The Impact of Reward, Punishment, and Frustration on Attention in Pediatric Bipolar Disorder

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Background: *Theories in affective neuroscience suggest that mood disorders involve perturbations in attention–emotion interactions. We tested the hypothesis that frustration adversely impacts attention and behavior in children with bipolar disorder (BPD).*

Methods: *Thirty-five children with BPD and 26 normal control subjects completed: 1) a Posner attention task with feedback but no contingencies; 2) an affective Posner with contingencies; and 3) an affective Posner that used rigged feedback to induce frustration. Reaction time (RT) and event-related potential (ERP) data were collected.*

Results: *At baseline (task 1), there were no between-group differences in behavior or ERPs. Children with BPD exhibited reduced parietal P3 amplitude on task 3 only. On trials occurring after negative feedback, control subjects showed decreased RT when contingencies were introduced (task 2), whereas BPD subjects did not.*

Conclusions: *The introduction of contingencies was associated with impaired performance of children with BPD, suggesting deficits in their ability to adapt to changing contingencies. In addition, frustration was associated with disrupted attention allocation in children with BPD. We hypothesize that children with BPD inappropriately deployed attention to their internal frustration rather than to the task, causing impaired performance.*

Key Words: Bipolar disorder, children, attention, emotion, frustration, ERPs

Despite increasing investigation of pediatric bipolar disorder (BPD), multiple facets of the condition remain relatively unexplored. The issue of responsivity to environmental contingencies is particularly salient because heightened sensitivity to feedback might explain mood lability in pediatric BPD (Leibenluft et al 2003a, 2003b; Phillips et al 2003).

Previous investigations of reward processing and sensitivity to emotional stimuli in BPD have yielded mixed results. In adults, some studies found normal responses to reward in BPD-spectrum patients (Rubinsztein et al 2001), but others found evidence of immediate reward-seeking (Murphy et al 2001) or heightened stress responsivity (Depue et al 1981; Goplerud and Depue 1985).

Contrary to our initial predictions, we have obtained evidence that children with BPD might be less sensitive to feedback than are control subjects, in that they are slower to learn stimulus–reward contingencies (Dickstein et al 2004; Gorrindo et al, in press). This deficit might relate to the inability of children with BPD to respond in a well-regulated manner to emotional cues in their environment and, furthermore, might be secondary to attentional deficits. Effective regulation of emotion requires effective control of attention (Kopp 2002), and a child's ability to deploy attention strategically is central to the moderation of irritability, frustration, and anger (Mischel et al 1989; Posner and Rothbart 1998; Sethi et al 2000). Frustration can be defined as the emotion experienced when goal-directed activity is thwarted. Low frustration tolerance is a prominent symptom in pediatric BPD, leading to explosive, highly irritable behavior. When children with BPD become frustrated in response to negative feedback, they might focus on their internal state rather than on the task at hand. This diversion of their attention would both compromise their task performance and accentuate their already negative internal state as they allocate increased attentional resources to it.

Studies in adult BPD find attention deficits across mood states (Basso et al 2002; Clark et al 2001; Ferrier et al 1999; Murphy et al 1999; Neu et al 2001; Sax et al 1995; Wilder-Willis et al 2001). In pediatric BPD, there is evidence of subtle attention deficits during euthymia on some tasks (McClure et al, unpublished data) but not others (McClure et al, in press; Robertson et al 2003). Importantly, these studies tested children under nonemotional contexts; robust deficiencies in attention modulation in pediatric BPD might occur only under motivationally salient circumstances.

The affective Posner task represents a sound paradigm for examining attention–emotion interactions. The Posner paradigm (Posner 1978; Posner and Cohen 1984) has been used widely to study spatial attention and orienting to cueing. The original Posner paradigm was modified by Derryberry and Reed (1994) and Perez-Edgar and Fox (2005) to include an affective component in the form of positive and negative feedback that produces faster reaction times, increased errors, and increased event-related potentials (ERP) amplitude on emotional, compared with neutral, trials.

We used the affective Posner paradigm of Perez-Edgar and Fox (2005) to examine the impact of frustration on attention in pediatric BPD. We recorded both behavioral responses and ERPs. We were particularly interested in the impact of emotion on attention as reflected in the P3 ERP component, thought to relate to cognitive processing (Verleger 1988) and allocation of attentional resources (Steger et al 2000). To our knowledge, this is the first study to examine ERPs in pediatric BPD. We predicted that emotional context would have an adverse impact on attentional functioning in patients with BPD, relative to control subjects. Specifically, we hypothesized that frustration would produce a reduction in P3 amplitude in children with BPD, relative to

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control subjects. This would be consistent with previous studies of the relationship between increasing task complexity and P3 amplitude in children with psychiatric illness, such as attention-deficit/hyperactivity disorder (DeFrance et al 1996; Jonkman et al 2000) and schizophrenia (Strandburg et al 1994). Specifically, these studies have shown that, as task complexity increases, control subjects demonstrate increased P3 amplitude, whereas children with psychopathology do not. We were particularly interested in between-group differences in P3 amplitude at parietal sites, given the demonstration in prior studies of between-group differences in parietal cortical activity in psychiatric populations (DeFrance et al 1996). Finally, we predicted that, whereas control subjects would display a reduced reaction time (RT) on emotional as compared with neutral trials, children with BPD would display a lesser reduction in RT (Derryberry and Reed 1994; Perez-Edgar and Fox 2005). Specifically, we hypothesized that frustration would cause patients but not control subjects to be distracted from the task and therefore less likely to respond appropriately to emotional contingencies by increasing their RT.

Methods and Materials

Participants

Inclusion/Exclusion Criteria. Pediatric BPD ($n = 35$) and control ($n = 26$) subjects were enrolled in an ongoing neurocognitive and neuroimaging study at the National Institute of Mental Health (NIMH). The NIMH Institutional Review Board approved the study. Parents and children gave written informed consent/assent.

Inclusion criteria for the BPD sample required that subjects, ages 7–17 years, meet DSM-IV (American Psychiatric Association 1994) criteria for BPD, including a history of at least one hypomanic or manic episode meeting full-duration criteria (i.e., lasting more than 4 days) during which the child exhibited abnormally elevated and expansive mood, and at least three other criterion "B" symptoms (Geller et al 2002). The Kiddie-Schedule for Affective Disorders-Present and Lifetime Version (Kaufman et al 1997) was administered to parents and children separately by different clinicians, and diagnoses were based on best-estimate procedures (Leckman et al 1982) generated in a consensus conference. Comorbid psychiatric diagnoses were assessed by inquiring about the presence of symptoms during a time of relative euthymia. Children with a history of irritability only without elevated or expansive mood, as well as those without distinct manic episodes, were excluded; thus this sample met criteria for the narrow phenotype of BPD (Leibenluft et al 2003b). Control subjects with no psychiatric history in the subject and his/her first-degree relatives were age- and gender-matched to the patients. See Dickstein et al (2004) for a more complete description of additional inclusion and exclusion criteria.

To evaluate mood at the time of testing, graduate-level clinicians with established interrater reliability administered the Children's Depression Rating Scale (CDRS; Poznanski et al 1984) and the Young Mania Rating Scale (YMRS; Young et al 1978) to patients with BPD and their parents. Bipolar subjects also completed the Manifest Anxiety Scale for Children (MASC; March et al 1997).

Demographics. Patients and control subjects did not differ on age (BPD, 12.88 ± 2.67 years; control subjects, 13.74 ± 2.33 years) or gender (BPD, boys = 60%; control subjects, boys = 50%). Among patients, 82.9% ($n = 29$) met criteria for Bipolar I and 17.1% ($n = 6$) met criteria for Bipolar II; 88.6% ($n = 31$) had at least one additional diagnosis, and the mean number of comorbid diagnoses was 2.54 ± 1.70. The most common comorbid diagnoses were attention-deficit/hyperactivity disorder (ADHD; 60%, $n = 21$), generalized anxiety disorder (40%, $n = 14$), oppositional defiant disorder (ODD; 34.3%, $n = 12$), and elimination disorder (28.6%, $n = 10$); 60% ($n = 21$) met criteria for at least one DSM-IV anxiety diagnosis.

Children's Depression Rating Scale and YMRS scores showed that 88.6% ($n = 31$) of the children with BPD were euthymic at the time of testing. The mean CDRS score was 24.60 ± 5.64, and only one participant exceeded the CDRS cut-off score for current depression (i.e., 40). The mean YMRS score was 3.77 ± 4.60. Three participants exceeded the YMRS cut-off for hypomania (i.e., 12), and none had scores indicating current mania (cut-off = 26). The mean MASC score was 38.29 ± 21.40, and only one patient exceeded the cut-off score for current anxiety.

Of our patients, 91.4% ($n = 32$) were medicated at the time of testing, with a mean of 2.94 ± 1.35 medications per subject. Most common medications (not mutually exclusive) were mood stabilizers (80.0%, $n = 28$), antipsychotics (68.6%, $n = 24$), lithium (40.0%, $n = 14$), stimulants (34.3%, $n = 12$), and antidepressants (31.4%, $n = 11$).

Procedure

Posner Task. The Posner task was completed as part of a larger battery of psychophysiology testing. Subjects were seated comfortably approximately 75 cm from a desktop computer NANAO FlexScan T561 monitor (EIZO Nanao Technologies, Cypress, California) with a 45-cm color display screen. Children were given a 12 cm × 7 cm × 3 cm response box with two buttons connected to the data acquisition computer.

Consistent with the design of Perez-Edgar and Fox (2005), the paradigm consisted of three tasks, with 100 trials in task 1, 50 trials in task 2, and 51 trials in task 3. The tasks all involved the same stimuli and task demands (see Figure 1) but differed in the contingencies for performance. A white fixation cross appeared in the center of the screen, followed by three boxes arranged horizontally. Cue presentation consisted of one of the three boxes illuminating blue; cues appeared in the central box on 20% of trials and equally in the right and left boxes for the remaining trials (40% each). After cue presentation, a white target square appeared inside either the left or right box. Subjects were instructed to press the button corresponding to the target location. Subjects were instructed to respond as quickly as possible while maintaining accuracy. The white target box remained on the screen until a response was given; if no response was given, the target disappeared after 1260 msec. After the response,

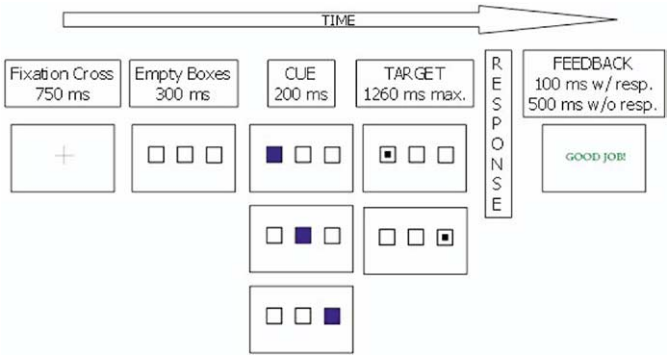

Figure 1. Depiction of the Posner Paradigm computer stimuli, with examples of stimuli material and associated timing of presentation.

feedback appeared on the screen and remained for 100 msec if the child responded or 500 msec if they failed to respond. This longer feedback display was based on the assumption that a lack of a response indicated inattention, thus the feedback remained on the screen longer in an effort to garner the subject's attention. After this feedback, the fixation cross reappeared on the screen initiating the next trial. Stimulus timing was consistent with that of Perez-Edgar and Fox (2005). Stimuli presentation was controlled by the STIM stimulus presentation system (James Long, Caroga Lake, New York). Before beginning the task, participants completed a practice block of six trials to ensure that they understood the task.

With the exception of the difference in trial number per task, the primary difference between the three tasks was in the nature of their contingencies. Task 1 served as the baseline, with subjects informed of the accuracy of their response ("Good job!" or "Incorrect!"). In task 2, subjects won or lost 10 cents on the basis of their performance; subjects were informed of the accuracy of their response and whether they had won or lost money. During task 3, correct responses resulted in accurate feedback and reward on 44% of trials, but on 56% of trials, rigged feedback informing the subject that he/she had been too slow was provided randomly regardless of performance, and the subject lost 10 cents. Task order was fixed in an effort to progressively heighten arousal and to avoid potential carryover arousal that might have occurred if the frustration task preceded the baseline or contingency tasks.

Whereas the task was designed to elicit frustration, it did not exceed the minimal risk standard of pediatric research. That is, the frustration resulting from the task did not exceed that which our participants encounter in their typical daily experience (e.g., when taking an examination at school, losing at a board game). At the beginning of the task, children were told that they could stop the task at any time without compromising their ability to participate in other aspects of the study. In fact, although subjects did become frustrated, all participants were able to complete the task, and none displayed inappropriate behavior or extreme affect either during or after the task.

Electroencephalogram Collection. Electroencephalogram (EEG) signals were recorded with an electrode cap from temporal (T3, T4, T5, T6), frontal (Fz, F3, F4), central (C3, C4, Cz), and parietal (Pz, P3, P4) sites with the international 10/20 system (Jasper 1958), referenced to the right earlobe, with a cap from Electro-Cap International (Eaton, Ohio). Impedances were kept below 10 kW. Data from each channel were digitized at a 512-Hz sampling rate and calibrated to a .477 volt rms 10-Hz signal that was input into each channel before testing. Signals were amplified with a bioamplifier filter (James Long) with settings of .10 Hz high-pass and 100 Hz low-pass. The digitized EEG data were edited for eye-blink and movement-related artifact with an automated algorithm filter that defined a blink as 100 μV/50 msec. Eye blinks were regressed out with software provided by James Long. All other artifactual EEG ($\pm$100 μV) were automatically removed from further analysis. The signal was digitized with Snapshot-Snapstream acquisition software (HEM Data, Southfield, Michigan).

Event-Related Potentials. Event-related potentials were collected to the presentation of each target, referenced to a 100-msec baseline. Only trials that were artifact-free for the 1000 msec after target presentation were included. Event-related potential components were chosen for analysis on the basis of a review of the grand ERPs, created by averaging mean ERPs from all of the participants. Event-related potentials to the valid and invalid trials were compared for P3 (200–400 msec). The peak amplitude within the designated time window was used for the analyses.

As in other studies in which EEG and ERP data were used to study emotional and cognitive development (Marshall et al 2002; Perez-Edgar and Fox 2005), this study used average referencing. Although there is some controversy regarding the use of the average reference with small electrode arrays (Davidson et al 2000; Hagemann et al 2001), the scalp distribution of electrodes in the present study was extensive enough to justify use of this reference configuration (Marshall et al 2002).

In plotting produced with average referencing, the ERP waves from the posterior sites (i.e., parietal and occipital) are inverted relative to the anterior sites. We labeled the components on the basis of their appearance in the ERPs produced by the frontal electrodes.

Affective Data. To provide self-report mood data, at the conclusion of each block subjects completed a paper-and-pencil rating of valence and arousal called the self-assessment manikin (McManis et al 2001). These consisted of unlabeled line-drawings of human manikins along a 9-point scale, with extremes of happy/unhappy (valence) and calm/aroused (arousal). Subjects provided three valence and three arousal ratings, with one valence and one arousal rating for their state 1) after each block; 2) after trials that resulted in reward; and 3) after trials that resulted in punishment.

Data and Statistical Analysis. We measured RT after target presentation and response accuracy (i.e., the percentage of responses that matched target location). Failure to give a response was considered incorrect and included in accuracy calculations but not in calculation of RT. Trials were classified as postpositive or postnegative feedback according to the type of feedback that immediately preceded the trial. This allowed for an assessment of the impact of feedback on subsequent performance. Trials were also categorized as valid (cue and target matched on location), invalid (cue and target mismatched on location), and neutral (cue in the middle box). For all tasks, 40% of the trials were valid cue, 40% were invalid cue, and 20% were neutral.

Data analysis used repeated measures analyses of variance (ANOVAs). Statistical corrections were implemented where assumptions of sphericity or homoscedasticity were violated. Results were considered significant on the basis of a two-tailed $\alpha < .05$. To minimize type 1 errors, the Greenhouse-Geisser procedure was applied when appropriate. All subsequent post hoc comparisons used the Tukey test. The data were analyzed with SPSS version 11.5 (SPSS, Chicago, Illinois).

Results

Event-Related Potentials

A series of ANOVAs were conducted to test the hypothesis that, during frustration, children with BPD would have decreased P3 amplitude compared with control subjects. Temporal, frontal, central, and parietal sites were analyzed separately. For temporal analyses, a $3 \times 2 \times 2$ ANOVA was conducted with task (1, 2, and 3), trial type (valid, invalid), and site (T3, T4) as the within-subject factors. For all other sites, a $3 \times 2 \times 3$ ANOVA was conducted, with the same task and trial type as the within-subject variables but different site locations: frontal (F3, F4, Fz); central (C3, C4, Cz); and parietal (P3, P4, Pz).

Because our interest was in between-group differences, only those results involving a significant group main effect or signif-

icant interactions between group and other variables are discussed. There were no significant between-group P3 differences at temporal, frontal, or central sites on any task. In addition, in the group × trial type (i.e., valid, invalid) [$F(1,36) = 2.21$, $p = .15$] and group × trial type × task analyses [$F(2,72) = 1.07$, $p = .35$], neither a main effect for trial type nor any interactions involving this variable were significant. Thus, post hoc analyses collapsed across the trial type variable.

At parietal sites, a repeated measures ANOVA revealed a significant group × task interaction [$F(2,72) = 3.73$, $p = .035$]. Post hoc analyses showed that on task 3 ($t = -2.77$, $p = .008$), but not on task 1 ($t = -.21$, $p = .84$) or task 2 ($t = .25$, $p = .81$), patients had significantly lower P3 amplitude than did control subjects, collapsed across parietal sites (see Table 1 and Figure 2). When this post hoc analysis was examined further, results showed a significant task-related increase in P3 in control subjects [$F(2,16) = 7.32$, $p = .006$], specifically between tasks 2 and 3 ($p = .009$). This suggests that control subjects allocated additional attentional resources to the task as its emotional demands increased, although in the bipolar sample the main effect of task was nonsignificant [$F(2,18) = .28$, $p = .76$], suggesting that P3 amplitude and allocation of attentional resources did not change in response to the increased emotional demands of task 3.

To maintain consistency with our analyses of behavioral data (see Behavioral Data section), P3 data were compared across feedback on task 3 (tasks 1 and 2 had an insufficient number of postnegative trials). On task 3, there was a significant group × site interaction [$F(2,78) = 3.05$, $p = .039$], in that children with BPD had significantly lower P3 amplitude than did control subjects at the Pz parietal site ($t = -2.23$, $p = .032$) on trials after negative feedback. Repeated measures ANOVAs on trials after positive feedback were nonsignificant.

Behavioral Data

Validity Effect. To examine the so-called Posner validity effect (i.e., the RT costs and benefits of cued vs. noncued targets), we compared RT for valid versus invalid trials. Previous studies have consistently found faster response to valid versus invalid trials (i.e., the Posner effect; Posner and Cohen 1984) because invalid, but not valid, trials require the subject to shift his attention from the location of the cue to that of the target (Hugdahl and Nordby 1994). With task (1, 2, 3) and trial type (valid, invalid, neutral) as the within-subject factors and group (bipolar, control) as the between-subjects factor, 3 × 3 × 2 repeated measures ANOVAs were conducted. As expected in a Posner paradigm, valid trials had significantly faster RT than did either invalid ($p < .001$) or neutral trials ($p < .001$), with nonsignificant RT difference between invalid and neutral trials ($p = .27$). All other main effects and interactions were nonsignificant. These results indicate that RT was slower for invalid than valid trials, regardless of group status or task.

Table 1. ERP Amplitude for P3 Component Across Parietal Sites and Across Valid/Invalid Trials

	Task 1		Task 2		Task 3	
	Mean	SE	Mean	SE	Mean	SE
Bipolar ($n = 36$)	2.10	.96	2.25	1.05	1.51	1.27
Control ($n = 25$)	2.67	1.01	2.19	1.11	4.81	1.34

Event-related potential (ERP) amplitude ($\mu V \times 10^6$) data for the P3 component averaged across parietal sites, from valid and invalid trials, for the bipolar and control samples. Data are compared across the three Posner task manipulations.

Task 1, baseline; Task 2, contingencies added; Task 3, contingencies and rigged feedback added.

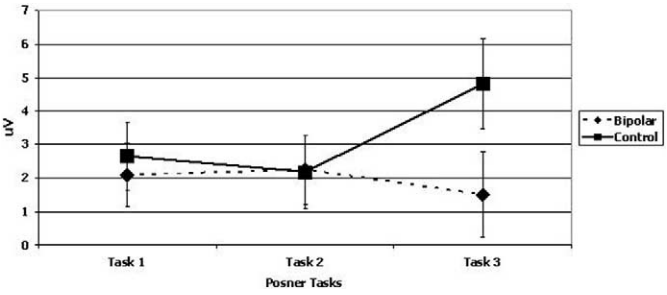

Figure 2. Event-related potential amplitudes for the P3 component at parietal sites across the three Posner task manipulations. Significant between-group differences emerged only in response to frustration on task 3, with control subjects displaying greater amplitude than did children with bipolar disorder.

Reaction Time. To examine our prediction that, relative to control subjects, children with BPD would display a lesser reduction in RT on emotional, as compared with neutral trials, a 3 × 2 repeated measures ANOVA for RT on trials after negative feedback was conducted with task (1, 2, and 3) as the within-subject factor and group (bipolar, control) as the between-group factor (see Table 2 for a summary of RT results). The group × task interaction was significant [$F(2,82) = 4.70$, $p = .015$]. Post hoc analyses found that RT did not differ between BPD patients and control subjects on task 1 ($t = 1.15$, $p = .22$), but patients were significantly slower than control subjects on task 2 ($t = 3.76$, $p = .001$) and task 3 ($t = 6.47$, $p < .001$). Thus, BPD patients' responsivity to negative feedback, equivalent to control subjects at baseline, was impaired when contingencies were introduced (task 2) and when frustration was induced (task 3). Examining the results within group and across task, control subjects showed significantly faster RT from task 1 to task 2 [$F(2,36) = 79.07$, $p < .001$] and task 2 to task 3 [$F(2,36) = 79.07$, $p < .001$]; however, BPD patients' RT did not change from task 1 to task 2 but became significantly faster from task 2 to task 3 [$F(2,46) = 14.52$, $p = .001$] (see Figure 3). Thus, control subjects responded to the introduction of contingencies as expected, with significantly faster RT. Children with BPD, however, were unresponsive to punishment on task 2, and although their RT decreased when frustration was induced (task 3), BPD subjects' RT remained significantly slower than that of the control subjects.

A similar 3 × 2 repeated measures ANOVA for RT on trials after positive feedback found significant group [$F(1,59) = 4.83$, $p = .032$] and task [$F(2,118) = 206.87$, $p < .001$] main effects, with faster RT for control subjects than BPD subjects, and faster RT as tasks progressed. The group × task interaction, however, was nonsignificant [$F(2,118) = 2.03$, $p = .14$], indicating that, in terms of RT on trials after positive feedback, patients and control subjects did not respond differently to the introduction of contingencies and/or frustration.

Accuracy. Identical ANOVAs to those with RT were conducted with percent correct as the outcome measure. The initial omnibus repeated measures 3 × 2 × 2 ANOVA found a significant main effect of group [$F(1,41) = 6.49$, $p = .015$], and post hoc analyses found patients to have significantly lower accuracy than control subjects; however, the task × group interaction was nonsignificant [$F(2,82) = 1.60$, $p = .21$], indicating that group differences in accuracy did not vary as a function

Table 2. Group Differences in Reaction Time After Varying Types of Feedback for Traditional and Affective Posner Tasks

	Bipolar (n = 36)	Control (n = 25)
Total RT		
Task 1	428.06 ± 104.85	402.20 ± 81.26
Task 2	398.52 ± 106.85[a]	333.72 ± 57.96[a]
Task 3	292.87 ± 78.28[b]	224.06 ± 60.10[b]
Post-Negative Feedback RT		
Task 1	467.83 ± 178.83[c]	427.98 ± 82.94
Task 2	510.65 ± 70.43[d,e]	322.08 ± 50.79[d]
Task 3	301.59 ± 78.31[f,g]	202.58 ± 40.05[f]
Post-Positive Feedback RT		
Task 1	419.95 ± 96.16[c]	383.49 ± 80.04
Task 2	393.97 ± 103.13[e]	332.49 ± 57.17
Task 3	234.26 ± 77.25[g]	209.50 ± 62.96

Reaction time (RT) (msec) data for the bipolar and control samples. Data are separated by reaction time total, as well as after negative and positive feedback, and are compared across the three Posner task manipulations. Values are means ± SD.

Task 1, baseline; Task 2, contingencies added; Task 3, contingencies and rigged feedback added.

[a] $t = -3.50$, $p = .001$.
[b] $t = -4.10$, $p < .001$.
[c] $t = 2.06$, $p = .04$.
[d] $t = 3.75$, $p = .001$.
[e] $t = 3.51$, $p = .001$.
[f] $t = 6.47$, $p < .001$.
[g] $t = 4.24$, $p < .001$.

of task/feedback manipulations (see Table 3 for a summary of accuracy scores).

Role of Mood, Comorbid Diagnoses, and Medication. Supplemental analyses were conducted in children with BPD to examine the potential role of mood, comorbidity, and medication. Bivariate correlational analyses found no significant correlations between YMRS, CDRS, or MASC scores and P3 amplitude, RT, or accuracy results. Regarding comorbid diagnoses, we divided the patients into those with and without comorbid ADHD (comorbid n = 21), anxiety disorder (comorbid n = 21), and/or ODD (comorbid n = 13) (comorbid diagnoses were not mutually exclusive). A series of repeated measures ANOVAs with comorbid status (yes vs. no comorbid ADHD, anxiety, ODD, separately) as the between-group factor and task (1, 2, 3) as the within-subject factor did not find significant differences for P3 amplitude, RT, or accuracy. Similar analyses that divided the patient sample into those taking and not taking mood stabilizers (taking n = 27), antipsychotics (taking n = 23), lithium (taking n = 14), stimulants (taking n = 11), and/or antidepressants (taking n = 11) (medication classes were not mutually exclusive) also did not find significant differences for P3 amplitude, RT, or accuracy.

Affective Data

To determine whether task manipulation resulted in group differences in self-reported mood, repeated measures ANOVAs were conducted with the self-assessment manikin data, with time (now, win, lose) and type (valence, arousal) examined separately. Results found no main effects of group nor group × task interactions for now valence, now arousal, win valence, or win arousal. For self-report of valence after punishment trials, there was a significant main effect of group [$F(1,34) = 5.76$, $p = .022$], in that, across the three tasks, children with BPD were significantly more unhappy than were control subjects in response to trials that resulted in punishment. For arousal after punishment, a significant group × task interaction [$F(2,33) = 3.93$, $p = .029$] found no group differences in excitation on tasks 1 and 2, but on task 3 (the frustration task), children with BPD reported being significantly more excited and aroused in response to punishment than did control subjects ($p = .018$).

Discussion

The current study examined the impact of introducing contingencies and frustration to an attentional task on bipolar children's behavioral performance and P3 amplitude. We predicted that, compared with control subjects, attentional functioning in children with BPD would be more sensitive to emotional context, manifest in an inability to respond to contingencies with the appropriate reduction in RT on emotional trials and in reduced P3 ERP amplitude in response to emotional stimuli. Results indicated that, although the performance of children with BPD did not differ from that of control subjects at baseline, control subjects reduced their RT after negative emotional contingencies were introduced, whereas patients did not, and patient P3 amplitude was lower than that of control subjects after frustration was induced. The relatively long RTs of the children with BPD on tasks 2 and 3 suggest that they might have difficulty adapting to contingencies, whereas the ERP results on task 3 indicate that behavioral deficits might be secondary to the impaired allocation of attention resources resulting from frustration.

Consistent with our predictions, we found significantly lower P3 amplitude in patients only at parietal sites and only on task 3. These data might indicate that the failure of the patients to allocate sufficient attentional resources to the task, in the setting of frustration, is manifest behaviorally in response to the most potent emotional stimulus (i.e., negative feedback in the context of frustration). Several researchers have concluded that competition for neural resources occurs because of inherent limitations of human processing ability (Bundesen 1990; Desimone and Duncan 1995; Grossberg 1980; Harter et al 1984). This competition means that certain stimuli will be suppressed, whereas others will attain increased salience. Our results suggest that frustration, or perhaps any heightened emotional state, might be more salient for patients with BPD than for control subjects. That is, the fact that the children with BPD had lower P3 amplitude than did control subjects only during the frustration task might suggest that the patients inappropriately deployed their atten-

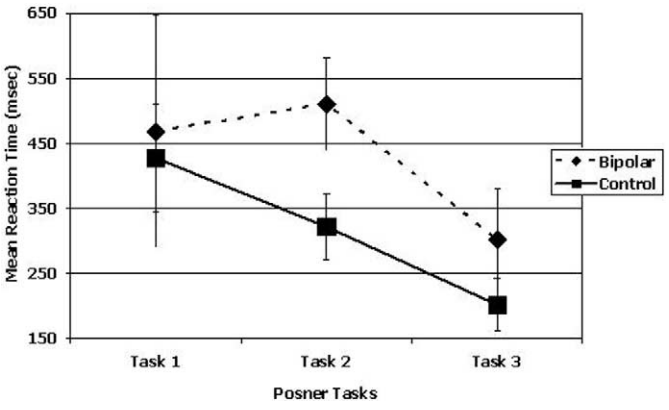

Figure 3. Reaction times (in msec) on trials that followed negative feedback. Significant between-group differences emerged only in response to the emotional contexts of tasks 2 and 3, with children with bipolar disorder being significantly slower than control subjects.

Table 3. Group Differences in Accuracy After Varying Types of Feedback for Traditional and Affective Posner Tasks

	Bipolar ($n = 36$)	Control ($n = 25$)
Total Accuracy		
Task 1	94.26 ± 7.40	97.69 ± 2.28
Task 2	96.60 ± 3.78	97.69 ± 1.91
Task 3	77.76 ± 10.10	80.02 ± 9.81
Post-Negative Feedback Accuracy		
Task 1	88.90 ± 15.40	100.00 ± 0
Task 2	95.83 ± 9.11	97.37 ± 11.47
Task 3	76.87 ± 8.99	79.23 ± 11.41
Post-Positive Feedback Accuracy		
Task 1	95.02 ± 5.89	97.64 ± 2.44
Task 2	97.65 ± 3.67	98.28 ± 1.94
Task 3	73.71 ± 15.10	79.01 ± 15.38

Accuracy (percent correct) data for bipolar and control samples. Data are seperated by accuracy total, as well as after negative and positive feedback, and are compared across the three Posner task manipulations. Values are means ± SD.

Task 1, baseline; Task 2, contingencies added; Task 3, contingencies and rigged feedback added.

tional resources to the emotional context rather than to the primary Posner task itself. Thus, the saliency of frustration resulted in distraction from the task and inappropriate allocation of attention to the negative affect of the environment, thus producing reduced P3 amplitude.

To a certain extent, our results in BPD are consistent with those in other pediatric psychopathologies. For example, whereas normal baseline P3 amplitude has been documented in ADHD children (Novak et al 1995; Oades et al 1996; Satterfield et al 1988) and in children at risk for schizophrenia (Friedman et al 1986), a lack of increased P3 amplitude in response to increased testing demands has been documented in ADHD children (Jonkman et al 2000) and actively psychotic children with schizophrenia (Strandburg et al 1994). It is important, however, to clarify that, in the affective Posner, task complexity remained constant, whereas the emotional demands increased across tasks. It was this manipulation that made the patients' behavioral and psychophysiologic impairment evident. In sum, the absence of baseline differences between patients with BPD and control subjects, the absence of group differences in the validity effect (a measure of the costs and benefits of cueing to attention), and our P3 results all suggest that the critical factor in eliciting attentional deficits in pediatric BPD is emotionally demanding environments, perhaps in particular those characterized by frustration.

Our behavioral results are consistent with the notion that the attentional performance of bipolar children was impaired only in the setting of negative emotions. We had predicted that the more substantial impact of emotion on attention in our sample of children with BPD, compared with control subjects, would be manifest in the patients' lesser reduction in RT on emotional, as compared with neutral trials. Consistent with this, whereas control subjects decreased their RT in response to negative feedback when contingencies were introduced on task 2, the RT of the patients remained unchanged. These results might suggest impaired adaptation on the part of the patients to the introduction of negative feedback and specifically, an inflexible responsivity to the emotional manipulation of the testing context with punishment. The pattern of decreasing RT also argues against fatigue or disengagement from the task as possible confounds.

It is also important to consider our behavioral data in light of the observation, noted in the Results section, that patients with BPD had decreased P3 amplitude on task 3 as compared with control subjects. Behaviorally, the decreased P3 amplitude on task 3 was associated with the patients having longer RT than the control subjects after negative trials, but there were no between-group differences in Posner effect or accuracy specific to task 3. To the extent that one would expect decreased performance in the setting of decreased P3 amplitude, our results are therefore somewhat mixed. That is, whereas in our BPD sample the neurophysiologic and behavioral performance on task 3 was highly consistent, on task 2 we found slower RT in BPD subjects without the corresponding P3 amplitude differences. Of note, it is not uncommon for ERP and behavioral data to find conflicting results (Harter et al 1988; Johnstone and Barry 1996; Karayanidis et al 2000). Conflicting results in the current study might reflect the fact that, whereas the ERP data were cued specifically to the target on punishment trials, behavioral responsivity reflected RT on trials after punishment. This discrepancy, a limitation inherent in the paradigm design, might in part explain the differences in our RT and ERP data. In addition, the inconsistency between our behavioral and neurophysiologic results on task 2 might speak to the extent to which punishment versus frustration impact performance but not allocation of attentional resources, and vice versa.

The failure of euthymic children with BPD to adapt to changing contingencies in this study is consistent with other results from our laboratory with the use of probabilistic response reversal (Gorrindo et al, in press) and the intradimensional/extradimensional shift task on the Cambridge Automated Neuropsychologic Testing Battery (Cambridge Cognition, Cambridge, United Kingdom; Dickstein et al 2004). In both of these tasks, children with BPD were impaired in their ability to learn new stimulus–reward associations and thus, as in the current study, were less able than control subjects to adapt to a changing emotional context. To understand the relevance of these findings to the pathophysiology of BPD, we note that patients with BPD, when in the midst of a manic or depressed episode, show a marked failure to adapt to behavioral contingencies. That is, while manic they are hyperhedonic, seeking reward inappropriately, whereas during depression they are anhedonic and unable to respond to reward (Leibenluft et al 2003a). Our results with bipolar children might suggest that, during euthymia, patients with BPD show a subtle trait variant of this impaired response to contingencies.

The fact that behavioral and neurophysiologic differences were not evident between the bipolar and control samples on task 1 suggests that medication effects might not account for the between-group behavioral and psychophysiologic differences on tasks 2 and 3. Furthermore, comparisons indicated that the behavioral and psychophysiologic results were a reflection of neither mood state nor comorbid diagnoses.

A limitation of the current study is that the tasks were not presented in randomized order. Although the task was designed in this fashion in an attempt to gradually increase emotionality, the lack of counterbalancing leaves open the possibility that the results are due to an order effect and that group differences reflect variability in rate of learning. We are currently piloting a new version of the paradigm with randomly ordered tasks. In addition, we plan to use the affective Posner in children with ADHD as well as those with chronic irritability and hyperarousal (the "broad phenotype" of pediatric BPD; Leibenluft et al 2003b). These studies will delineate the extent to which the deficits seen here are specific to pediatric BPD or occur in other children with severe irritability. In addition, given that the mixed medication status of our patient sample makes it difficult to elucidate the impact of specific medi-

cations, future studies with unmedicated children with BPD would be highly valuable. Ultimately, functional neuroimaging could be used to elucidate the neural dysfunction mediating the observed patient–control subject differences.

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