; a score of zero indicates no perceptual bias. The 36-item version of the CFT has high split-half reliability (Wirsen, Klinteberg, Levander, & Schalling, 1990). The present study used an 18-item version (Compton, Fisher, Koenig, Mc Keown, & Munoz, 2003). Adequate internal consistency was found (α = .77).

Converging lines of evidence suggest that one component of perceptual asymmetry scores measured using the CFT reflects individual differences in relative right versus left posterior hemisphere functioning. First, the posterior right hemisphere is activated during face processing, as indicated by findings from tachistoscopic tasks (e.g., Hilliard, 1973; Klein, Moscovitch, & Vigna, 1976), lesion studies (e.g., Newcombe, De Haan, Ross, & Young, 1989), and neuroimaging studies (e.g., Sams, Hietanen, Hari, Ilmoniemi, & Lounasmaa, 1997; Sergent, Ohta, & MacDonald, 1992). Second, electrophysiological activation in posterior regions of the brain explains 50% of the variance in behaviorally assessed perceptual asymmetry scores (Green, Morris, Epstein, West, & Engler, 1992), which suggests that such tasks index patterns of regional brain activity. Research also supports the idea that performance on the CFT reflects individual differences in the processing of emotional information. Specifically, a reduced right hemisphere bias on the CFT is associated with deficits in the identification and understanding of emotions in oneself (Berenbaum & Prince, 1994; Flynn & Rudolph, 2008; Lane et al., 1995) and others (Berenbaum & Prince, 1994; Lane et al., 1995); the average effect size of these associations is medium (Cohen, 1992). Overall, multiple lines of research indicate that performance on the CFT taps posterior right hemisphere functioning and reflects individual differences in the understanding and processing of emotional information.

Children's Depression Inventory (CDI; Kovacs, 1981)—The CDI is a 27-item self-report questionnaire assessing depressive symptoms in youth. For each item, youth endorse one of three statements that describe no (scored as 0), mild (scored as 1), or severe (scored as 2) depressive symptoms, yielding a total score ranging from 0 to 54. This measure has

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demonstrated sound psychometric properties, including adequate internal consistency and test-retest reliability (Kovacs, 1981; Smucker, Craighead, Craighead, & Green, 1986). This scale had high internal consistency in the present sample at W_1 (α = .84) and W_2 (α = .91).

Responses to Stress Questionnaire (RSQ; Connor-Smith et al., 2000)—The RSQ assesses youths' effortful coping versus involuntary, dysregulated responses to stress. This measure distinguishes engagement with, and disengagement from, stressors. Confirmatory factor analysis during original measure development supported a factor structure with four subscales (Connor-Smith et al., 2000), which demonstrated adequate internal consistency in the present sample: engagement coping (efforts to resolve or adapt to the stressor or one's response to the stressor; e.g., problem solving, cognitive restructuring, emotional regulation; 21 items; α = .82), disengagement coping (e.g., denial, avoidance, wishful thinking; 9 items; α = .78), involuntary engagement (e.g., rumination, emotional and physiological arousal; 15 items; α = .93), and involuntary disengagement (e.g., inaction, emotional numbing; 12 items; α = .89). Convergent validity and retest reliability have been established for these subscales (Connor-Smith et al., 2000).

Youth completed the peer stressor version of the RSQ. Specifically, youth reported how much they engaged in each type of response to a variety of peer stressors (e.g., fighting with other kids, having problems with a friend) on a scale from 1 (Not at All) to 4 (A Lot). Consistent with previous research involving this measure (Connor-Smith et al., 2000; Flynn & Rudolph, 2007), to correct for base-rate differences in the endorsement of responses to stress (Compas, Connor-Smith, Saltzman, Thomsen, & Wadsworth, 2001), proportion scores were calculated as the total score for each subscale divided by the total score on the RSQ. Higher scores indicate greater enactment of each type of response to stress. To examine our specific study hypotheses, a composite score of maladaptive stress responses was computed. The engagement coping, involuntary engagement, and involuntary disengagement subscales were standardized; engagement coping Z-scores were subtracted from the sum of the involuntary engagement and disengagement Z-scores, such that higher scores reflect more maladaptive stress responses.

Peer stress—To assess peer stress, trained graduate students, advanced undergraduate students, and a post BA-level research assistant individually administered the Youth Life Stress Interview (Rudolph & Flynn, 2007) to youth and caregivers. This semi-structured interview was adapted from the Child Episodic Life Stress Interview (Rudolph & Hammen, 1999; Rudolph et al., 2000) and uses the contextual threat method (Brown & Harris, 1978) to ascertain the occurrence and intensity of stressful episodic events that youth had experienced during the previous year. Because of our interest in exposure and responses to peer stress, this study used the peer stressor section of the interview.

First, interviewers used an open-ended query about youths' exposure to stressful episodic events of any nature during the year between the W_1 and W_2 assessments. Next, interviewers used standardized probes to elicit information about specific stressful experiences in the peer group (e.g., conflict with peers, break-up of a friendship). Upon endorsement of a stressful event, detailed follow-up questions were asked to obtain comprehensive information regarding the temporal occurrence and context of the event, as

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well as its objective consequences. The interviewer created a narrative summary of each stressful event.

Integrating information across youth and caregivers, interviewers presented the narrative summaries to a team of coders with no prior knowledge of youths' experience of psychopathology or of their subjective response to the events. Coders assigned an objective stress rating associated with each stressor for typical youth under such conditions on a scale from 1 (No Negative Stress) to 5 (Severe Negative Stress). Episodic peer stress scores were calculated as the total of the objective stress ratings for each peer event with a stress rating above 1. To establish reliability, two independent teams coded 160 life events; strong reliability was found for objective stress ratings (one-way random-effects intra-class correlation coefficient = .90). Cohen's kappa for agreement on whether an event was peer-related or not was 1.00.

Results

Overview of Analytic Approach

First, zero-order correlations were computed to examine the general pattern of associations among all of the variables in boys and girls. Second, regression analyses were conducted to investigate whether the moderating effect of peer stress on a reduced posterior right hemisphere bias differed in boys and girls. Third, regression analyses were conducted separately in boys and girls to examine whether maladaptive stress responses accounted for the association between a reduced posterior right hemisphere bias and subsequent depressive symptoms.

Correlational Analyses

Table 2 presents correlations among the variables. CFT scores were significantly associated with maladaptive stress responses and W_2 depressive symptoms in boys but not in girls. Maladaptive stress responses were associated with depressive symptoms in both boys and girls. Peer stress was significantly associated with depressive symptoms in girls but not boys.

Examination of Sex Differences

A hierarchical multiple regression analysis was conducted to examine whether the CFT x Peer Stress interaction contributed to W_2 depressive symptoms differently in boys and girls. W_1 depressive symptoms were entered in the first step. Sex and the mean-centered main effects of CFT scores and peer stress were entered in the second step. All two-way interactions were entered in the third step, and the three-way CFT x Peer Stress x Sex interaction was entered in the fourth step. Results revealed a significant three-way interaction ($\beta = .34$, $t(86) = 3.73$, $p < .001$), suggesting that the nature of the two-way CFT x Peer Stress interaction differed across sex. Thus, separate follow-up regressions were conducted in boys and girls (see Table 3).

The analysis in boys revealed a significant main effect of CFT scores; the main effect of peer stress and the CFT x Peer Stress interaction were nonsignificant. The analysis in girls

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revealed a nonsignificant main effect of CFT scores, a significant main effect of peer stress, and a significant CFT x Peer Stress interaction. Following Aiken and West (1991), the CFT x Peer Stress interaction in girls was interpreted by computing the simple slopes at high (one standard deviation above the mean), medium (mean), and low (one standard deviation below the mean) levels of peer stress. A reduced posterior right hemisphere bias was positively associated with W_2 depressive symptoms in girls who experienced high levels of peer stress ($\beta = .46$, $t(41) = 2.98$, $p < .01$), nonsignificantly associated with W_2 depressive symptoms in girls who experienced medium levels of peer stress ($\beta = .11$, $t(41) = 1.14$, *ns*), and negatively associated with W_2 depressive symptoms in girls who experienced low levels of peer stress ($\beta = -.25$, $t(41) = -2.22$, $p < .05$) (see Figure 1).

Examination of Mediation in Boys

Analyses were conducted to examine whether maladaptive stress responses accounted for the association between a reduced posterior right hemisphere bias and subsequent depressive symptoms in boys. Preliminary correlation analyses revealed that a reduced posterior right hemisphere bias was significantly associated with maladaptive stress responses, and that maladaptive stress responses were significantly associated with W_2 depressive symptoms (see Table 2). A series of hierarchical multiple regression analyses was then conducted to examine whether maladaptive stress responses mediated the association between a reduced posterior right hemisphere bias and subsequent depressive symptoms in boys. All analyses adjusted for W_1 depressive symptoms. The prior regression analysis established that a reduced posterior right hemisphere bias significantly predicted W_2 depressive symptoms (see Table 3). This regression was repeated omitting the nonsignificant main effect of peer stress and the nonsignificant CFT x Peer Stress interaction term from the equation (see Table 4).

To test mediation, two additional regressions were conducted (Baron & Kenny, 1986; see Table 4). First, results revealed that the effect of a reduced posterior right hemisphere bias on maladaptive stress responses was significant. Second, results revealed that the effect of maladaptive stress responses on W_2 depressive symptoms, after including the influence of a reduced posterior right hemisphere bias, was significant. Consistent with partial mediation, the association between a reduced posterior right hemisphere bias and W_2 depressive symptoms reduced to nonsignificance after including maladaptive stress responses. In further support of partial mediation, the indirect effect (IE; Sobel, 1982; 1986) of a reduced posterior right hemisphere bias on subsequent depressive symptoms was marginally significant (IE = .09, $Z = 1.72$, $p < .10$). Finally, an effect proportion (indirect effect/total effect; Shrout & Bolger, 2002) indicated that maladaptive stress responses accounted for 38% of the total effect of a reduced posterior right hemisphere bias on subsequent depressive symptoms. Overall, these findings suggest that maladaptive stress responses partially mediated the association between a reduced posterior right hemisphere bias and subsequent depressive symptoms in boys.

Examination of Mediation in Girls

Preliminary correlation analyses revealed that a reduced posterior right hemisphere bias was not significantly associated with maladaptive stress responses or depressive symptoms in

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girls (see Table 2). However, building on the regression findings that peer stress moderated the effect of a reduced posterior right hemisphere bias on girls' depressive symptoms, analyses were conducted to test whether maladaptive stress responses accounted for this overall moderation effect (i.e., test of mediated moderation; Edwards & Lambert, 2007; Muller, Judd, & Yzerbyt, 2005).

Following the guidelines set forth by Muller and colleagues (2005), two conditions must be satisfied to demonstrate mediated moderation. Condition 1 requires that the magnitude of the overall effect of the independent variable (i.e., a reduced posterior right hemisphere bias) on the dependent variable (i.e., subsequent depressive symptoms) depends on the moderator (i.e., peer stress); Condition 1 was previously satisfied in girls (see Table 3). Condition 2 requires that the mediator (i.e., maladaptive stress responses) accounts for the overall moderation effect. To satisfy Condition 2 in the present analyses, two independent regression analyses were conducted. The first regression should establish that the path from a reduced posterior right hemisphere bias to maladaptive stress responses is moderated by peer stress (Condition 2a). The second regression should establish that the path from maladaptive stress responses to depressive symptoms is moderated by peer stress (after adjusting for the main and interactive effects of a reduced posterior right hemisphere bias and peer stress; Condition 2b), and that the overall interactive effect of a reduced posterior right hemisphere bias and peer stress no longer significantly predicts depressive symptoms upon inclusion of maladaptive stress responses and the Maladaptive Stress Responses x Peer Stress interaction (Condition 2c; Muller et al., 2005).

A hierarchical multiple regression analysis was conducted to examine whether peer stress moderated the association between a reduced posterior right hemisphere bias and maladaptive stress responses (Condition 2a). W_1 depressive symptoms were entered in the first step, the mean-centered main effects of CFT scores and peer stress were entered in the second step, and the CFT x Peer Stress interaction was entered in the third step. Results revealed that peer stress moderated the effect of a reduced posterior right hemisphere bias on maladaptive stress responses (see Table 5, Regression 1). As reflected in Figure 2, decomposition of this interaction revealed that a reduced posterior right hemisphere bias was significantly positively associated with maladaptive stress responses in girls who experienced high levels of peer stress ($\beta = .62$, $t(41) = 3.20$, $p < .01$) but not in girls who experienced medium ($\beta = .22$, $t(41) = 1.88$, *ns*) or low ($\beta = -.18$, $t(41) = -1.29$, *ns*) levels of peer stress.

Next, a hierarchical multiple regression analysis was conducted to examine whether peer stress moderated the effect of maladaptive stress responses on depressive symptoms (after adjusting for the main effects of CFT scores and peer stress, and the CFT x Peer Stress interaction) (Condition 2b). W_1 depressive symptoms were entered in the first step. The mean-centered main effects of CFT scores and peer stress were entered in the second step; the CFT x Peer Stress interaction, the mean-centered main effect of maladaptive stress responses, and the Maladaptive Stress Responses x Peer Stress interaction were entered in the third step. Consistent with Condition 2b, results revealed a significant Maladaptive Stress Responses x Peer Stress interaction (see Table 5, Regression 2). As reflected in Figure 3, decomposition of the interaction revealed that maladaptive stress responses were

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significantly associated with depressive symptoms in girls who experienced high ($\beta = .31$, $t(40) = 2.48$, $p < .05$), but not medium ($\beta = .09$, $t(40) = .79$, *ns*) or low ($\beta = -.14$, $t(40) = -1.11$, *ns*), levels of peer stress.

Finally, the residual effect of the CFT x Peer Stress interaction on depressive symptoms was examined after including maladaptive stress responses and the Maladaptive Stress Responses x Peer Stress interaction (Condition 2c). Results revealed that the CFT x Peer Stress interaction no longer significantly predicted depressive symptoms after including maladaptive stress responses and the Maladaptive Stress Responses x Peer Stress interaction (see Table 5, Regression 2).

Thus, evidence was obtained for the moderating influence of peer stress on the associations between (a) a reduced posterior right hemisphere bias and depressive symptoms, (b) a reduced posterior right hemisphere bias and maladaptive stress responses, and (c) maladaptive stress responses and depressive symptoms (i.e., a total effect moderation model; Edwards & Lambert, 2007). Specifically, these three paths of interest were positive and significant in girls who experienced high, but not low, levels of peer stress. Accordingly, the mediating role of maladaptive stress responses in the association between a reduced posterior right hemisphere bias and depressive symptoms was examined in girls who experienced high levels of peer stress (Edwards & Lambert, 2007). Consistent with mediation, the indirect effect (IE; Sobel, 1982; 1986) was significant (IE = .19, $Z = 1.96$, $p = .05$). In addition, the effect proportion (indirect effect/total effect; Shrout & Bolger, 2002) indicated that maladaptive stress responses accounted for 41% of the total effect of a reduced posterior right hemisphere bias on subsequent depressive symptoms in girls who experienced high levels of peer stress. Overall, these findings support the hypothesis that maladaptive stress responses accounted for the association between a reduced posterior right hemisphere bias and subsequent depressive symptoms in girls experiencing high, but not low, levels of peer stress.

Discussion

Building on past descriptive research documenting associations between atypical posterior right hemisphere functioning and depression, the goals of the present study were (a) to examine sex differences in the contribution of a reduced posterior right hemisphere bias to depression, and (b) to identify interpersonal factors that account for this link. Results supported the hypothesis that a reduced posterior right hemisphere bias during the processing of facial expressions would predict subsequent depressive symptoms over time. As expected, maladaptive responses to interpersonal stress, in the form of dampened engagement coping and heightened involuntary responses, partially accounted for this longitudinal association. Further, consistent with theory and research suggesting sex differences in rates of hemispheric maturation, the conditions under which this mediational process held varied across boys and girls. Collectively, these findings are the first to link neuropsychological performance, interpersonal functioning, and the development of depressive symptoms over time in youth.

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Maladaptive Stress Responses as a Mediating Mechanism

The observed link between a reduced posterior right hemisphere bias and subsequent depressive symptoms is consistent with prior concurrent evidence (Bruder et al., 2005; Flynn & Rudolph, 2007), and extends this area of research by suggesting that this bias confers vulnerability to youth depression over time (for a similar longitudinal finding in adults, see Voelz et al., 2001). Results also supported the proposed process model, wherein maladaptive interpersonal stress responses, in the form of dampened engagement coping and heightened involuntary responses, partially accounted for the association between a reduced posterior right hemisphere bias and depressive symptoms over time. Evidence for this mediational process replicates findings from a previous study (Flynn & Rudolph, 2007), and extends this research by demonstrating that this process model holds over time. A reduced posterior right hemisphere bias during the processing of facial expressions is linked to difficulties in identifying and processing emotions (Berenbaum & Prince, 1994; Flynn & Rudolph, 2008; Lane et al., 1995). Thus, it is not surprising that youth who display this bias show less adaptive self-regulation in response to interpersonal stress, resulting in heightened depressive symptoms. Notably, a series of exploratory analyses revealed that this mediational process was specific to the onset of depressive symptoms, as opposed to symptoms of anxiety or externalizing psychopathology.

Sex Differences in the Mediational Process

This study also advances previous research by exploring sex differences in the contribution of a reduced posterior right hemisphere bias to maladaptive interpersonal stress responses and depressive symptoms. Drawing from theory and research suggesting that boys experience an earlier and more rapid maturation of the right hemisphere than do girls during childhood (Ehrlich et al., 2006; Geschwind & Galaburda, 1985; Grossi et al., 1979; Levine et al., 1999; Levy & Heller, 1992; Orsini et al., 1981), we proposed that boys may rely more heavily than girls on this hemisphere for information processing, thereby strengthening associations between a reduced right hemisphere bias and socioemotional difficulties in boys. In contrast, girls' slower maturation of the right hemisphere during childhood may lead them to develop a left-hemisphere advantage and to rely more heavily on left-hemisphere driven (e.g., verbal) strategies during information processing (Cioffi & Kandel, 1979; Levy & Heller, 1992; Shucard et al., 1981). Consequently, under optimal conditions girls may be able to compensate somewhat for a reduced right hemisphere bias when processing emotions. However, a reduced bias may exert an adverse effect on girls' socioemotional functioning when their typical information-processing strategies become overloaded, for instance, by heightened exposure to stress. Consistent with these ideas, a reduced posterior right hemisphere bias predicted subsequent maladaptive interpersonal stress responses and depressive symptoms in boys. In contrast, the contribution of a reduced posterior right hemisphere bias to subsequent maladaptive interpersonal stress responses and depressive symptoms was apparent in girls only following exposure to heightened peer stress.

Interestingly, for girls experiencing low levels of stress, a reduced posterior right hemisphere bias was significantly negatively associated with depressive symptoms. Perhaps under conditions of low stress, girls with a reduced posterior right hemisphere bias display

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more gender normative left-hemisphere driven behaviors that buffer them from depressive symptoms. For instance, girls with a left hemisphere preference may be more apt to draw on verbally based problem-solving skills, such as talking through conflicts, requesting advice, or discussing their emotional distress with others; these strategies may be effective when girls' are not overwhelmed by high levels of stress.

Although this interpretation is admittedly speculative, it is consistent with theory and research on sex differences in hemispheric maturation (Cioffi & Kandel, 1979; Ehrlich et al., 2006; Geschwind & Galaburda, 1985; Grossi et al., 1979; Levine et al., 1999; Levy & Heller, 1992; Orsini et al., 1981; Shucard et al., 1981). Moreover, a similar sex-linked pattern of hemispheric maturation emerged in our own sample. Specifically, a significant Age x Sex interaction for CFT scores ($\beta = -.39$, $t(91) = -2.58$, $p < .05$) revealed that age was significantly negatively associated with a reduced posterior right hemisphere bias in girls ($\beta = -.40$, $t(44) = -2.92$, $p < .01$) but not in boys ($\beta = .15$, $t(47) = 1.06$, *ns*)[1]. Examination of the specific pattern of development revealed that boys showed a strong bias toward the right hemisphere independent of age whereas girls became increasingly lateralized toward the right hemisphere with age. As a result, younger girls were more lateralized toward the left hemisphere than younger boys but older girls and boys showed similar lateralization toward the right hemisphere. Although the sex difference in lateralization disappears by adolescence, girls' history of employing left-hemisphere driven information-processing strategies may persevere even after maturation of right-hemisphere driven strategies, and may compensate for a reduced posterior right hemisphere bias when processing emotions. Of course, replication of these findings is needed to provide additional support for these proposed processes.

The present findings also are consistent with developmental patterns of sex differences in depression. During preadolescence, research shows either equivalent rates of depression in boys and girls, or a slight tendency toward higher rates in boys (Nolen-Hoeksema, Girgus, & Seligman, 1991; for a review see Nolen-Hoeksema & Girgus, 1994). During adolescence, a robust sex difference emerges, such that girls show significantly higher rates than boys (Hankin & Abramson, 2001). Given that the progression through adolescence is particularly challenging for girls (for a review, see Rudolph, in press), a reduced posterior right hemisphere bias may emerge as one of a package of vulnerabilities that interact with the stressors of adolescence to predict heightened depression in girls.

Caveats and Future Directions

Although the present findings are consistent with research indicating sex differences in rates of hemispheric maturation, little is known about the precise factors that influence hemispheric development across childhood and adolescence. Given that sex differences emerge during infancy and remain until adolescence (for a review, see Levy & Heller, 1992), it is possible that genetic or biological influences contribute to hemispheric

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[1]To investigate whether other markers of development yielded a similar pattern of findings, moderation analyses also were conducted using indices of pubertal status; the pattern of findings replicated those for age. We also examined whether age or pubertal status moderated the prior findings. Analyses revealed that neither age nor pubertal status significantly moderated the CFT x Peer Stress x Sex interaction to predict depressive symptoms over time.

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development. However, as theorized by Levy and Heller (1992), the development of skills associated with hemispheric maturation is likely to influence children's self-initiated environmental experiences. In turn, these different experiences may influence subsequent hemispheric maturation. Consistent with the idea that experiences influence hemispheric development, a twin study revealed that CFT scores were predicted by non-shared environmental factors (Valera, Heller, & Berenbaum, 1999). One goal of future research should be to examine the transactions between children and their environments that guide the development of neuropsychological processes.

To conclude, limitations of this study warrant attention. Although results reached statistical significance, the effect sizes were small to medium (Cohen, 1992). Moreover, maladaptive interpersonal stress responses only partially mediated the association between a reduced posterior right hemisphere bias and depressive symptoms, suggesting that alternate pathways also may account for this association. As suggested earlier, a reduced posterior right hemisphere bias likely interferes with emotion processing, leading to an inability to identify and interpret emotional cues. One might imagine that these emotion processing deficits could lead to a variety of difficulties other than maladaptive stress responses, such as the inability to empathically engage with others and to form adaptive relationships, which also may increase vulnerability to depression. In addition, although analyses adjusted for prior depressive symptoms, they did not adjust for prior exposure to stress. It is possible that exposure to a variety of stressors, such as maltreatment, environmental trauma, or parental psychopathology, influences the development of hemispheric asymmetry, interpersonal stress responses, and depressive symptoms. Future research would therefore benefit from the exploration of other possible mediating processes, as well as other potential moderators of these pathways.

Finally, two measurement issues deserve mention. First, stress responses and depressive symptoms were both assessed using self-report, which might have inflated findings due to shared method variance; future research would be strengthened by the use of multiple informants. Second, although multiple lines of research provide evidence that performance on the CFT engages posterior right hemisphere functioning, CFT scores provide an imprecise index of posterior right hemisphere activity and could be a function of interactions with anterior regions of the brain that have been linked to depression (e.g., Henriques & Davidson, 1991). The direct measurement of posterior right hemisphere activity using neuroimaging or electrophysiological methods, as well as the examination of its interactions with anterior brain regions, would provide a more precise and integrative perspective on the links among right hemisphere functioning, responses to interpersonal stress, and depressive symptoms.

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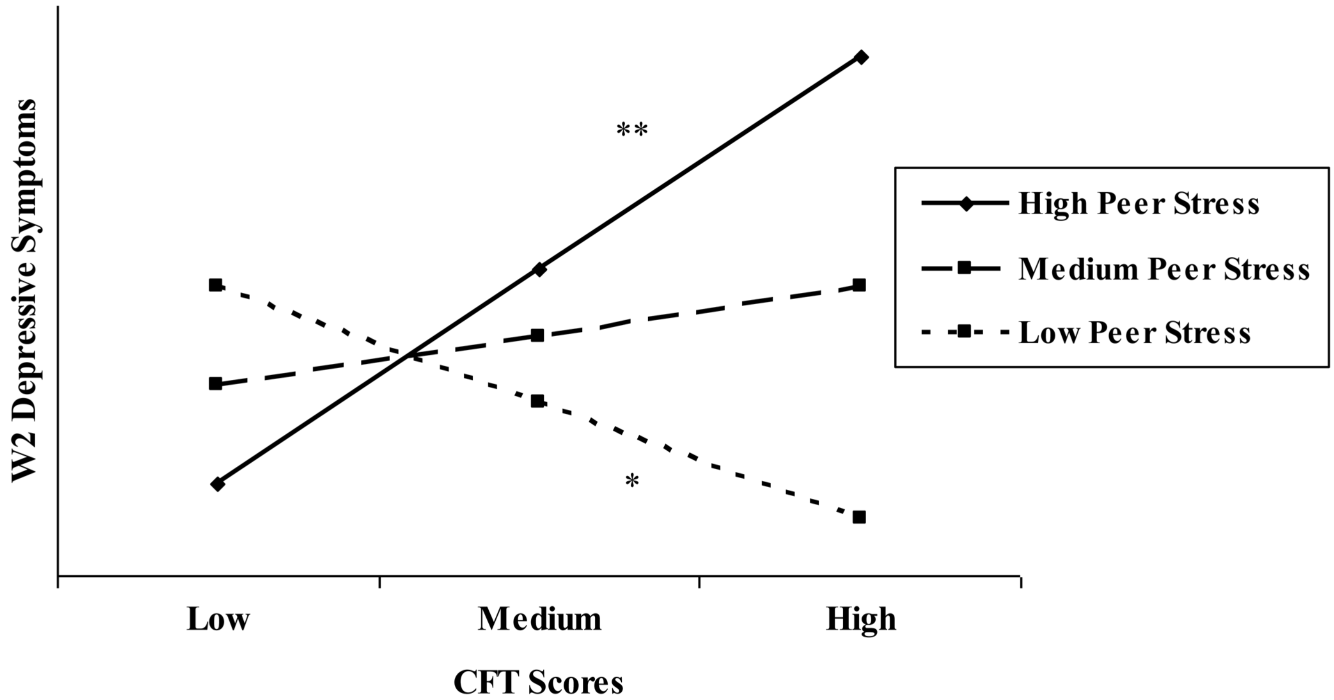

Figure 1.

Graph of the CFT x Peer Stress interaction displaying predicted values of W_2 depressive symptoms in girls (N = 46). *p < .05. **p < .01.

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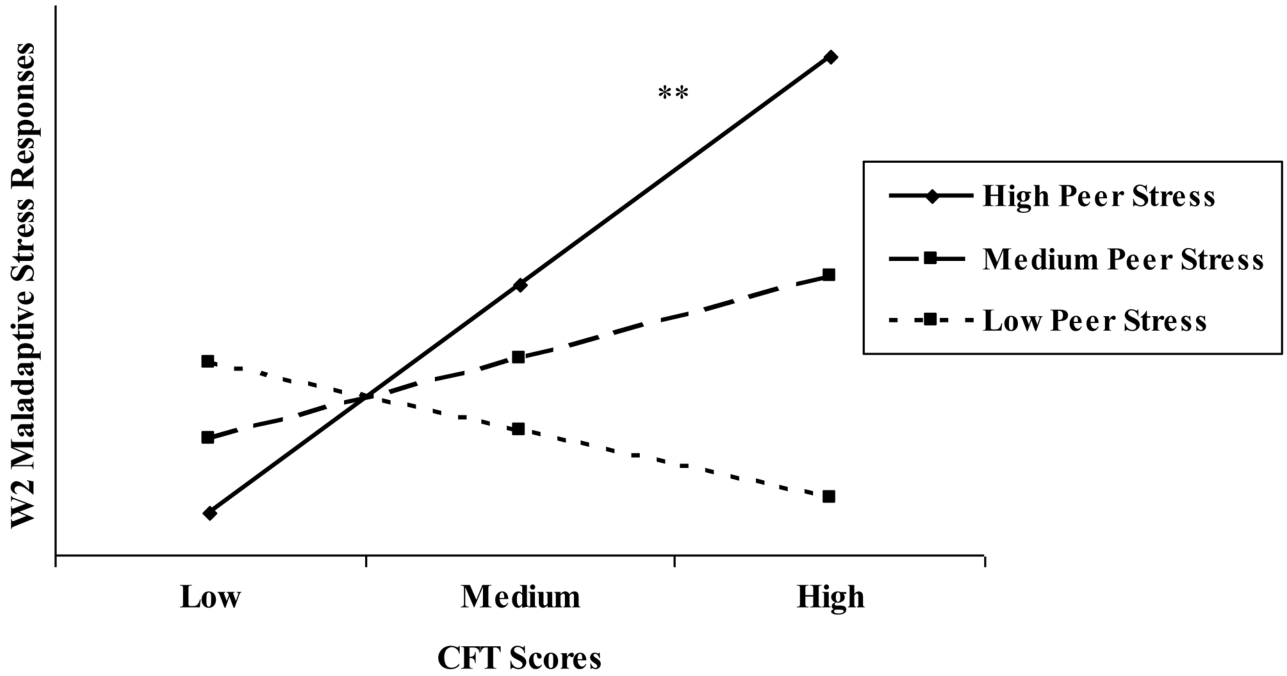

Figure 2.
Graph of the CFT x Peer Stress interaction displaying predicted values of W_2 maladaptive responses to stress in girls (N = 46). **p < .01.

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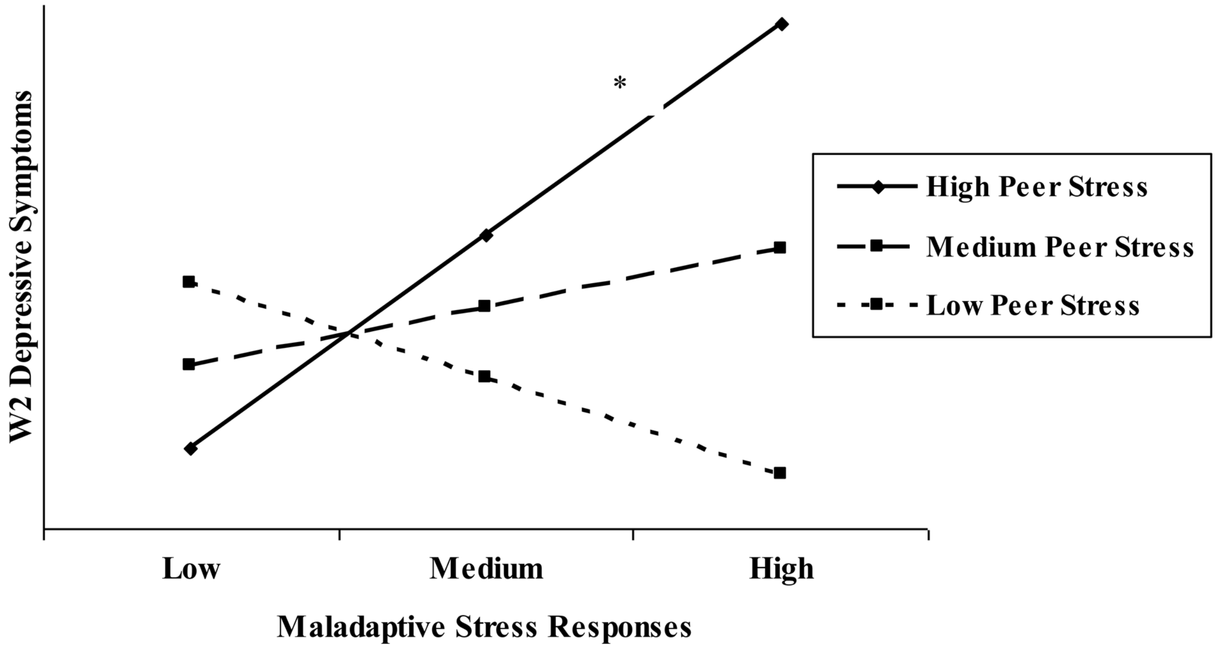

Figure 3.
Graph of the Maladaptive Stress Responses x Peer Stress interaction displaying predicted values of W_2 depressive symptoms in girls ($N = 46$). $^*p < .05$.

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Table 1

Descriptive Information on All Measures

Measures	Boys		Girls	
	Range	***M (SD)***	**Range**	***M (SD)***
W_1 CFT Scores	−1.00 – .78	−.43 (.43)	−.89 – .67	−.33 (.38)
W_1 Depressive Symptoms	.00 – 15.00	3.93 (3.86)	.00 – 26.00	5.30 (5.66)
W_2 Depressive Symptoms	.00 – 17.00	3.57 (4.31)	.00 – 35.00	4.87 (7.39)
W_2 Engagement Coping	.34 – .59	.48 (.07)	.27 – .66	.50 (.08)
W_2 Involuntary Engagement	.15 – .32	.22 (.05)	.14 – .34	.22 (.05)
W_2 Involuntary Disengagement	.12 – .23	.16 (.03)	.10 – .23	.15 (.03)
$W_{1–2}$ Peer Stress	.00 – 18.50	2.93 (3.70)	.00 – 12.50	2.68 (2.85)

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Table 2

Intercorrelations Among the Variables

Measure	**1**	**2**	**3**	**4**	**5**
1. W_1 CFT Scores	----	.08	.19	.10	.20
2. W_1 Depressive Symptoms	.11	----	.55**	.74**	.48**
3. W_2 Maladaptive Stress Responses	.30*	.47**	----	.62**	.53**
4. W_2 Depressive Symptoms	.31*	.70**	.64**	----	.55**
5. W_{1-2} Peer Stress	−.02	.17	.29*	.18	----

* $p < .05$.

** $p < .01$.

Note. Intercorrelations presented above the diagonal are for girls; intercorrelations presented below the diagonal are for boys.

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Table 3

Predicting Depressive Symptoms Over Time From CFT Scores, Peer Stress, and the CFT x Peer Stress Interaction

Predictors		Boys (N = 49)			Girls (N = 46)		
		β	t	ΔR^2	β	t	ΔR^2
Step 1	W_1 Depressive Symptoms	.70	6.74***	.49***	.74	7.30***	.55***
Step 2	W_1 CFT Scores	.24	2.37*		−.00	−.01	
	$W_{1–2}$ Peer Stress	.07	.66	.06$^{\wedge}$	.26	2.24*	.05$^{\wedge}$
Step 3	W_1 CFT Scores x $W_{1–2}$ Peer Stress	−.07	−.67	.01	.34	3.63**	.10**

$^{\wedge}$ $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Note. βs and *t*s represent standardized coefficients and *t* statistics at each step; ΔR^2 represents percent of variance accounted for at each step.

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Table 4

Examination of Mediation in Boys (N = 49)

Predictors		***B***	***t***	**Δ*R*²**
W_2 Depressive Symptoms				
Step 1	W_1 Depressive Symptoms	.70	6.74***	.49***
Step 2	W_1 CFT Scores	.24	2.36*	.06*
W_2 Maladaptive Stress Responses				
Step 1	W_1 Depressive Symptoms	.47	3.61**	.22**
Step 2	W_1 CFT Scores	.25	2.00*	.06*
W_2 Depressive Symptoms				
Step 1	W_1 Depressive Symptoms	.70	6.74***	.49***
Step 2	W_1 CFT Scores	.15	1.55	
	W_2 Maladaptive Stress Responses	.36	3.38**	.15***

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Note. βs and *t*s represent standardized coefficients and *t* statistics at each step; ΔR^2 represents percent of variance accounted for at each step.

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Table 5

Examination of Mediation in Girls (N = 46)

	Predictors	B	t	ΔR^2
Regression 1				
W_2 Maladaptive Stress Responses				
Step 1	W_1 Depressive Symptoms	.55	4.31**	.30***
Step 2	W_1 CFT Scores	.10	.81	
	W_{1-2} Peer Stress	.32	2.32*	.10*
Step 3	W_1 CFT Scores × W_{1-2} Peer Stress	.38	3.28**	.13**
Regression 2				
W_2 Depressive Symptoms				
Step 1	W_1 Depressive Symptoms	.74	7.30***	.55***
Step 2	W_1 CFT Scores	.00	−.01	
	W_{1-2} Peer Stress	.26	2.24*	.05^
Step 3	W_1 CFT Scores x W_{1-2} Peer Stress	.11	.99	
	W_2 Maladaptive Stress Responses	.09	.79	
	W_2 Maladaptive Stress Responses × W_{1-2} Peer Stress	.35	3.61**	.18***

^ $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Note. βs and *t*s represent standardized coefficients and *t* statistics at each step; ΔR^2 represents percent of variance accounted for at each step.