Emotional Face Identification in Youths With Primary Bipolar Disorder or Primary Attention-Deficit/Hyperactivity Disorder

Karen E. Seymour, Ph.D., Matthew F. Pescosolido, B.A., Brooke L. Reidy, B.A., B.S., Thania Galvan, B.A., Kerri L. Kim, Ph.D., Matthew Young, Ph.D., Daniel P. Dickstein, M.D.

Objective: Bipolar disorder (BD) and attention-deficit/hyperactivity disorder (ADHD) are often comorbid or confounded; therefore, we evaluated emotional face identification to better understand brain/behavior interactions in children and adolescents with either primary BD, primary ADHD, or typically developing controls (TDC). **Method:** Participants included individuals 7 to 17 years of age (overall sample mean age 12.40 ± 3.01 years), with "narrow-phenotype" pediatric BD (n = 30) or ADHD (n = 38), or typically developing controls (TDC) with no psychiatric disorders themselves or in their first-degree relatives (n = 41). In the BD group, comorbid diagnoses were allowed; however, youth in the ADHD group were excluded for comorbid mood or anxiety disorders. Patient groups were not excluded for psychotropic medication use. Emotional face identification was assessed using the computerized Diagnostic Analysis of Non-Verbal Accuracy (DANVA). **Results:** Participants with BD made significantly more identification errors on child happy faces than either TDCs (p = .03) or participants with ADHD (p = .01). Furthermore, youth with BD (0.33 ± 0.55) were more likely than youth with ADHD (0.11 ± 0.31) to make errors on low-intensity child happy faces (p = .05) but not high-intensity happy faces (p = NS). Participants with BD and ADHD made significantly more total errors in child face labeling than did TDCs, although participants with BD and ADHD did not differ from one another. **Conclusion:** Our data suggest that youths with BD have specific alterations in emotional face identification of happy faces, an important finding that supports theories that response to positively valenced emotional stimuli may be especially salient in BD. Clinical trial registration information—Brain Imaging and Computer Games in Children With Either Bipolar Disorder, ADHD, Anxiety or Healthy Controls (BBPP); http://clinicaltrials.gov/; NCT01570426. J. Am. Acad. Child Adolesc. Psychiatry, 2013;52(5):537–546. **Key Words:** attention-deficit/hyperactivity disorder (ADHD), bipolar disorder, children, emotion, face processing

Disentangling attention-deficit/hyperactivity disorder (ADHD) from bipolar disorder (BD) in children is difficult for clinicians and researchers alike, because of overlapping clinical presentations and diagnostic criteria. For example, a child who presents with hyperactivity, impulsivity, low frustration tolerance, distractibility, and who is talkative may be diagnosed with ADHD by one clinician, with BD by another, and with ADHD and BD by a third. Overlapping symptoms have been implicated in the rising diagnostic rates of both disorders.[1,2] Specifically, the percentage of children and adolescents discharged from U.S. psychiatric hospitals with a BD diagnosis surged from less than 10% in the mid-1990s to more than 20% in the mid-2000s.[3] Similarly, epidemiological data indicate that the prevalence of ADHD among children has increased from 4% to 6% in 2000, to 8% to 10% currently.[4-6] An alternative approach is needed whereby greater understanding of the brain–behavior interactions underlying youths with either BD or ADHD leads to bio-behavioral markers for more precise diagnosis and treatment.

Supplemental material cited in this article is available online.

In this vein, emotional face identification provides a window into one of the most basic aspects of emotion regulation—i.e., categorizing another's emotional state. The human face is an important emotional stimulus, as people are hard-wired from birth to attend to faces.[7] From a developmental perspective, emotional face identification involves the bottom-up evaluation of emotionally evocative stimuli, which typically develops before top-down regulation of attention and processing of visual stimuli.[8-10] Emotional face identification holds the potential to advance our understanding of how these fundamental emotional processes are altered in children with primary BD versus primary ADHD.[11-13]

Prior studies have shown behavioral alterations in emotional face identification in youths with BD versus typically developing controls (TDC). Youths with BD make significantly more errors than TDCs in identifying child and adult facial emotions on the computerized Diagnostic Analysis of Nonverbal Accuracy (DANVA), and require greater intensity of emotion to correctly identify facial emotions than TDCs, as assessed using multi-morph tasks whereby the intensity of emotional face expression is varied from neutral to 100%.[14-16] Emotional face identification may represent a trait marker for pediatric BD, as children at elevated risk for BD, by having a first-degree relative with BD, have emotional face identification deficits similar to those of youths with BD themselves.[17]

Functional magnetic resonance imaging (fMRI) studies have demonstrated aberrant fronto-amygdala-striatal neural activity among children and adults with BD when processing happy faces.[18-25] For example, adults with BD have significantly increased left amygdala and striatal activity compared to adult TDCs when processing happy faces.[19,23,24] Because happy faces are rewarding in adult TDCs,[26,27] and because individuals with BD show aberrant striatal activity when anticipating and processing rewards[28,29] and processing happy faces,[19,23,24] some speculate that individuals with BD may find happy faces less socially rewarding or even potentially aversive. However, this hypothesis remains untested.

Far fewer studies have evaluated emotional face processing in children with primary ADHD.[30] Youths with ADHD are less accurate in identifying facial emotional expression than TDCs even when presented with situational or contextual clues.[31-34] Participants who are ADHD hyperactive/impulsive also make more errors than TDCs in identifying emotional faces, particularly angry and sad faces.[32] Compared to TDCs, children at elevated risk for ADHD by having elevated teacher ratings of ADHD also make significantly more errors on emotional face identification.[35] Neuroimaging studies show that youths with ADHD have amygdala hyperactivation when processing fearful faces versus TDCs or completing subjective fear ratings of neutral faces versus youths with BD, severe mood dysregulation (SMD; chronic nonepisodic irritability and ADHD-like symptoms of hyperactivity), or TDCs.[12,36] These results support pathophysiological models implicating altered noradrenergic pathways in ADHD.[37]

Unfortunately, virtually no studies have directly compared emotional face identification among youths with primary BD versus those with primary ADHD. To the best of our knowledge, only Guyer *et al.* have examined emotional face identification among youths with BD versus a combined ADHD/conduct disorder (CD) sample ($n = 35$), showing that youths with BD made significantly more face identification errors than youths with ADHD/CD.[38] Conclusions about those with primary ADHD were limited in this study because the combined ADHD/CD group included youths with either ADHD ($n = 18$), CD ($n = 7$), or both ADHD and CD ($n = 10$).[38]

To address this knowledge gap, we evaluated child and adult emotional face identification ability among youths with either primary BD, primary ADHD, or TDC. We hypothesized that youths with BD would make more errors on happy face identification than TDC or ADHD groups, given prior work suggesting BD involves neural alterations to happy faces and to positively valenced emotional stimuli.[13,18-25] We hypothesized that youths with ADHD would make more errors on fearful faces versus BD and TDC groups, based on research showing that ADHD involves brain/behavior alterations in fear processing.[17,39]

METHOD

Participants

Children and adolescents 7 through 17 years of age were enrolled in a study approved by the Institutional Review Boards of Bradley Hospital and Brown University, after informed parental consent and child assent.

All participants were evaluated for psychopathology using the Child Schedule for Affective Disorders and Schizophrenia, Present and Lifetime version (K-SADS-PL) administered by either a board-certified child/adolescent psychiatrist (D.P.D.) or licensed clinical psychologist (K.L.K.; $\kappa > 0.85$) to parents and youths separately.[40] During the K-SADS, comorbid diagnoses for the BD group were assessed by asking about symptoms and associated impairment during periods of generally euthymic mood to avoid counting manic or depressive symptoms twice.

For all groups, inclusion criteria were as follows: age between 7 and 17 years; English fluency; and a consenting parent/guardian. Exclusion criteria were as follows: Wechsler Abbreviated Scale of Intelligence Full-Scale IQ (WASI FSIQ) $\leq$70; substance/alcohol abuse or dependence within the last 2 months; autism spectrum disorders or primary psychosis; and medical/neurological conditions that mimic either BD or ADHD.[41]

BD ($n = 30$) inclusion criteria consisted of meeting *DSM-IV-TR* criteria for BD, including history of at least one episode of hypomania ($\geqq$4 days) or mania ($\geqq$7 days) wherein the child exhibited abnormally elevated or expansive mood and three or more *DSM-IV* criterion "B" mania symptoms. All participants with BD had type I BD, although type II was not exclusionary. Children presenting with irritable mood only (i.e., without elated or expansive mood) were not included. Thus, the BD group met Leibenluft's "narrow phenotype" pediatric BD criteria.[42] Youths with primary BD were not excluded for comorbid conditions (e.g., ODD, ADHD).

ADHD ($n = 38$) inclusion criteria were: meeting *DSM-IV-TR* criteria for any subtype of ADHD. ADHD exclusion criteria were the presence of any current or lifetime mood (i.e., major depression or BD) or anxiety disorders. Participants with ADHD were not excluded for the presence of BD in their first-degree relatives ($n = 5/38$ [13%]) or the presence of comorbid behavioral disorders (e.g., ODD, CD, etc.); however, ADHD was their primary diagnosis.

Because this was not a treatment study, participants with BD and ADHD remained on their outpatient medication regimens; however, those taking ADHD stimulant medications were asked, but not required, to hold those medications for 4 drug half-lives before behavioral testing, as such medication holidays are common in standard clinical care on weekends or holidays.

TDC participant ($n = 41$) inclusion criteria were absence of current or lifetime psychiatric illness or substance abuse/dependence, and absence of first-degree relatives with history of psychiatric illness.

Measures

Overall functional impairment in the BD and ADHD groups was assessed using the Children's Global Assessment Scale (CGAS).[43] Participants with BD mania and depressive symptoms during the week of DANVA testing were assessed using the Young Mania Rating Scale (YMRS) and Children's Depression Rating Scale (CDRS).[44,45] ADHD symptoms for both patient groups were assessed using the Conners ADHD Rating Scale–Parent Report (ADHD index, t-scores).[46] Socioeconomic status (SES) was assessed via parent report on the four-factor Hollingshead scale.[47]

DANVA Emotional Face Identification Task

Emotional face identification ability was assessed using the DANVA.[48] The DANVA comprises two subtests: adult and child emotional faces. Each subtest included 24 standardized photographs of models (12 male, 12 female) displaying one of four facial emotions (happy, sad, angry, fearful) at two levels of intensity (high and low). Faces were presented for 2 seconds, and participants had to choose which of the four emotions listed was expressed in the photograph. Both DANVA subtests have been standardized and demonstrate adequate construct validity, internal reliability (Cronbach $\alpha = 0.64$–0.81), and test–retest reliability for children and adolescents 4 to 16 years old.[48] Outcome variables for each subtest include total errors per emotion, total errors at each intensity level, and total errors across all emotion conditions. Specific types of errors can also be examined (e.g., mislabeling a face as sad rather than angry).

Data Analysis

The Statistical Package for Social Sciences (version 19.0; SPSS Inc., Chicago, IL) was used for all analyses. We evaluated between-group differences in demographic variables (age, sex, FSIQ, and SES) using analysis of variance (ANOVA) or χ^2 tests as appropriate.[49] We examined potential between-group differences in ADHD symptoms and functional impairment using separate analysis of covariance (ANCOVA), covarying for significant between-group differences in FSIQ and SES.

We conducted four primary analyses of DANVA data: total child face errors, child face errors by emotion type (four emotions), total adult face errors, and adult face errors by emotion type (four emotions). Examination of child and adult total errors used general linear models (GLM) univariate analyses (GLM analysis of covariance [ANCOVA]), whereas examination of child and adult face errors by emotion type (four emotions each) used GLM multivariate analyses (GLM multivariate analysis of covariance [MANCOVA]). All models included FSIQ and SES as covariates. Main effects and subsequent pairwise comparisons were examined. Significance was set at $p < .05$ with Bonferonni correction for multiple comparisons. Effect size was evaluated using Cohen's d.[50] Post-hoc analyses were conducted to explore the effects of comorbid ADHD and medication.

RESULTS

Participants

There were significant between-group differences for both SES ($F_{2,106} = 7.57$, $p = .001$) and FSIQ ($F_{2,106} = 9.41$, $p < .001$), but not age, gender, or ethnicity. Specifically, participants with TDC had significantly higher average incomes and higher FSIQs than participants with BD and ADHD, who did not significantly differ from one another (Table 1).

During the week of DANVA testing, the BD sample was overall euthymic by clinician-administered mood ratings (YMRS: 8.5 ± 7.3, CDRS: 29.4 ± 12.0). Among participants with BD, 70% (21/30) were euthymic (YMRS≤12 CDRS<40), 10% (3/30) depressed (YMRS≤12 CDRS≥40), 13% (4/30) hypomanic (YMRS=13−24 CDRS<40), 7% (2/30) mixed (YMRS>12 CDRS≥40), and none were manic (YMRS>25, CDRS<40). Participants with BD were significantly more impaired with lower CGAS scores than participants with ADHD ($F_{3,64} = 6.49$, $p = .01$). BD and ADHD groups did not differ on ADHD symptom scores ($F_{3,64} = 1.81$, $p = .18$), (ADHD Index t-scores: BD: 72.0 ± 12.5; ADHD: 68.8 ± 10.2). At testing, 18% (2/11) of BD and 12% (4/33) of participants with ADHD were taking their stimulant medications ($\chi^2 = 0.31$, $p = .58$).

DANVA Child Face Labeling Errors

Total Errors. On total child face identification errors, we found a significant main effect of group ($F_{4,104} = 6.20$, $p = .003$). Post-hoc pairwise comparisons showed that participants with BD ($p = .03$, Cohen's d = 0.69) and ADHD ($p = .003$, Cohen's d = 0.65) made significantly more total errors on child faces than TDCs, but patient groups did not differ significantly from one another.

Errors by Emotion Type. Examining child face errors by emotion type, we found a significant effect of group (Wilks' $\lambda = 0.76$, $p = .001$), with a univariate main effect of group on errors on

TABLE 1 Sample Characteristics

Variable	BD (n = 30)	ADHD (n = 38)	TDC (n = 41)	Significance
Age (years), mean ± SD	13.03 ± 2.99	12.08 ± 2.78	12.24 ± 3.23	$F_{2,106} = 0.93$
Sex: male, n (%)	20 (67)	22 (58)	16 (39)	$\chi^2(2,N = 109) = 5.83$
Full scale IQ[a]	105.4 (11.0)	110.0 (13.9)	117.0 (8.8)	$F_{2,106} = 9.41$***
Ethnicity: white, n (%)	24 (80)	27 (71)	33 (81)	$\chi^2(2,N = 109) = 1.20$
Socioeconomic status (Hollingstead)[b]	41.1 (13.8)	38.6 (16.4)	50.6 (12.7)	$F_{2,106} = 7.57$**
K-SADS Diagnosis (past 6 mo), n (%)				
Manic episode	27 (90)	0	—	
Depressive episode	15 (50)	0	—	
ADHD	18 (60)	38 (100)	—	
Oppositional defiant disorder	21 (70)	8 (21)	—	
Conduct disorder	2 (7)	0	—	
Generalized anxiety disorder	4 (13)	0	—	
Social phobia	0	0	—	
Simple phobia	6 (20)	0	—	
Separation anxiety disorder	2 (7)	0	—	
Posttraumatic stress disorder	1 (3)	0	—	
Obsessive-compulsive disorder	3 (10)	0	—	
Young Mania Rating Scale, mean ± SD	8.5 ± 7.3	—	—	
Children's Depression Rating Scale, mean ± SD	29.4 ± 12.0	—	—	
Children's Global Assessment Scale, mean ± SD	63.4 ± 15.3	72.9 ± 13.8	—	
Conners ADHD index t score,[c] mean ± SD	72.0 ± 12.5	68.8 ± 10.2	—	$F_{3,64} = 1.81$
Medication, n (%)				
Lithium	11 (37)	0	—	
Atypical neuroleptic	18 (60)	0	—	
Antiepileptic	5 (17)	0	—	
Antidepressant	5 (17)	0	—	
Stimulant[d]	11 (37)	33 (87)	—	
α-Agonist ADHD medication	5 (17)	4 (11)	—	

Note: K-SADS = Child Schedule for Affective Disorders and Schizophrenia.

[a]*Full Scale IQ is reported as standard scores on the Wechsler Abbreviated Scale of Intelligence (WASI).*

[b]*Socioeconomic status is reported as total score on the Hollingstead.*

[c]*Data were not available for all participants for these variables: participants with bipolar disorder (BD) (n=29); participants with attention-deficit/hyperactivity disorder (ADHD) (n=37).*

[d]*Two participants with BD and 4 participants with ADHD were taking stimulant medication when tested.*

**$p \leq .01$, ***$p \leq .001$.

TABLE 2 Between-Group Differences in Emotional Face Identification Errors

	Group, mean ± SD			Analysis			
	BD (n = 30)	ADHD (n = 38)	TDC (n = 41)	F	*p*	Post-hoc	Cohen's d
Child Face Errors							
Total	4.47 ± 2.86	4.74 ± 3.79	2.85 ± 1.67	6.20	.003	ADHD>TDC, *p* = .003	0.65
						BD>TDC, *p* = .03	0.69
Happy	0.45 ± 0.68	0.13 ± 0.34	0.15 ± 0.36	5.00	.008	BD>TDC, *p* = .03	0.55
						BD>ADHD, *p* = .01	0.60
Angry	2.07 ± 1.31	1.84 ± 1.20	1.42 ± 1.05	3.60	.03	BD>TDC, *p* = .04	0.55
Sad	0.83 ± 0.95	0.61 ± 0.72	0.41 ± 0.84	3.01	.05	BD>TDC, *p* = .05	0.47
Fearful	1.10 ± 1.03	1.53 ± 0.80	0.88 ± 0.84	4.96	.009	ADHD>TDC, *p* = .009	0.79
Adult Face Errors							
Total	6.37 ± 2.65	6.39 ± 4.43	4.80 ± 1.76	2.25	.11		
Happy	0.80 ± 0.85	0.50 ± 1.06	0.27 ± 0.50	1.39	.25		
Angry	1.90 ± 1.32	1.92 ± 1.24	1.85 ± 1.15	0.06	.94		
Sad	1.90 ± 1.35	1.21 ± 1.38	1.12 ± 1.05	2.51	.09		
Fearful	1.77 ± 1.38	2.13 ± 1.21	1.56 ± 1.14	2.08	.13		

Note: ADHD = attention-deficit/hyperactivity disorder; BD = bipolar disorder; TDC = typically developing control.

happy ($F_{2,104}$ = 5.00, *p* = .008), angry ($F_{2,104}$ = 3.60, *p* = .03), sad ($F_{2,104}$ = 3.01, *p* = .05), and fearful faces ($F_{2,104}$ = 4.96, *p* = .009) (Table 2 and Figure 1).

Post-hoc pairwise comparisons of happy face errors showed that participants with BD made significantly more errors on happy faces than participants with either ADHD (*p* = .01, Cohen's d = 0.60) or TDC (*p* = .03, Cohen's d = 0.55), but participants with ADHD and TDC did not differ.

To further probe this BD specific deficit, we examined the effect of emotional face intensity on child happy faces errors. We found that youths with BD (0.33 ± 0.55) were more likely than those with ADHD (0.11 ± 0.31) to make errors on low-intensity child happy faces ($t_{43.50}$ = 2.04, *p* = .05, Cohen's d = 0.49), but not high-intensity child happy face errors (BD 0.13 ± 0.43; ADHD 0.03 ± 0.16; $t_{35.41}$ = 1.28, *p* = NS).

Post-hoc pairwise comparisons of angry face errors revealed that youths with BD made significantly more errors than TDCs (*p* = .04, Cohen's d = 0.55), but not versus youths with ADHD. Youths with ADHD did not differ from TDCs.

Post-hoc pairwise comparisons of sad face errors showed that participants with BD made significantly more errors than TDCs (*p* = .05, Cohen's d = 0.47), but not significantly versus participants with ADHD, nor did participants with ADHD differ from TDCs.

Post-hoc pairwise comparisons of fearful face errors demonstrated that participants with ADHD made significantly more errors than TDC (*p* = .009, Cohen's d = 0.79), but not than participants with BD, nor did participants with BD differ from TDCs.

DANVA Adult Face Labeling Errors

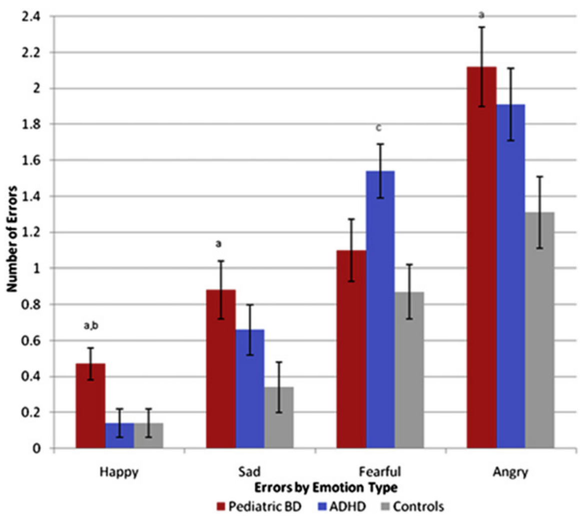
Total Errors. On total adult face identification errors, there was no main effect of group ($F_{4,104}$ = 2.25, *p* = NS); therefore, we did not conduct post-hoc pairwise analyses.

Errors by Emotion Type. Examination of errors by facial emotion type on adult faces did not show a main effect of group (Wilks' λ = 0.90, $F_{8,\ 202}$ = 1.39, *p* = NS); therefore, we did not examine univariate analyses.

Post-Hoc Exploration of Potential Medication Effects

To assess potential medication effects, GLM MANCOVAs were conducted on child subtest total errors, given prior results suggesting differences on child, but not adult faces. There was no effect of medication status (i.e., medicated versus not medicated) on child face total errors for participants with BD or ADHD (BD: $F_{3,26}$ = 0.02, *p* = .88; ADHD: $F_{3,34}$ = 0.24, *p* = .6). In youths with BD, we found no differences on child face total errors among those taking atypical neuroleptics (n = 18) versus not (n = 12) ($F_{3,26}$ = 0.02, *p* = .9) or child face errors by emotion type (Wilks' λ = 0.99, $F_{4,23}$ = 0.03, *p* = 1.0). Similarly, no effect was found when comparing youths with BD taking lithium (n = 11) versus not (n = 19) on child face total errors ($F_{3,26}$ = 0.15, *p* = .7) or child face errors by emotion type (Wilks' λ = 0.76, $F_{4,23}$ = 1.81, *p* = .2).

FIGURE 1 Errors on child facial emotions by group. Note: Means adjusted for Full Scale IQ and socio-economic status. [a]Pediatric bipolar disorder (BD) significantly different from controls. [b]Pediatric BD significantly different from attention-deficit/hyperactivity disorder (ADHD). [c]ADHD significantly different from controls.



Post-Hoc Examination of ADHD Diagnostic Comorbidity

To explore potential effects of ADHD, we conducted a post-hoc comparison of participants with BD with comorbid ADHD (BD+ADHD, n = 18) and participants with BD without ADHD (BD-ADHD, n = 12) versus the ADHD-only and TDC samples. We found significant main effects of group on child angry ($F_{3,103} = 2.73$, $p = .05$), sad ($F_{3,103} = 3.51$, $p = .02$), fearful ($F_{3,103} = 3.89$, $p = .01$), and happy faces ($F_{3,103} = 3.35$, $p = .02$) (Table 3).

Post-hoc pairwise comparisons on child angry faces showed that participants with BD+ADHD differed significantly from TDCs ($p = .05$, Cohen's d = 0.64), but not from participants with BD-ADHD or ADHD-only. Similarly, on child sad faces, participants with BD+ADHD differed significantly from TDCs ($p = .01$, Cohen's d = 0.80), but not from participants with BD-ADHD or ADHD-only. For child fearful faces, participants with ADHD-only made significantly more errors than TDCs ($p = .02$, Cohen's d = 1.15), but not than participants with BD+ADHD or BD-ADHD. There were no significant pairwise differences on child happy faces errors.

On child face total identification errors, we found a main effect of group ($F_{3,103} = 4.67$, $p = .004$). Post-hoc pairwise comparisons showed that participants with BD+ADHD ($p = .03$, Cohen's d = 0.90) and participants with ADHD-only ($p = .007$, Cohen's d = 0.65) made significantly more total child face errors than TDCs, but not versus participants with BD-ADHD. There were no significant differences between participants with BD+ADHD and ADHD-only.

DISCUSSION

The principal finding of our study, the first to compare emotional face identification in youths with primary BD versus primary ADHD, was that participants with BD made significantly more errors while identifying child happy faces than either participants with ADHD or TDC. In this BD-specific deficit, youths with BD were more likely to make errors on low- rather than high-intensity happy faces. Participants with BD also made significantly more errors on child angry and sad faces than participants with TDC. Participants with ADHD made more errors on child fearful faces than participants with TDC. Both patient groups made more total face identification errors than TDCs on the child faces subtest. No significant group differences were found using adult faces. Taken together, this suggests that child happy face identification may be a specific behavioral marker of children with primary BD versus those with primary ADHD or TDC.

Our results are consistent with other behavioral studies of emotional face processing in youths with BD. Our finding that youths with BD made more total child face identification errors than TDCs aligns with previous DANVA studies in youths with BD.[14,17] Similar to McClure *et al.* (2005), our participants with BD made more identification errors on child happy and angry faces than TDCs.[15] Perhaps most intriguing and unique is our finding that participants with BD made significantly more errors on child happy faces than either participants with ADHD or TDC, suggesting a BD-specific behavioral deficit in emotional face processing. Our finding that youths with BD were more likely to make errors on low- versus high-intensity happy faces complements research showing youths with BD require greater emotional intensity to correctly identify facial emotions compared to TDCs.[16]

Our data also advance what is known about emotional face identification in youths with ADHD.[30] Youths with ADHD made more total errors when identifying child faces than did TDCs, which is consistent with prior literature.[31-34,36] Others have shown that children and

TABLE 3 Effect of Attention-Deficit/Hyperactivity Disorder (ADHD) Comorbidity on Child Face Identification Errors

Child Face Errors	Group, mean ± SD				Analysis			
	BD+ADHD (n=18)	BD-ADHD (n = 12)	ADHD only (n = 38)	TDC (n = 41)	F	*p*	Post-hoc	Cohen's d
Total	5.11 ± 3.12	3.50 ± 2.20	4.74 ± 3.79	2.85 ± 1.67	4.67	.004	BD + ADHD > TDC, *p* = .03	0.90
							ADHD > TDC, *p* = .007	0.65
Happy	0.44 ± 0.70	0.50 ± 0.67	0.13 ± 0.34	0.15 ± 0.36	3.35	.02	BD + ADHD = BD–ADHD = ADHD = TDC	N/A
Angry	2.28 ± 1.60	1.75 ± 0.62	1.84 ± 1.20	1.41 ± 1.05	2.73	.05	BD + ADHD > TDC, *p* = .05	0.64
Sad	1.11 ± 0.90	0.42 ± 0.90	0.61 ± 0.72	0.41 ± 0.84	3.51	.02	BD + ADHD > TDC, *p* = .01	0.80
Fearful	1.27 ± 0.21	0.84 ± 0.27	1.53 ± 0.80	0.87 ± 0.15	3.89	.01	ADHD > TDC, *p* = .021	1.15

Note: ADHD = attention-deficit/hyperactivity disorder; BD = bipolar disorder; TDC = typically developing control.

adults with ADHD have altered neural and behavioral responses to fearful faces versus TDCs.[36,39,51] Given that noradrenergic pathways regulate fear responses and have been implicated in the pathophysiology of ADHD, further work is needed to examine the relationship between fear processing and noradrenergic circuitry in youths with ADHD.[37,52] Our findings contrast with work suggesting that children with ADHD have particular difficulty with the identification of angry and sad faces.[32] However, this discrepancy may result from use of different tasks, as Pelc used a morphed faces task probing "happiness," "sadness," "anger," and "disgust," whereas we used the nonmorphed DANVA, tapping happiness, anger, sadness, and fear.[32] Most importantly, we extend the ADHD emotional face processing literature by comparing youths with ADHD those with another form of psychopathology—i.e., BD.

Our results differ from those of Guyer *et al.*, the only other study to compare youths with BD versus ADHD. We found that both participants with BD and ADHD made more total child, but not adult, emotional face identification errors, whereas Guyer *et al.* found that participants with BD and SMD made more total errors in both child and adult emotional face identification than youths with ADHD/CD, anxiety/depression (ANX/DEP) or TDCs. They also found that participants with ADHD/CD were no different than TDCs on overall face identification ability. This discrepancy may result from Guyer's use of a combined ADHD and/or CD group, which may represent an extreme sample of youths who are not representative of youths with ADHD more generally.[38] Moving forward, differences in emotional face identification in youths with primary BD versus primary ADHD require replication.

Our behavioral results should also be examined within the context of the neuroimaging literature examining emotional face processing in BD. Compared to TDCs and individuals with other forms of psychopathology, adults and children with BD demonstrate aberrant neural activation and connectivity in fronto-amygdala-striatal regions when processing happy faces.[18-25] For example, atypical striatal activation has been shown during happy face processing and encoding among adults and youths with BD.[19,20,23,24] Furthermore, adults with BD and their unaffected first-degree relatives have increased medial prefrontal cortex activation versus TDCs when processing happy faces; however, only those with BD have increased activation in the putamen.[53] Finally. Blumberg *et al.* found significant increases in amygdala activation for adult participants with BD versus TDCs when passively viewing happy faces.[19] Although TDCs find happy faces rewarding,[26,27] neuroimaging and behavioral studies of happy face processing in individuals with BD, including our own, suggest the need to determine whether individuals with BD find happy faces less socially rewarding or even aversive. However, this hypothesis requires further empirical testing.

Albeit highly speculative, the relationship between our data indicating impaired emotional face identification is interesting in light of others' work on social impairment in youths with either BD or ADHD. Compared to youths with ADHD and TDCs, youths with BD demonstrate greater impairments in parental and peer social interactions.[54] Furthermore, even asymptomatic youths with BD demonstrate significant interpersonal deficits compared to TDCs.[55] Although few studies have examined the relationship between impaired social skills and emotional face processing in youths with either BD or ADHD, a preliminary study by Rich *et al.* found a negative relationship between delayed face identification and parent-reported social reciprocity (e.g., social awareness, social information processing, etc.) in youths with BD.[56] Being effective in social relationships requires the ability to interpret others' emotions and to respond appropriately. Thus, impaired emotional identification in youths with either primary BD or primary ADHD might lead to inappropriate behavioral responses, such as reactive aggression or intrusions on others. Further work is needed to examine the impact of deficits in emotional face processing on actual social impairments with peers and adults in youths with either BD or ADHD.

Our study has several limitations. First, most participants with BD were taking their usual psychiatric medications when tested, as this was not a treatment study, and it would be unethical to withdraw them from anti-manic or anti-depressant medications for a phenomenology study. Our post-hoc analyses did not find differential DANVA performance based on participants with BD's current use of lithium or atypical neuroleptics. To minimize the effect of stimulants, most participants with BD and ADHD were tested having held their stimulants for at least 4 drug half-lives. However, further examination of the effect of psychotropic medications on emotional face identification is needed.

Second, the BD sample as a whole was euthymic, although there was some heterogeneity. Additional work is warranted to examine the role of mood state on emotional face identification in a sample of youths with BD sufficiently powered to examine all potential mood states, given exploratory analyses suggesting a relationship between depression symptoms and child sad face errors (see Supplement 1, available online).

Third, exploratory analyses showed that ADHD symptoms, regardless of child diagnosis, predicted child emotional face total, sad, and angry face errors, suggesting the need to better understand the role of inattention and hyperactivity/impulsivity in emotional face identification (see Supplement 1, available online).

Fourth, 70% of our BD sample had comorbid ODD, which, albeit consistent with rates of comorbid ODD in other studies of pediatric BD (range, 47–88%), is higher than that of Guyer *et al.* (41%), thus potentially limiting comparisons of these studies.[36,38,57,58] Furthermore, our BD groups had a higher rate of comorbid ODD than the ADHD (21%) group, and neither BD nor ADHD groups had sufficient numbers of participants with and without comorbid ODD for adequately powered evaluations of its effect on emotional face identification. We note that this is an important area for future investigation.

Finally, as with all behavioral tasks, the DANVA has some limitations. For example, its lack of neutral trials used as a control condition versus specific emotional exemplars (i.e., angry) reduces our ability to determine whether that would help tease apart whether our groups had specific difficulties with emotional face processing (e.g., emotional aspect of the task) versus more global difficulties with face processing. Although the DANVA's limited number of trials per emotion could potentially reduce power to detect group-by-emotion interactions, this was neither true in our study nor in a wealth of other studies.[14,15,17,38] Also, it is beyond the DANVA's scope to disentangle potential contributions of other cognitive processes, including working memory or attention, to emotional face processing, which might be especially relevant to ADHD. However, others, have shown deficits in emotional face processing among youths with ADHD even when accounting for deficits in cognitive control.[59] Future work is needed with behavioral tasks designed to elucidate the relationship between cognition and emotional face processing.

In summary, comparing emotional face identification ability in children and adolescents with either primary BD, primary ADHD, or TDCs, we found a BD-specific deficit on child happy faces, with youths with BD making more errors than both youths with ADHD and TDCs. Such results suggest a potential disorder-specific behavioral marker of BD in youths. Further research is needed to elucidate the neural underpinnings of emotional face identification, especially of happy faces, as a potential bio-behavioral marker of pediatric BD. &

Accepted March 15, 2013.

Drs. Seymour, Kim, Young, and Dickstein, Mr. Pescosolido, Ms. Reidy, and Ms. Galvan are with Bradley Hospital's Pediatric Mood, Imaging, and NeuroDevelopmental (PediMIND) Program and the Alpert Medical School of Brown University.

This research was supported by the National Institute of Mental Health grants 5K22MH074945 and 3K22MH074945-02S1 (PI: D.P.D.) and Bradley Hospital.

Disclosure: Drs. Seymour, Kim, Young, and Dickstein, Mr. Pescosolido, Ms. Reidy, and Ms. Galvan report no biomedical financial interests or potential conflicts of interest.

Correspondence to Karen Seymour, Ph.D., PediMIND program, EP Bradley Hospital, 1011 Veterans Memorial Parkway, East Providence, RI 02915; e-mail: karen_seymour@brown.edu

http://dx.doi.org/10.1016/j.jaac.2013.03.011

REFERENCES

1. Youngstrom EA, Arnold LE, Frazier TW. Bipolar and ADHD comorbidity: both artifact and outgrowth of shared mechanisms. Clin Psychol. (New York). 2010;17:350-359.
2. Galanter CA, Leibenluft E. Frontiers between attention deficit hyperactivity disorder and bipolar disorder. Child Adolesc Psychiatr Clin N Am. 2008;17:325-346.
3. Blader JC, Carlson GA. Increased rates of bipolar disorder diagnoses among U.S. child, adolescent, and adult inpatients, 1996-2004. Biol Psychiatry. 2007;62:107-114.
4. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders 4th Edition Text Revision (DSM-IV-TR). Washington, DC: American Psychiatric Association; 2000.
5. Getahun D, Jacobsen SJ, Fassett MJ, Chen W, Demissie K, Rhoads GG. Recent trends in childhood attention-deficit/hyperactivity disorder. JAMA Pediatr.. 2013;167:1-7.
6. Larson K, Russ SA, Kahn RS, Halfon N. Patterns of comorbidity, functioning, and service use for US children with ADHD, 2007. Pediatrics. 2011;127:462-470.
7. Leibenluft E, Gobbini MI, Harrison T, Haxby JV. Mothers' neural activation in response to pictures of their children and other children. Biol Psychiatry. 2004;56:225-232.
8. Johnson MH, Griffin R, Csibra G, *et al*. The emergence of the social brain network: evidence from typical and atypical development. Dev Psychopathol. 2005;17:599-619.
9. Gobbini MI, Haxby JV. Neural systems for recognition of familiar faces. Neuropsychologia. 2007;45:32-41.
10. Palermo R, Rhodes G. Are you always on my mind? A review of how face perception and attention interact. Neuropsychologia. 2007;45:75-92.
11. Phillips ML, Drevets WC, Rauch SL, Lane R. Neurobiology of emotion perception II: implications for major psychiatric disorders. Biol Psychiatry. 2003;54:515-528.
12. Leibenluft E, Charney DS, Pine DS. Researching the pathophysiology of pediatric bipolar disorder. Biol Psychiatry. 2003;53: 1009-1020.
13. Leibenluft E. Severe mood dysregulation, irritability, and the diagnostic boundaries of bipolar disorder in youths. Am J Psychiatry. 2011;168:129-142.
14. McClure EB, Pope K, Hoberman AJ, Pine DS, Leibenluft E. Facial expression recognition in adolescents with mood and anxiety disorders. Am J Psychiatry. 2003;160:1172-1174.
15. McClure EB, Treland JE, Snow J, *et al*. Deficits in social cognition and response flexibility in pediatric bipolar disorder. Am J Psychiatry. 2005;162:1644-1651.
16. Rich BA, Grimley ME, Schmajuk M, Blair KS, Blair RJ, Leibenluft E. Face emotion labeling deficits in children with bipolar disorder and severe mood dysregulation. Dev Psychopathol. 2008;20:529-546.
17. Brotman MA, Guyer AE, Lawson ES, *et al*. Facial emotion labeling deficits in children and adolescents at risk for bipolar disorder. Am J Psychiatry. 2008;165:385-389.
18. Almeida JR, Mechelli A, Hassel S, Versace A, Kupfer DJ, Phillips ML. Abnormally increased effective connectivity between parahippocampal gyrus and ventromedial prefrontal regions during emotion labeling in bipolar disorder. Psychiatry Res. 2009; 174:195-201.
19. Blumberg HP, Donegan NH, Sanislow CA, *et al*. Preliminary evidence for medication effects on functional abnormalities in the amygdala and anterior cingulate in bipolar disorder. Psychopharmacology (Berl).. 2005;183:1-6.
20. Dickstein DP, Rich BA, Roberson-Nay R, *et al*. Neural activation during encoding of emotional faces in pediatric bipolar disorder. Bipolar Disord. 2007;9:679-692.
21. Passarotti AM, Sweeney JA, Pavuluri MN. Differential engagement of cognitive and affective neural systems in pediatric bipolar disorder and attention deficit hyperactivity disorder. J Int Neuropsychol Soc. 2010;16:106-117.
22. Pavuluri MN, O'Connor MM, Harral E, Sweeney JA. Affective neural circuitry during facial emotion processing in pediatric bipolar disorder. Biol Psychiatry. 2007;62:158-167.
23. Hassel S, Almeida JR, Kerr N, *et al*. Elevated striatal and decreased dorsolateral prefrontal cortical activity in response to emotional stimuli in euthymic bipolar disorder: no associations with psychotropic medication load. Bipolar Disord. 2008;10: 916-927.
24. Lawrence NS, Williams AM, Surguladze S, *et al*. Subcortical and ventral prefrontal cortical neural responses to facial expressions distinguish patients with bipolar disorder and major depression. Biol Psychiatry. 2004;55:578-587.
25. Versace A, Thompson WK, Zhou D, *et al*. Abnormal left and right amygdala-orbitofrontal cortical functional connectivity to emotional faces: state versus trait vulnerability markers of depression in bipolar disorder. Biol Psychiatry. 2010;67:422-431.
26. Chakrabarti B, Kent L, Suckling J, Bullmore E, Baron-Cohen S. Variations in the human cannabinoid receptor (CNR1) gene modulate striatal responses to happy faces. Eur J Neurosci. 2006; 23:1944-1948.
27. Phillips ML, Bullmore ET, Howard R, *et al*. Investigation of facial recognition memory and happy and sad facial expression perception: an fMRI study. Psychiatry Res. 1998;83:127-138.
28. Bermpohl F, Kahnt T, Dalanay U, *et al*. Altered representation of expected value in the orbitofrontal cortex in mania. Hum Brain Mapp. 2010;31:958-969.
29. Nusslock R, Almeida JR, Forbes EE, *et al*. Waiting to win: elevated striatal and orbitofrontal cortical activity during reward anticipation in euthymic bipolar disorder adults. Bipolar Disord. 2012;14: 249-260.
30. Dickstein DP, Castellanos FX. Face processing in attention deficit/hyperactivity disorder. Curr Top Behav Neurosci. 2012;9:219-237.
31. Corbett B, Glidden H. Processing affective stimuli in children with attention-deficit hyperactivity disorder. Child Neuropsychol. 2000;6:144-155.

32. Pelc K, Kornreich C, Foisy ML, Dan B. Recognition of emotional facial expressions in attention-deficit hyperactivity disorder. Pediatr Neurol. 2006;35:93-97.
33. Yuill N, Lyon J. Selective difficulty in recognising facial expressions of emotion in boys with ADHD. General performance impairments or specific problems in social cognition? Eur Child Adolesc Psychiatry. 2007;16:398-404.
34. Da Fonseca D, Seguier V, Santos A, Poinso F, Deruelle C. Emotion understanding in children with ADHD. Child Psychiatry Hum Dev. 2009;40:111-121.
35. Kats-Gold I, Besser A, Priel B. The role of simple emotion recognition skills among school aged boys at risk of ADHD. J Abnorm Child Psychol. 2007;35:363-378.
36. Brotman MA, Rich BA, Guyer AE, *et al*. Amygdala activation during emotion processing of neutral faces in children with severe mood dysregulation versus ADHD or bipolar disorder. Am J Psychiatry. 2010;167:61-69.
37. Scassellati C, Bonvicini C, Faraone SV, Gennarelli M. Biomarkers and attention-deficit/hyperactivity disorder: a systematic review and meta-analyses. J Am Acad Child Adolesc Psychiatry. 2012;51:1003-1019.
38. Guyer AE, McClure EB, Adler AD, *et al*. Specificity of facial expression labeling deficits in childhood psychopathology. J Child Psychol Psychiatry. 2007;48:863-871.
39. Boakes J, Chapman E, Houghton S, West J. Facial affect interpretation in boys with attention deficit/hyperactivity disorder. Child Neuropsychol. 2008;14:82-96.
40. Kaufman J, Birmaher B, Brent D, *et al*. Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL): initial reliability and validity data. J Am Acad Child Adolesc Psychiatry. 1997;36:980-988.
41. Wechsler D. Wechsler Abbreviated Scale of Intelligence. San Antonio, TX: The Psychological Corporation; 2005.
42. Leibenluft E, Charney DS, Towbin KE, Bhangoo RK, Pine DS. Defining clinical phenotypes of juvenile mania. Am J Psychiatry. 2003;160:430-437.
43. Shaffer D, Gould MS, Brasic J, *et al*. A Children's Global Assessment Scale (CGAS). Arch Gen Psychiatry. 1983;40:1228-1231.
44. Young RC, Biggs JT, Ziegler VE, Meyer DA. A rating scale for mania: reliability, validity and sensitivity. Br J Psychiatry. 1978;133:429-435.
45. Poznanski E, Freeman LN MH. Children's Depression Rating Scale-Revised. Psychopharmacol Bull. 1985;21:979-984.
46. Conners CK, Wells KC, Parker JD, Sitarenios G, Diamond JM, Powell JW. A new self-report scale for assessment of adolescent psychopathology: factor structure, reliability, validity, and diagnostic sensitivity. J Abnorm Child Psychol. 1997;25:487-497.
47. Hollingshead AB. Four Factor Index of Social Status. New Haven, CT: Yale University; 1975.
48. Nowicki S, Duke M. Individual differences in the nonverbal communication of affect: the Diagnostic Analysis of Nonverbal Accuracy Scale. J Nonverb Behav. 1994;18:9-35.
49. Miller GA, Chapman JP. Misunderstanding analysis of covariance. J Abnorm Psychol. 2001;110:40-48.
50. Cohen J. A power primer. Psychol Bull. 1992;112:155-159.
51. Miller M, Hanford RB, Fassbender C, Duke M, Schweitzer JB. Affect recognition in adults with ADHD. J Atten Disord. 2011;15:452-460.
52. Kim CH, Waldman ID, Blakely RD, Kim KS. Functional gene variation in the human norepinephrine transporter: association with attention deficit hyperactivity disorder. Ann N Y Acad Sci. 2008;1129:256-260.
53. Surguladze SA, Marshall N, Schulze K, *et al*. Exaggerated neural response to emotional faces in patients with bipolar disorder and their first-degree relatives. Neuroimage. 2010;53:58-64.
54. Geller B, Bolhofner K, Craney JL, Williams M, DelBello MP, Gundersen K. Psychosocial functioning in a prepubertal and early adolescent bipolar disorder phenotype. J Am Acad Child Adolesc Psychiatry. 2000;39:1543-1548.
55. Goldstein TR, Miklowitz DJ, Mullen KL. Social skills knowledge and performance among adolescents with bipolar disorder. Bipolar Disord. 2006;8:350-361.
56. Rich BA, Fromm SJ, Berghorst LH, *et al*. Neural connectivity in children with bipolar disorder: impairment in the face emotion processing circuit. J Child Psychol Psychiatry. 2008;49:88-96.
57. Geller B, Luby JL, Joshi P, *et al*. A randomized controlled trial of risperidone, lithium, or divalproex sodium for initial treatment of bipolar I disorder, manic or mixed phase, in children and adolescents. Arch Gen Psychiatry. 2012;69:515-528.
58. Joshi G, Wilens T. Comorbidity in pediatric bipolar disorder. Child Adolesc Psychiatr Clin N Am. 2009;18:291-viii.
59. Posner J, Maia TV, Fair D, Peterson BS, Sonuga-Barke EJ, Nagel BJ. The attenuation of dysfunctional emotional processing with stimulant medication: an fMRI study of adolescents with ADHD. Psychiatry Res. 2011;193:151-160.

SUPPLEMENT 1

Exploratory Analyses: Examination of Dimensional Measures of Psychopathology and Impairment in Relation to Emotional Face Identification Ability

Aligning with a growing emphasis by the National Institute of Mental Health (NIMH) and others on dimensional assessment of psychopathology, we explored the effect of dimensional levels of psychopathology (i.e., mania, depression, attention-deficit/hyperactivity disorder [ADHD] symptoms) and functional impairment (i.e., Clinical Global Assessment Scale [CGAS]) on emotional face identification errors in youth with primary bipolar disorder (BD) versus primary ADHD versus typically developing controls (TDC).[1,2]

Data Analysis

First we examined the relationship between predictor variables (i.e., mania, depression, ADHD symptoms, functional impairment) using Pearson product–moment correlations. Because of the significant relationship between predictors (i.e., multi-collinearity), we ran separate regression analyses for each predictor rather than including all predictors in one regression. Next, we examined the correlations between predictor variables and (a) child face errors (total errors and errors by emotion type; Table S1, available online) and (b) adult face errors (total errors and errors by emotion type; Table S2, available online) separately. If predictors were significantly related to face identification variables, we ran hierarchical linear regressions in which covariates (full-scale IQ and SES) were entered in block 1 and the specified predictor variable was entered in block 2. Face identification variables were used as the dependent variable, and child and adult face identification variables were examined separately. Given multiple analyses, significance was set at $p \leq .007$ (0.05/7 tests) for child face variables and $p \leq .01$ (0.05/4 tests) for adult face variables.

RESULTS

Correlational Analyses

All predictor variables (Young Mania Rating Scale [YMRS], Children's Depression Rating Scale [CDRS], Conner ADHD index, CGAS) were highly intercorrelated (Table S1, available online).

On child faces, youth symptoms of mania ($r = 0.29$, $p < .05$), depression ($r = 0.32$, $p < .01$), and ADHD ($r = 0.29$, $p < .01$) were positively related to child sad face errors, whereas functional impairment was negatively related to child sad face errors ($r = -0.41$, $p < .001$). ADHD symptoms were significantly positively related to child face total errors ($r = 0.31$, $p < .001$), child angry face errors ($r = 0.29$, $p < .01$), and child fearful face errors ($r = .21$, $p < .05$).

On adult faces, youth depression was positively related to errors on adult sad faces ($r = 0.25$, $p < .05$), whereas functional impairment was negatively related to adult sad face errors ($r = -0.27$, $p < .05$). Youth ADHD symptoms were positively related to adult total face errors ($r = 0.25$, $p < .01$) and adult fearful face errors ($r = 0.22$, $p < .05$).

Hierarchical Linear Regressions

Child Face Variables. We found that youth depression significantly predicted child sad face errors accounting for 13% of the variance in the model ($\beta = 0.34$, $p = .006$, $R^2\Delta = 0.111$). In addition, youth ADHD symptoms significantly

TABLE S1 Relationship Between Predictor Variables and Child Face Identification Variables

Variable	1	2	3	4	5	6	7	8	9
1. YMRS total	–								
2. CDRS total	0.534**	–							
3. Conners ADHD index	0.382**	0.341**	–						
4. CGAS score	−0.487**	−0.474**	−0.470**	–					
5. Child face total errors	−0.007	0.074	0.312**	−0.054	–				
6. Child happy face errors	0.043	−0.015	0.111	−0.099	0.303**	–			
7. Child angry face errors	0.083	0.117	0.293**	−0.203	0.484**	0.247**	–		
8. Child sad face errors	0.286*	0.323**	0.285**	−0.409**	0.440**	0.116	0.246*	–	
9. Child fearful face errors	−0.018	−0.166	0.214*	−0.087	0.429*	0.143	0.266**	0.303**	–

Note: ADHD = attention-deficit/hyperactivity disorder; CDRS = Children's Depression Rating Scale; CGAS = Clinical Global Assessment Scale; YMRS = Young Mania Rating Scale.
*$p < .05$, **$p < .01$.

TABLE S2 Correlations Between Predictor Variables and Adult Face Identification Variables

Variable	1	2	3	4	5	6	7	8	9
1. YMRS total	—								
2. CDRS total	0.534**	—							
3. Conners ADHD index	0.382**	0.341**	—						
4. CGAS score	−0.487**	−0.474**	−0.470**	—					
5. Adult face total errors	−0.056	0.102	0.252**	−0.101	—				
6. Adult happy face errors	−0.019	0.027	0.124	−0.086	0.417**	—			
7. Adult angry face errors	−0.027	0.085	0.163	−0.131	0.332**	0.017	—		
8. Adult sad face errors	0.080	0.252*	0.109	−0.269*	0.517**	0.350**	0.061	—	
9. Adult fearful face errors	0.078	−0.080	0.222*	−0.222	0.426**	0.122	0.078	0.192*	—

Note: ADHD = attention-deficit/hyperactivity disorder; CDRS = Children's Depression Rating Scale; CGAS = Clinical Global Assessment Scale; YMRS = Young Mania Rating Scale.
$^*p < .05$, $^{**}p < .01$.

predicted total child face identification errors ($\beta = 0.35$, $p = .001$, $R^2 = 0.013$, $R^2\Delta = 0.107$), child sad face errors ($\beta = 0.33$, $p = .001$, $R^2 = 0.011$, $R^2\Delta = 0.099$), and child angry face errors ($\beta = 0.33$, $p = .001$, $R^2 = 0.011$, $R^2\Delta = 0.098$). After controlling for covariates, ADHD symptoms did not significantly predict child fearful face errors, nor did youth mania symptoms or CGAS score significantly predict child sad face errors.

Adult Face Variables. We found that none of the youth symptom variables significantly predicted adult face identification errors, after controlling for the variance accounted for by the covariates. However, youth ADHD symptoms approached significance in the prediction of total adult face identification errors ($\beta = 0.22$, $p = .02$, $R^2\Delta = 0.044$).

DISCUSSION

In line with the emphasis of the National Institute of Mental Health (NIMH) on the examination of dimensional aspects of psychopathology, we examined the relationship between symptoms of mania, depression, and ADHD, as well as functional impairment in relation to emotional face identification in youth.[1] Our results suggest that symptoms of mania, depression, and ADHD may be particularly important in the identification of negative emotional faces. For example, ADHD symptoms appear to positively predict errors on child faces (total, sad, and angry). It is possible that symptoms of inattention, hyperactivity, and impulsivity may impair emotional face identification regardless of the children's primary *DSM-IV* diagnosis.[3]

Regarding the role of symptoms of mania and depression, some have compared face processing in youth with euthymic versus symptomatic BD, or in youth with euthymic BD versus TDCs; however, little research has examined the effect of mood state on emotional face identification in youth with BD[4,5] (for a review of this literature, refer to the Discussion section within the main article). Although none have examined emotional face identification in depressed youths with BD, our data indicating that depression symptoms were predictive of child sad face errors suggests that this would be an important line of inquiry.

Exploratory Analyses: Examination of Subtypes of ADHD on Emotional Face Identification

Given that our ADHD sample contained all subtypes (ADHD combined type [CT] n = 30/38 [79.0%], inattentive type n = 7/38 [18.4%], hyperactive/impulsive type n = 1/38 [2.6%]), to determine whether our child emotional face results were confounded by the inclusion of all ADHD subtypes, we re-ran our analyses restricting the ADHD sample to only those with ADHD-CT.

Total Child Face Errors

There was a significant main effect of group on total child face identification errors ($F_{4,96} = 5.70$, $p = .005$). Post-hoc pairwise comparisons showed that both participants with BD ($p = .05$) and ADHD ($p = .005$) made significantly more total errors on child faces than TDCs. However, BD and ADHD groups did not significantly differ from each other.

Child Face Errors by Emotion Type

Results showed a significant effect of diagnostic group (Wilks' $\lambda = 0.77$, $p = .002$) on child face errors by emotion type with a univariate main effect of group on errors on happy ($F_{2,96} = 5.43$, $p = .006$), angry ($F_{2,96} = 3.03$, $p = .05$), and fearful faces ($F_{2,96} = 3.40$, $p = .04$), but not child sad faces ($F_{2,96} = 2.90$, $p = .06$).

Post-hoc pairwise comparisons of happy face errors showed that participants with BD made significantly more errors on happy faces than either participants with ADHD ($p = .01$) or TDCs ($p = .02$), but there were no significant differences between participants with ADHD and TDC.

Post-hoc pairwise comparisons of angry face did not show significant between group differences after correcting for multiple analyses (all p values $<.05$).

Post-hoc pairwise comparisons of fearful face errors demonstrated that participants with ADHD made significantly more errors than TDC ($p = .04$) but not significantly more than participants with BD, nor did participants with BD make significantly more errors than participants with TDC.

Exploratory Analyses: Group Comparison of Identification Errors in High- Versus Low-Intensity Emotional Faces

Given prior work suggesting the importance of emotional intensity on emotional face identification for youth with BD or with ADHD, we evaluated errors on low- and high-intensity faces on child and adult faces separately.[6,7]

Child Face Errors by Intensity of Emotion

We found a significant effect of diagnostic group (Wilks' $\lambda = 0.89$, $p = .014$) on child face errors by intensity, with a univariate main effect of group on low-intensity ($F_{2,\ 104} = 6.14$, $p = .003$) but not high-intensity ($F_{2,104} = 2.45$, $p = .09$) face errors.

Post-hoc pairwise comparisons of child low intensity face errors showed that both BD ($p = .007$) and participants with ADHD ($p = .009$) made more errors on low intensity faces versus TDCs; however, BD and ADHD groups did not differ.

Adult Face Errors by Intensity of Emotion

There was no significant multivariate effect of diagnostic group (Wilks' $\lambda = 0.96$, $p = .312$) on adult face errors by intensity; therefore, we did not examine univariate analyses.

SUPPLEMENTAL REFERENCES

1. Insel T, Cuthbert B, Garvey M, *et al*. Research domain criteria (RDoC): toward a new classification framework for research on mental disorders. Am J Psychiatry. 2010;167: 748-751.
2. Insel TR, Cuthbert BN. Endophenotypes: bridging genomic complexity and disorder heterogeneity. Biol Psychiatry. 2009;66: 988-989.
3. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders 4th Edition Text Revision (DSM-IV-TR). Washington, DC: American Psychiatric Association; 2000.
4. Dickstein DP, Rich BA, Roberson-Nay R, *et al*. Neural activation during encoding of emotional faces in pediatric bipolar disorder. Bipolar Disord. 2007;9:679-692.
5. Guyer AE, McClure EB, Adler AD, *et al*. Specificity of facial expression labeling deficits in childhood psychopathology. J Child Psychol Psychiatry. 2007;48:863-871.
6. Rich BA, Fromm SJ, Berghorst LH, *et al*. Neural connectivity in children with bipolar disorder: impairment in the face emotion processing circuit. J Child Psychol Psychiatry. 2008;49:88-96.
7. Dickstein DP, Castellanos FX. Face processing in attention deficit/hyperactivity disorder. Curr Top Behav Neurosci. 2012;9:219-237.