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Multiple Levels of Analysis of the Positive Affect System: Relation to Depressive Symptoms in Parents and Children

Sherryl H. Goodman

psysg@emory.edu

Emory University

Judy Garber

Vanderbilt University

Yuk Fai Cheong

Emory University

Katherine Cullum

Emory University

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Abstract

The positive affect (PA) system includes multiple features (e.g., hedonic, behavioral, motivational, and physiological) that are associated with depressive symptoms in youth and may serve as important mechanisms underlying depression. Examining associations between each feature with each other and with depressive symptoms can provide important information about the PA system and its link to mood disorders. Moreover, studying these relations in children who vary in risk of depression may provide information about vulnerabilities underlying depression. This study examined these questions in a sample of 8- to 10-year-old (*M* = 9.34; *SD* = 0.85) children of mothers with and without a depression history. Correlational analyses revealed significant associations among some PA features; these associations were not moderated by mothers' depression history. One PA feature, lower motivation, was associated with higher depressive symptoms in children, and this association was specific to offspring of mothers with a depression history. Regardless of mothers' depression history, children's higher depressive, but not anxiety, symptoms correlated with less adaptive mood repair. Overall, the mixed levels of association across the measures of PA provide only partial evidence of convergence of these features of the positive affect system, with a limited role of children's current depression level and mothers' depression history.

Introduction

Alterations in positive affect systems play a key role in the emergence of depressive symptoms in youth, as conceptualized within affective neuroscience and developmental psychopathology (Forbes & Dahl, 2005; Olino et al., 2016). Positive affect (PA) typically is understood to consist of several features including affective state (i.e., subjective experience of positive mood or pleasure), behavior (e.g., reward seeking or positive emotional expressivity), motivation (e.g., the anticipation of a positive outcome), and physiology (e.g., resting parasympathetic nervous system activity, indexed by respiratory sinus arrhythmia [RSA]) (Davidson et al., 1994; Forbes & Dahl, 2005; Gross et al., 2000; Ramsey & Gentzler, 2015). Each individual feature has been associated with depressive symptoms in youth (Forbes et al., 2007; Griffith et al., 2023; Hayden et al., 2006; Khazanov & Ruscio, 2016; Zhang et al., 2017). As specified by Forbes and Dahl, and Olino et al., these features reveal potential vulnerabilities to the development of depression, which are especially a concern among at risk samples of youth (e.g., those whose mothers have a history of elevated depression symptom levels). Moreover, several researchers have conceptualized these positive affect features as functioning as a system, including approach (relative to withdrawal) emotions or temperament (Davidson et al., 1990), behavioral/social activation or approach systems (Gray, 1990), positive valence systems within RDoC (Olino, 2016; PVS Work Group, 2011), and neural systems of positive affect (Forbes & Dahl, 2005).

Less is known, however, regarding the extent to which the various PA features are interrelated. Correlations among the features would be consistent with the notion of a positive affect system in that the processes may work not only individually but also together in the service of maintaining adaptive behavior, suggesting the importance of considering multiple features in research and practice. Conversely, finding that the features are not correlated may mean that they represent distinct and possibly independent measures of positive affect; if so, then an incremental variance approach might be appropriate for testing their unique

contributions to the prediction of depression (Dang et al., 2020). The first aim of this study was to examine the degree of association among positive affect features measured with multi-method approaches to evaluate empirical support for a positive affect system in children.

Several conceptual perspectives and empirical findings provide a compelling rationale for examining convergence across positive affect features. For example, developmental psychopathologists have highlighted the importance of integrating multiple levels of analysis in studies of psychopathology (e.g., Beauchaine & Hinshaw, 2020; Cicchetti, 2008). Beauchaine and Hinshaw reviewed evidence that modeling "multiple interactive functional dimensions of behavior" is the best approach to understanding the development of psychopathology. Similarly, the Research Domain Criteria (RDoC) framework emphasizes exploring multiple domains of functioning and asserts that the understanding of mental health will be strengthened by incorporating the major domains of neurobehavioral functioning (Cicchetti, 2008; Cuthbert, 2014; Franklin et al., 2015). Bauer, Quas, and Boyce (2002) likewise noted the importance of investigating associations between physiological and behavioral systems. De Los Reyes and colleagues also have emphasized the need to determine the degree of correspondence among various units of analysis (De Los Reyes & Aldao, 2015; De Los Reyes et al., 2020) .

Despite the considerable conceptual rationale for exploring convergence across the various components of positive affect and the recognition of the potential utility of examining such convergence (e.g., Olino et al., 2016), empirical tests of the strength of these associations is limited. Evidence exists of correspondence between two or three positive affect domains, such as physiological (resting RSA) with trait-level positive affectivity and positive emotional expressivity (self-reported) (Calkins, 1997; Oveis et al., 2009; Wang et al., 2013). Children's higher baseline RSA has been found to prospectively predict greater emotion regulation (Gottman & Katz, 2002), indicating that RSA reflects a physiological capacity to regulate positive emotions and suggesting a similar skill across these two levels of measurement.

Many of these studies, however, have been with very young children (Calkins, 1997) or young adults (Oveis et al., 2009; Wang et al., 2013), and typically have been in general population samples, rather than in individuals at risk of depression.

Further, developmental psychopathologists have argued to expect only small to moderate convergence across domains; small effect sizes likely are due to complex, interdependent factors underlying psychopathology, and to differences across units of analysis corresponding to the diverse domains, i.e., between-unit variability (Beauchaine & Hinshaw, 2020; De Los Reyes et al., 2020). This may be particularly true for associations between self-report measures, which emphasize between-person contrasts, and behavioral measures, which emphasize within-person contrasts of the same construct and essentially measure different response processes (Dang et al., 2020). For comparison, in a test of the connections among units of analysis in the RDoC's Social Processing Domain, Clarkson and colleagues (2020) found minimal evidence of correspondence among pairs of units. Moreover, researchers have failed to find evidence of an underlying positive valence system as conceptualized by RDoC when measuring variables across different units of analysis (self-report, behavioral, physiological, and neural circuits) among adults with clinically significant mood and anxiety symptoms (Peng et al., 2021). Thus, given that a reasonable

case can be made both for and against finding convergence across the various domains of positive affect, our primary aim (Question 1) was to determine the strength of the associations between distinct indices of positive affect in children at varied risk for depression.

Following the seminal review by Forbes and Dahl (2005) and later replication and extension by Olino et al. (2016), we conceptualized the positive affect system as being composed of four features – physiological, hedonic, behavioral, and motivational. Physiological functioning relevant to PA can be measured by respiratory sinus arrhythmia (RSA), i.e., the amount of heart rate variability in the respiration cycle, which is the most studied index of parasympathetic nervous system (PNS) functioning (Porges, 2021). Resting RSA (also known as tonic RSA or vagal tone) captures individuals' physiological ability to socially engage, with higher values reflecting stronger positive emotional capacity. Lower resting RSA has been found to predict depression symptoms in children and adolescents (Mezulis et al., 2015; Vazquez et al., 2016; Zhang et al., 2017) and thus, may be a vulnerability to depression. Resting RSA is empirically associated with trait positive affect and positive emotionality (Oveis et al., 2009; Wang et al., 2013), which may be explained by polyvagal theory in that RSA (indexing the myelinated vagus) supports social engagement, which then facilitates positive emotions (Porges, 2011, 2021). Further support for resting RSA as an index of PA comes from studies showing that higher resting RSA has been found in infants and toddlers with higher positive emotionality (Shin et al., 2024) and in young children whose mothers were observed to be more positively emotionally responsive (Delgadillo et al., 2021).

The hedonic domain refers to the capacity to experience pleasure, which, as the opposite of anhedonia, is considered critical to understanding depression. Given the subjective nature of the hedonic domain, it typically has been measured with self-report. Although self-report measures have been criticized, in part, because they are subject to demand characteristics, they provide a face-valid measure of the positive valence of an experience (Harmon-Jones & Harmon-Jones, 2021).

The behavioral domain of PA measured here included two constructs. First, children's frequency and intensity of engaging in pleasant experiences that provide opportunities for positive reinforcement (approach relative to withdrawal). We measured the frequency of children's engagement in and enjoyment of pleasant or rewarding activities (i.e., reinforcement density) with the Pleasant Events Schedule (PES; McPhillamy & Lewinsohn, 1982). The PES was derived from Lewinsohn's (1975) model that engaging in fewer positively reinforcing events is associated with the onset and maintenance of depression.

The second key behavioral aspect of PA assessed here was children's intentional engagement in behavioral strategies to restore positive affect when it is lost or threatened. The *Feelings and Me – Child Version (FAM-C)* measures behavioral strategies that children use to restore positive affect after a stressful or disappointing experience; that is, they explicitly downregulate dysphoric affect to restore positive affect.

The motivational feature of PA refers to children's willingness to work for rewards. Reduced reward functioning has been proposed to be an index of a vulnerability to depression (Hasler et al., 2004; Kujawa et al., 2020). Motivational PA is conceptualized as children's anticipation of reward, motivation to obtain reward (approach motivation), and expectation of reward (anticipatory anhedonia). We used an effort discounting task, which is a behavioral measure of how, as the effort required for reward increases, the

perceived value of the reward may decrease, thereby decreasing motivation or drive to attain the reward (Wilson & Gratz, 2016). Effort discounting tasks are conceptualized as measures of reward motivation, approach behavior, or reward sensitivity, all of which are key to the construct of PA (Roane, 2008).

Each feature of positive affect individually has been found to be concurrently associated with depression or is a vulnerability to later depression, although typically only one feature of positive affect at a time has been tested for associations with depression. Therefore, our second aim (Question 2) was to examine in a single study the associations of the four features of positive affect with children's depressive symptom levels. Further, as a test of specificity to depression, we also examined associations with anxiety symptoms. According to the tripartite model of depression, high negative affect characterizes both depression and anxiety, whereas low positive affect is specific to depression (Klein et al., 2013). Therefore, we expected positive affect features to be associated with depression but not anxiety.

Finally, we explored whether the strength of the hypothesized relations among the variables differed by mothers' depression history. Maternal depression is associated with elevated risk for the development of depression in their offspring (Goodman et al., 2011). Particularly concerning is that depression in women is three times more prevalent than in men (Kessler, 2006) and, in heterosexual households, women spend more time than men as child caregivers (National Alliance for Caregiving and AARP, 2009). Thus, children have ample opportunities to be exposed to their mothers' more negative and less positive affect (anhedonia), lower motivation, and other symptoms relevant to positive affect. Such exposure may facilitate the intergenerational transmission of depression through modeling or mothers' less positive parenting behaviors. Children of depressed mothers also may have acquired dysfunctional neuroregulatory mechanisms through early (especially prenatal) exposures or having inherited or acquired, via epigenetic changes, vulnerabilities to depression that may express themselves as low positive affect in multiple domains (Goodman, 2020).

Depression in mothers has been found to be associated with lower positive affect in offspring in several domains of the positive valence system. That is, offspring of depressed mothers show lower self-reported positive affect (McMakin et al., 2011; Olino et al., 2011), reduced reward functioning (Olino et al., 2014), challenges with mood repair (Daches et al., 2019), slower development of emotion regulation (Blandon et al., 2008), and lower resting RSA (Gentzler et al., 2012) relative to children of non-depressed mothers. Given that depression in mothers has been associated with various individual PA features in their children, we explored whether the components of PA hung together (i.e., as a system) more strongly among offspring of depressed mothers relative to children of nondepressed mothers.

In summary, our aims were to build on the published literature by determining, in a single study using a multi-method approach to measure four commonly recognized domains of positive affect, the strength of the associations between distinct indices of positive affect in children (Aim 1), the strength of associations of the four features of positive affect with children's depressive symptom levels (Aim 2), and whether the strength of the hypothesized relations among the PA variables in children differed by mothers' depression history. We addressed these questions in children between the ages of 8 and 10 years old who differed in whether their mother had a history of depression in the child's lifetime, i.e., children at varied risk of

depression. Middle childhood may be an important developmental period for exploring PA as a system in relation to elevated risk for depression in adolescence because even before the onset of depressive episodes, youth may show vulnerabilities to, or early signs of depression in the form of low positive affect features. Identifying such risk factors could guide the development of preventive interventions for vulnerable children (Costello et al., 2011; Klein et al., 2013; Wilcox & Anthony, 2004).

Method

Participants

A total of 131 women and their 8- to 10-year-old children (*M* = 9.34; *SD* = 0.85) enrolled in the study. This included 65 children of mothers who had a history of a depressive episode in the child's lifetime and 66 children of mothers with no history of a depressive disorder (controls). On average, mothers were 40 years old (*SD* = 6 years); about half the children (53%; n = 70) were female. The sample of mothers was 55% Caucasian, 31% African American, 4% Asian American, 1% Hispanic or Latino, and 9% did not specify their race or ethnicity. Forty-four percent of mothers had completed a graduate or professional degree. Seventy-nine percent of mothers were married and had a median household income of between $90,000 and $100,000. Table 1 presents the demographic characteristics, scores on the positive affect measures, and children's clinical symptom measures for the whole sample and by mothers' depression history.

Table 1

Demographic, positive affect domains, and clinical characteristics of the sample

Age (M; SD)	**Total Sample**	**Maternal Depression –YES**	**Maternal Depression – NO**	**Maternal Depression (Yes / No)**	**Test Statistic**	***p*[a]**	***p_FDR*[b]**
	9.36 (0.86)	**9.26 (0.82)**	**9.45 (0.88)**	**65 / 65**	***t* = 1.294**	**.198**	**0.826**
Gender (% Female)	54%	57%	51%	65 / 65	X^2 = .495	.482	0.826
Ethnicity (%) Hispanic/Latinx	.8%	1.5%	0%	65 / 65	--[c]	--	--
Race (%) Asian	3.8%	0%	7.7%	65 / 65	--[c]	--	--
Black/African American	31.5%	38.5%	24.6%				
White	54.6%	46.2%	63.1%				
Other	9.2%	13.8%	4.6%				
Respiratory Sinus Arrhythmia (RSA)	6.52 (1.14)	6.52 (1.20)	6.52 (1.09)	61 / 63	*t* = − .016	.987	0.987
Positive Affect (PANAS-C)	52.74 (9.46)	51.80 (10.58)	53.68 (8.17)	65 / 65	*t* = 1.132	.260	0.826
Effort Discounting, Highest Ratio	142.70 (47.67)	147.10 (43.05)	138.44 (51.74)	62 /64	*t* = -1.022	.309	0.826
Pleasure Frequency (PES)	420.35 (139.78)	425.49 (147.92)	415.22 (132.51)	65 / 65	*t* = − .417	.677	0.952
Emotion Regulation (FAM-C)	60.03 (17.77)	61.16 (19.41)	58.88 (16.00)	65 /64	*t* = − .727	.469	0.826
Children's Depression (SMFQ)	4.48 (4.28)	4.40 (4.59)	4.57 (3.99)	65 / 65	*t* = .224	.823	0.952
Children's Anxiety (SCARED)	22.18 (14.06)	22.52 (14.85)	21.83 (13.33)	65 / 65	*t* = − .280	.780	0.952
Mothers' PANAS (PA)	35.38 (7.88)	32.46 (8.16)	38.47 (5.84)	64 / 64	*t* = 4.789	< .001	0.012

Age (M; SD)	Total Sample	Maternal Depression –YES	Maternal Depression – NO	Maternal Depression (Yes / No)	Test Statistic	p^a	p_FDR^b
	9.36 (0.86)	9.26 (0.82)	9.45 (0.88)	65 / 65	t = 1.294	.198	0.826

RSA = Respiratory Sinus Arrhythmia, index of resting heart rate; PANAS-C = Positive and Negative Affect Schedule – Child version; Effort Discounting Task, highest ratio completed (how many presses); PES = Pleasant Events Schedule sum—the product of the frequency sum and the enjoyment sum; FAM-C = Feelings and Me – Child Version, AMBERR score = adaptive/maladaptive balance of emotion regulatory responses ratio; SMFQ = Short Mood and Feeling Questionnaire, SCARED = Screen for Child Anxiety Related Emotional Disorders

Notes: [a]*p* value corresponding to a two-sample *t*-test for continuous variables and a χ^2 test for categorical variables.

[b]*p* value reflecting false discovery rate (FDR) correction across the set of comparisons using the Benjamini–Hochberg procedure (Benjamini & Hochberg, 1995), which remains valid under common forms of dependence among tests (Benjamini & Yekutieli, 2001).

[c]Group differences for ethnicity and race were examined descriptively only, as several cells had expected frequencies below 5 (including cells with zero counts), violating assumptions of the chi-square test.

Recruitment

We recruited women and their children from two sites in the South and mid-South of the United States. Recruitment was from the university's Child Study Center database, the university's research listserv, Kaiser Permanente, referrals, and a birth record database. The study protocol was approved by the Institutional Review Boards at each site. Mothers provided written informed consent for themselves and their child to participate.

Eligibility was determined by a phone screen of the mother using a modified version of the Structural Clinical Interview for DSM-IV (SCID: First et al., 2002). Eligible dyads were mothers who, during their child's lifetime, either met diagnostic criteria for a depressive disorder or had no history of depression in the child's lifetime. Participants were excluded if the mother reported current suicidality, psychosis, or substance abuse, or had ever been diagnosed with bipolar I disorder or schizophrenia. Additional exclusion criteria were the child having a pervasive developmental disorder, intellectual disability, psychosis, autism, bipolar disorder, or had ever met criteria for major depressive disorder (MDD) or dysthymia (DYS) as determined by interviews with the mother. Monolingual, non-English speaking children were excluded. If multiple children in a family were in the age range, only one child was selected randomly to avoid non-independent data.

Procedure

Prior to coming to the lab, mothers were sent a link to complete an online survey. In the lab, the experimenter read a series of self-report questionnaires to the children who entered their responses on the

computer. During this time, an experimenter fastened electrodes to the child's chest and rib cage for the acquisition of RSA data.

Next, children listened to a 4-minute resting baseline audio recording (an instructional clip from a science textbook about plant adaptations to environments), during which RSA was recorded. Children then completed a computerized reward motivation task, which assesses changes in effort involved in the pursuit of a reward of fixed value (Forbes, personal communication, May 17, 2016). At the end of the visit, mothers received $40 and children were given a small toy and their earnings from the reward task (up to $6).

Measures

Mother Measures.History of Depression. Maternal history of depression was assessed using the depression module of the SCID-IV (First et al., 2002). Interviewers were trained graduate students supervised by the senior investigators (masked for review) who reviewed all information and made the final diagnosis of the presence or absence of a past depressive episode. Children whose mothers met diagnostic criteria for a depressive disorder during the child's lifetime comprised the at-risk participants. We included mothers who had at least one episode of depression during the child's life because that increased the likelihood of children being exposed to their mothers' more negative and less positive affect as well as other symptoms relevant to positive affect (e.g., anhedonia, low motivation). The comparison group included children whose mothers had no history of depression.

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) contains 20 words that describe different feelings and emotions; 10 words comprised the positive affect (PA) score. Mothers rated how much they had experienced each affect over the past week. Each item was rated on a 5-point Likert scale from 1 (not at all) to 5 (very much). In this sample, the omega coefficient for PANAS positive affect (PA) was .94. This measure of mothers' positive affect was included for descriptive purposes (see Table 1).

Child Measures of Positive Affect Domains

Physiological: Respiratory Sinus Arrhythmia (*RSA).* Child electrocardiograms (ECGs) were recorded from disposable electrodes while children listened to a 4-minute resting baseline audio recording (an instructional clip from a science textbook about plant adaptations to environments). Event markers were used to separate the resulting file into different segments (e.g., resting, negative). ECG signals were edited by trained research assistants using CardioEdit (Brain-Body Center for Psychophysiology and Bioengineering, 2022); RSA was computed using CardioBatch (Brain-Body Center for Psychophysiology and Bioengineering, 2016). Consistent with Kovacs, Yaroslavsky et al. (2016), we used average RSA across the first resting segment as the index of resting heart rate.

Hedonic: Positive Affect State. The Positive and Negative Affect Schedule for Children *(PANAS-C;* Laurent et al., 1999) is a 30-item child self-report measure of PA and NA. In the current study, we measured state PA with the PANAS-C, which assesses the extent to which children feel each adjective in the moment. We measured state, rather than trait, PA to be consistent with the timescale of the other PA measures. The

PANAS-C state positive scale consists of 15 items, with response options on a 5-point Likert scale (ranging from 1 = Not much or not at all, to 5 = A lot); the total score is the sum of items and could range from 15 to 45. Higher scores indicate higher levels of hedonic self-reported positive affect. Laurent et al. (2009) found that the PANAS-C yielded high internal consistency as well as good convergent and divergent validity. For the current sample, internal consistency with a McDonald's omega estimate calculated using the lavaan package in R (Rosseel, 2012) was .795. McDonald's omega is recommended for computing internal consistency, in contrast to Cronbach's alpha, as it does not assume tau-equivalence (i.e., all items have the same true score variance and factor loadings; that is, each item has an equal contribution to the measurement of the underlying construct).

Behavioral. We used two measures to capture the behavioral domain of positive affect. First, the **Pleasant Events Schedule** focused on engaging in rewarding behaviors, especially social interactions. Second, the **Feelings and Me – Child Version (FAM-C)** measures behavioral strategies to restore positive affect after a stressful or disappointing experience.

Pleasant Events Schedule (PES; MacPhillamy & Lewinsohn, 1982**)** is a 12-item measure that asks children to report the frequency of occurrence of recent behaviors (0 times, 1 time, 2 or more times) and how pleasant, enjoyable, or rewarding commonly pleasant events (e.g., listen to music; watch TV; play a game) were for them during the past month (0 = not, 1 = some, or 2 = very). The PES yields scores on the sum of the frequency ratings and sum of the enjoyability ratings, each divided by the number of items in the scale. The Obtained Pleasure score used in the analyses is the product of the frequency and enjoyability sums and is conceptualized as measuring total reinforcement density. The test-retest reliability of the PES over one to three months has ranged from 0.49 to 0.88 (MacPhillamy & Lewinsohn, 1982); the PES has been found to correlate significantly with another measure of positive events – the Behavioral Activation for Depression Scale (Manos et al., 2011). Internal consistency estimated with McDonald's omega for the PES in the current sample was = .65. This is consistent with other measures of life events that have found Cronbach's alpha to be modest, ranging from 0.67 to 0.71. Family life events scales yielded alphas ranging from 0.58 to 0.62, and the adolescent events scale has yielded alphas ranging from 0.50 to 0.54 (Wills et al., 1996). Thus, the internal consistency of the PES in this sample was within the range found for similar measures.

Feelings and Me – Child Version (FAM-C) (Bylsma et al., 2016; Kovacs et al., 2015; Kovacs et al., 2016; Tamás et al., 2007). The FAM-C was developed for 7- to 17-year-old children to assess mood repair response repertoires. The 30 questions ask children *what they do* when they are feeling "sad or upset," yielding a total Adaptive score, and 23 items yielding a total Maladaptive score (note: we excluded one item from the original scale that asked about taking pills or drugs or drinking alcohol). Each response represents behavioral (planned action), social-interpersonal (engaging with other people to relieve one's stress), cognitive (re-evaluation), and physical/somatic regulatory (self-soothing, eating) domains that are deployed when feeling sad or upset (Kovacs et al., 2009). There are three stems "When I feel sad or upset I: …" that are followed by a series of statements such as: "…throw, kick, or hit things." "The adaptive scale includes behaviors that are likely to downregulate dysphoric feelings (e.g., thinks about feeling better; listens to fun music; talks to family), whereas the maladaptive scale comprises responses that are likely to upregulate

dysphoric feelings (e.g., thinks about things being my fault; listens to sad music; yells and screams at family)" (Gentzler et al., 2009, p. 6).

Responses range from 0 = not true of me to 2 = many times true of me. The final score is the balance between Adaptive and Maladaptive Emotion Regulation Responses (AMBERR), with a potential range from 0% to 100%. The score reflects the extent to which the child engaged in behavioral strategies to repair mood that were dominated by adaptive regulatory responses. To compute AMBERR scores, items are first dichotomized so that the "Adaptive percent frequency" is 100 times the proportion of adaptive items that were rated "sometimes" or "often." For example, if a participant responded "sometimes" or "often" on 15 of 30 adaptive items, their adaptive frequency would be 50%. If the same participant endorsed 6 of 23 maladaptive items, their maladaptive frequency would be 26%. The AMBERR for this participant would be 100*26/(26 + 50) = 34. AMBERR scores above 65% characterize normative samples (Kovacs, personal communication, March 15, 2024). The AMBERR scores have good test-retest reliability over one year and construct validity regarding its relations to depressive symptoms and rumination in large clinical samples of youth (Tamás et al., 2007). The aggregated adaptive and maladaptive indices had strong internal consistency in the current sample (adaptive = .90; maladaptive = .83).

Motivation. The motivational domain of positive affect was assessed with the **Effort Discounting Task (EDT)**, which measures anticipation of reward, motivation to obtain reward (approach motivation), and attention to reward (anticipatory anhedonia). The EDT was developed for youth by Forbes (personal communication, May 17, 2016) based on similar effort/ motivation tasks used widely with adults (Chen et al., 2022; Roane, 2008; Wilson & Gratz, 2016). The Forbes EDT task for youth has no published reliability or validity, although Treadway et al. (2009) found in adults that EDTs are a reliable, valid, and objective measure of reward motivation that captures a key component of depression (Leonard et al., 2026; Treadway et al., 2012). Progressive ratio scheduled tasks measure reward motivation – the willingness to expend increasingly greater effort to obtain a set value reward, which in this case was quarters that the child could earn and keep. The task was programmed and administered in E-Prime 2.0. Sitting in front of a computer, the child was instructed to hit a key 10 times and then an additional 10 times on each subsequent trial. After each trial, they received a set monetary reward of 25 cents. The measure yields two scores: the highest ratio completed and total money earned, which were highly correlated, r (126) = .996, p < .001. To reduce redundancy and enhance interpretability of the findings, we used only one of the two scores – the highest ratio completed, which captures the amount of effort that a child exerted.

Depressive and Anxious Symptoms in Children

Short Mood and Feelings Questionnaire (SMFQ; Messer et al., 1995) was derived from a 34-item measure – the *Mood and Feelings Questionnaire* and is a 13-item child-report measure of affective and cognitive symptoms of depression, and feelings (e.g., miserable or unhappy) experienced over the past week. Each item is rated on a three-point scale (0 = Not true; 1 = Sometimes True; 2 = True); items are summed to yield a total score ranging from 0 to 26, with higher scores indicating higher levels of depressive symptoms.

The SMFQ has been shown to correlate with the Children's Depression Inventory (CDI) (Kovacs, 1992), and the Diagnostic Interview Schedule for Children (Costello et al., 1984) depression scale. The SMFQ discriminates depressed from non-depressed individuals in a general sample. Exploratory factor analyses have shown a one-dimensional factor structure with high internal consistency (Angold et al., 1995; Messer et al., 1995). Previous research has reported a coefficient alpha for the SMFQ of .86 (Karevold et al., 2009). In the current study, coefficient alpha was .84.

Screen for Child Anxiety Related Emotional Disorders- Revised (SCARED-R; Birmaher et al., 1999) consists of 41 items measuring DSM-IV-defined anxiety symptoms with response options on a 3-point scale (0 = not true or hardly ever true, 1 = somewhat true or sometimes true, 2 = very true or often true). The four separate DSM-IV linked subscales are panic disorder/ somatic (e.g., "When frightened my heart beats fast"), separation anxiety including school phobia (e.g., "I am scared to go to school"), generalized anxiety disorder (e.g., "I am a worrier"), and social anxiety (e.g., "I don't like to be with people I don't know"). Total scores are the sum of each subscale. Scores on the SCARED-R have been found to correlate positively with other childhood anxiety measures including the Revised Children's Manifest Anxiety Scale (r = 0.86), the Fear Survey Schedule for Children- Revised (r = 0.62), and r = 0.73 with the trait version of the State-Trait Anxiety Inventory for Children (Muris et al., 2001). In the current study, we conducted a reliability analysis on the 41 ordinal items using the *psych* package in R (Revelle, 2023), treating the items as ordinal and calculating McDonald's Omega Total (ωt) to assess internal consistency. A polychoric correlation matrix was used to account for the ordinal nature of the data. The omega ωt function from the *psych* package (Revelle, 2023) was used to compute an Omega Total. The estimate was 0.96, indicating excellent internal consistency across the items.

Data Analytic Strategy

Question 1 focused on the degree of association between each domain of positive affect (hedonic, behavioral, motivational, and physiological); we computed Pearson correlations to assess the relations between the individual domains. A correlation matrix provided an overview of the strength and direction of these associations (see Table 2). With a total sample of 130 participants (65 per group), we did not pursue latent variable modeling or tests of measurement invariance across the two groups. Estimating multidimensional factor structures and evaluating invariance typically requires large samples (e.g., several hundreds) to achieve stable and well-identified solutions (MacCallum et al., 1999). To test whether the associations among the positive affect domains differed by mothers' depression history we estimated interaction terms between maternal depression history and each of the 10 unique pairwise PA associations.

Table 2

Correlations among the positive affect domains (N = 131)

Respiratory Sinus Arrhythmia (RSA)	Resting Heart Rate (RSA)	Positive Affect (PANAS-C)	Effort Discounting (Highest Ratio)	Pleasure Frequency (PES)	Emotion Regulation (FAM-C)
	--				
Positive Affect (PANAS-C)	-0.029	--			
Effort Discounting (Highest Ratio)	0.120	-0.007	--		
Pleasure Frequency (PES)	-0.168	**0.309*****	0.038	--	
Emotion Regulation (FAM-C)	0.040	**0.206***	0.175~	**0.238****	--

~ p = .051; *p < .05; **p < .01; ***p < .001

RSA = Respiratory Sinus Arrhythmia, index of resting heart rate; PANAS-C = Positive and Negative Affect Schedule – Child version; Effort Discounting Task, highest ratio completed (how many presses); PES = Pleasant Events Schedule sum—the product of the frequency sum and the enjoyment sum; FAM-C = Feelings and Me – Child Version, AMBERR score = adaptive/maladaptive balance of emotion regulatory responses ratio.

Question 2 explored the relations between the PA domains and children's symptoms of depression and anxiety. We first calculated bivariate correlations between each PA domain and scores on depression (SMFQ) and anxiety (SCARED-R) symptoms. Partial correlation analyses were performed to examine the relations between depressive symptoms and PA domains controlling for anxiety symptoms. These analyses tested the specificity of the associations between PA domains and depression by removing the shared variance attributable to anxiety symptoms.

Finally, we conducted moderation analyses to determine whether the associations of each PA domain and children's depression varied as a function of maternal depression history. Interaction terms (e.g., PA domain × maternal depression history) were included in the regression models. Significant interactions were plotted to interpret the extent to which the relations between PA domains and children's depressive symptoms varied by risk (i.e., maternal depression history).

Results

Descriptive Analyses

Table 1 shows the demographic, positive affect measures, and clinical measures for the whole sample and separately by mothers' depression history. After false discovery rate (FDR) correction for multiple comparisons, mothers' positive affect (PANAS) differed significantly by depression history, with mothers

who had a history of depression reporting lower positive affect. No other group differences remained significant.

Associations among the Positive Affect Domains (Question 1)

Table 2 presents the correlations among the different positive affect domains. Higher child positive affect (PANAS-C) correlated significantly with the behavioral indices of enjoyment of positive activities (PES) and emotion regulation (FAM-C), which also correlated significantly with each other.

To test whether maternal depression history moderated associations among the positive affect (PA) domains, interaction terms between maternal depression history and each of the 10 unique pairwise PA associations were estimated. After controlling for multiple testing using false discovery rate (FDR) correction (Benjamini & Hochberg, 1995), none of the interaction effects were statistically significant. The smallest FDR-adjusted *p*-value across the 10 moderation tests was .34, indicating that associations among PA domains did not differ as a function of maternal depression history.

Associations among Positive Affect Domain Indices and Children's Depression and Anxiety Symptoms (Question 2)

Children's depression and anxiety symptom scores were correlated significantly with a large effect size, $r = -.65$, $p < .001$. Table 3 (top row) shows that higher depression symptoms on the SMFQ were significantly associated with lower scores on the motivation domain (Effort Discounting Ratio; $r = -.208$, $p = .02$) and less adaptive mood repair regulatory responses on the behavioral domain index of FAM-C AMBERR; $r = -.444$, $p < .001$). Children's depressive symptom levels were not significantly associated with the other positive affect features including physiology, hedonic, or the other behavioral index (Obtained Pleasure/PES).

Table 3

Correlations of the positive affect domains and depressive and anxious symptoms

Children's Depressive Symptoms (SFMQ)	**Resting Heart Rate (RSA)**	**Positive Affect (PANAS-C)**	**Effort Discounting (Highest Ratio)**	**Pleasure Frequency (PES)**	**Emotion Regulation (FAM-C)**
	− .081	**− .073**	**− .208***	**− .095**	**− .444*****
Children's Anxiety Symptoms (SCARED)	− .028	.057	− .108	− .022	**− .296*****

*p < .05; **p < .01; ***p < .001

SMFQ = Short Mood and Feeling Questionnaire, SCARED = Screen for Child Anxiety Related Emotional Disorders, RSA = Respiratory Sinus Arrhythmia, index of resting heart rate; PANAS-C = Positive and Negative Affect Schedule – Child version; Effort Discounting Task (motivation), highest ratio completed (how many presses); PES = Pleasant Events Schedule sum—the product of the frequency sum and the enjoyment sum; FAM-C = Feelings and Me – Child Version, AMBERR score = adaptive/maladaptive balance of emotion regulatory responses ratio.

The relation between Effort Discounting (EDT) and children's depressive symptoms was moderated by maternal depression history (see Fig. 1). The interaction between the EDT ratio (motivation) and mothers' history of depression (Yes or No) in predicting children's depressive symptoms (SMFQ) was significant, b = − 0.0368, se = 0.0158, t = − 2.33, p = .021, with a 95% confidence interval of [−0.0680, − 0.0056]. This interaction accounted for a significant proportion of additional variance in depressive symptoms, ΔR^2 = .041, $F(1, 122) = 5.45$, p = .021. For offspring of mothers with a history of depression, the relation between effort/motivation and children's depressive symptoms was significant $t(121) = -3.304$, p = .0012, but not for children of mothers with no depression history, $t(121) = -0.352$, p = .726. That is, among offspring of mothers with a history of depression, lower motivation was associated with higher depressive symptoms, whereas for children of mothers without a depression history the association between motivation and depressive symptoms was not significant. The interaction effect explains an additional 4.09% of the variance in children's depressive symptoms, ΔR^2 = .0409. Maternal depression history did not moderate the association between the other PA domains and children's depressive symptoms.

Specificity. In bivariate correlations (Table 3, second row), children's anxiety symptoms did not correlate significantly with any positive affect domain except emotion regulation (FAM-C; r = − .296, p < .001). To further test the specificity of the link between the positive affect domains and children's depression, we ran partial correlations to examine the strength of associations between each positive affect index and depression, controlling for anxiety. Higher depression symptoms on the SMFQ remained significantly associated with the behavioral domain (Fam-C AMBERR; r = .258, p < .004) when controlling for anxiety, but not with the motivation domain. When controlling for depression, the associations between anxiety and each positive affect domain were nonsignificant.

Discussion

Several interesting findings emerged from this study. First, there were significant associations among some features of children's positive affect system assessed with multi-method approaches, although not complete convergence across all measures; this pattern was robust to mothers' depression history. Second, children's higher levels of depressive symptoms, but not anxiety, were significantly associated with several, but not all positive affect domains; the association between children's depressive symptoms and their effort/motivation was significant for children whose mothers had been depressed and not for those of mothers with no depression history.

The primary aim of this study was to explore the associations among measures of the positive affect system – hedonic, behavioral, motivational, and physiological (Forbes & Dahl, 2005) in a sample of elementary school-aged children who varied in risk for depression as a function of their mother's history of depression. Based on published studies primarily with very young children, adolescents, or adults showing correspondence between two or three positive affect domains (e.g., Calkins, 1997; Oveis et al., 2009; Wang et al., 2013) as well as assertions by developmental psychopathologists that convergence across domains in children are likely to be low to medium (Beauchaine & Hinshaw, 2020; De Los Reyes et al., 2020), we predicted small, but significant associations among these domains of positive affect.

The correlations among the different PA measures revealed some convergence across measures. Higher positive affect (PANAS-C) correlated significantly with the behavioral indices of pleasure/enjoyment of positive activities (PES) and with emotion regulation (FAM-C), and these two behavioral indices correlated significantly with each other. Olino et al. (2016) similarly found significant correlations between positive affect and the experience of pleasure using a different measure of pleasure. These relations among the behavioral and hedonic measures of PA suggest that at least some positive affect processes may work not only individually, as found in studies that included only a single PA domain, but also together. Future studies might examine how additive, incremental, or interactive patterns of association among PA domains underlie or enhance children's adaptive behaviors and emotional health.

The present study, however, did not find significant correlations of the physiological index of resting heart rate – higher Respiratory Sinus Arrhythmia (RSA) – with the other PA domains. The study by Olino et al. (2016) did not include a physiological index of PA but rather focused on self-report measures. Future studies should use several measures of each positive affect domain to explore whether multiple underlying, latent positive affect constructs emerge, with physiological indices of PA possibly acting separately from other indices of PA.

The second aim of this study was to examine the extent to which each positive affect domain was associated with depressive symptoms in children. Previous research has shown that the various measures of the positive affect system are linked with depression in children (Forbes & Dahl, 2005; Olino et al., 2016). The current study found that children's elevated depressive symptoms were significantly associated with less adaptive emotion regulation on the FAM-C and with lower motivation on the effort discounting task, but not with the other indices of positive affect (i.e., RSA, positive affect, or pleasant events). Perhaps a more nuanced understanding of the link between elevated depressive symptoms in youth and positive affect, broadly defined, is needed. For example, how do elevated depressive symptoms contribute to children not

engaging in strategies to upregulate their dysphoric mood or to their lack of motivation to work towards a reward. Conversely, not regulating their negative affect or not seeking reward can perpetuate depressive symptoms. The direction of these cross-sectional associations needs to be determined to guide when and how best to intervene.

The relation between children's motivation and depression varied by maternal depression history. That is, among offspring of mothers with a history of depression as compared to offspring of mothers without a depression history, children's lower motivation was associated with higher depressive symptoms. Perhaps depressed mothers model anhedonia, disengagement, and reduced energy, which may result in children experiencing their own symptoms of depressed mood, low energy, diminished behavioral activation, or less optimism/hopefulness that would support higher motivation. Maternal depression history, however, did not moderate the correlations between children's depressive symptoms and the other positive affect domains. Thus, although mothers' history of depression was potentially important for understanding the relation between children's motivation and depressive symptoms, it was not a factor here regarding the link between children's depressive symptoms and the other positive affect domains. If replicated, this finding has implications for a more complex understanding of the intergenerational transmission of risk for depression. For instance, development and testing of preventive interventions that specifically target motivation in at-risk children (e.g., a prevention version of behavioral activation) would provide a more direct test of motivational deficits as one potential mechanism underlying risk in offspring of depressed mothers.

Regarding the specificity of the link between the positive affect system features and symptoms of depression versus anxiety, results showed that children's anxious symptoms only correlated with less adaptive mood repair but not with the other positive affect measures. As predicted, the partial correlations conducted to examine the strength of associations between each positive affect index and depression, controlling for anxiety, revealed that higher depressive symptoms remained significantly associated with more maladaptive mood repair regulation (Fam-C), but not with the other positive affect domains.

When accounting for children's depressive symptoms, the associations between anxiety and the positive affect domains were nonsignificant, which is consistent with the tripartite model (Clark & Watson, 1991; Klein et al., 2013) that proposes that high negative affect characterizes both depression and anxiety, whereas low positive affect is specific to depression. Although the strength of the correlations between the positive affect domains and children's depressive symptoms was small to moderate, the correlations with anxiety were small and mostly nonexistent. Thus, our findings on PA domains in relation to depression, relative to anxiety, support further study of the role of low positive affect in youth and the potential for testing interventions similar to positive affect treatment in adults with low positive affect, which is showing benefits on clinical status relative to comparison groups (Meuret et al., 2026).

Finally, we explored whether the associations among the positive affect domains differed for offspring of mothers with versus without a history of depression and found that mothers' depression history did not moderate the strength of the associations among the PA domains. Given the published studies showing lower PA in several individual domains for children whose mothers have been depressed relative to

controls, the current study was an important next step of testing whether the components of PA hang together (i.e., as a system) more strongly among children of depressed mothers relative to controls. Finding that the degree of association among PA domains did not vary as a function of maternal depression history might indicate that PA coherence is not a primary mechanism in the intergenerational transmission of depression. On the other hand, the mothers with depression in our sample, for the most part, were not currently in a depressive episode (although they had lower Positive Affect relative to controls). It is possible that a moderating effect of maternal depression on the correlations among the measures of positive affect in at-risk offspring might emerge in a sample of mothers with current, chronic, or more severe depression.

Strengths, Limitations, and Future Directions

A strength of the current study was the use of multiple methods to assess central features of the positive affect system. Measures of physiology, affect, motivation, and behavior represent several levels of analysis of the Positive Valence System in RDoC. The observed covariation among some positive affect measures is not likely explained simply by shared method variance (e.g., self-report).

Another strength of this study was the assessment and substantive test of maternal depression history when exploring the associations among the measures of the positive affect system and the correlations of the positive affect measures with depression in at-risk children. Of note was the finding that low motivation was linked with depressive symptoms among offspring of mothers with a history of depression but not children of mothers with no depression history. Given the heterogeneity of depression, future studies should examine different aspects of maternal depression (e.g., timing, duration, severity, comorbidity) when exploring the relations among the components of the positive affect system with each other and with depression in children. Moreover, because anxiety is highly correlated with depression, future studies should examine the specificity of our findings to depression in the mothers.

Limitations of the study should be noted as they highlight directions for future research. Although some of the positive affect domain measures were significantly correlated, the generally small to moderate correlations and the absence of clear convergence across all four positive affect domains examined here likely was due to several factors. First, it may be that the different levels of analysis of the Positive Valence System do not converge because they do not represent components of a single underlying positive valence construct. Rather, the positive affect system may be comprised of several somewhat related, but distinct features.

Second, although the measures had adequate reliability, we only used a single measure of each feature, except for two measures of the behavioral domain. Future studies should use multiple measures of each domain rather than only one or two. In addition, the relatively small sample reduced our power and constrained our ability to use more sophisticated data analytic methods such as confirmatory factor analysis and structural equation modeling to test for an underlying latent positive affectivity construct.

Finally, the generalizability of the findings is limited to a relatively educated, mostly maritally intact, and socioeconomically well-resourced sample. Future studies of the positive affect system in offspring of depressed and non-depressed mothers should include a larger and more financially, educationally, racially,

and ethnically diverse sample. Additionally, participants were of a small and young age range. Future studies should include children and adolescents that span a more developmentally varied sample to test how the positive affect system emerges over time.

Even before the onset of depressive episodes, youth may show vulnerabilities to, or early signs of depression in the form of low positive affect features, which then can be targeted for interventions aimed at reducing or preventing depression in youth (e.g., Burkhouse et al., 2023; McMakin, Siegle, & Shirk, 2011). Moreover, interventions being developed to improve different components of the positive affect system could test whether they alter other parts of the system. As one example, Behavioral Activation for anhedonia has been found to increase adolescents' activation, which subsequently was associated with higher daily positive affect and lower depressive symptoms (Fisher et al., 2025). Knowing whether the intervention also improves other aspects of the positive affect system without directly targeting them would inform the design of future interventions in terms of which components to target to maximize efficacy. Testing the extent to which targeting specific positive affect features mediates changes in depressive symptoms is a critical next step.

Declarations

Author Note

Katherine Cullum is now at the Department of Psychiatry and Behavioral Sciences, Emory University School of Medicine.

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Correspondence concerning this article should be addressed to Sherryl H Goodman, Department of Psychology, 36 Eagle Row, Emory University, Atlanta, GA 30322. Email: sherryl.goodman@emory.edu

Competing Interest Declaration and Compliance with Ethical Standards

None of the authors has financial or non-financial interests that directly or indirectly relate to this work. No competing interests. The research was approved by institutional review boards; all participants engaged in informed consent.

Other Declarations

Clinical trial number: not applicable. **Data Availability Declaration**: This study was not preregistered. Data will be made available on the Open Science Framework website. **Author Contribution Declaration**: Drs. Garber and Goodman conceived the study and oversaw all aspects of its completion; Dr. Cullum participated in data collection, conceptualization, and manuscript writing; Dr. Cheong participated in designing and implementing data analyses.

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Figures

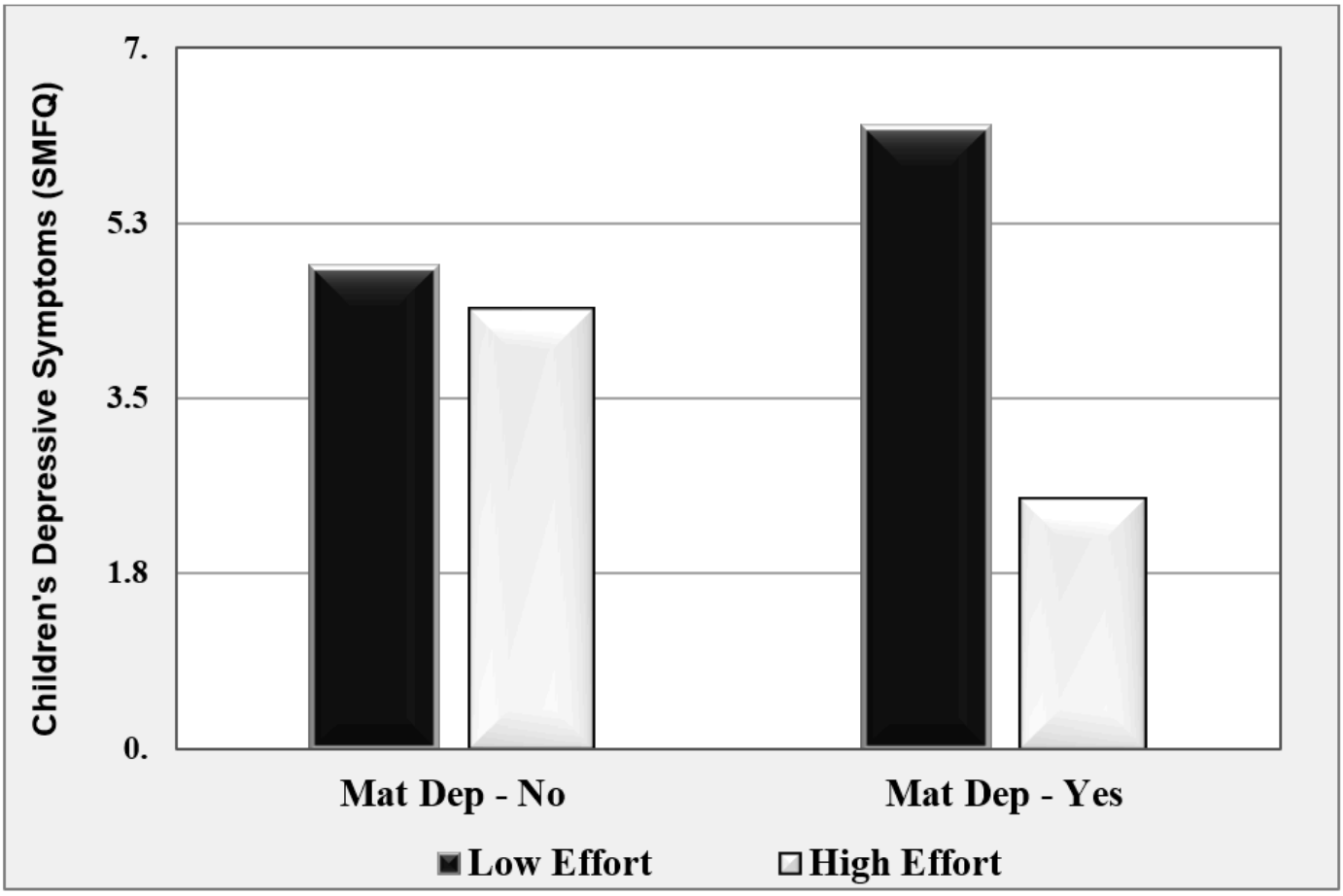

Figure 1

The interaction between the effort discounting task (EDT) ratio and mothers' history of depression (Mat Dep = No or Yes) on children's depressive symptoms (SMFQ).

The relation between effort/motivation and children's depressive symptoms was significant for children of mothers with a depression history, but not for children of mothers with no depression history; that is, among children of mothers with a history of depression, lower effort/motivation was associated with higher depressive symptoms, whereas for children of mothers without a depression history the association between children's effort/motivation and depressive symptoms was not significant.