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A Multimethod Investigation of the Behavioral Activation System in Bipolar Disorder

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Dysregulation in behavioral activation system (BAS) activity has been implicated in the pathogenesis of bipolar disorder (BPD). To characterize BAS activity and related facets in this disorder, the authors compared 59 participants with BPD to 44 controls on multiple measures of BAS activity, including a standardized behavioral task, self-reports, and electroencephalographic indexes of regional cortical activity. Levels of putative BAS activity differed depending on assessment strategy. When a behavioral task indexing reward sensitivity was used, euthymic BPD patients showed evidence of higher BAS activity than either control participants or patients who were in a mood episode. Following a mood induction procedure designed to elicit BAS activity, currently episodic patients showed relatively greater left anterior cortical activity than either euthymic or control participants. Implications of the findings for future research on BPD vulnerability are described.

Keywords: behavioral activation system, bipolar disorder, reward, EEG asymmetry

The behavioral approach system (BAS; Gray, 1972, 1990, 1994), also described as a behavioral activation system (Fowles, 1994) and a behavioral facilitation system (Depue & Iacono, 1989), is a broad trait that emerges from several biobehavioral models of temperament and is thought to have implications for individual differences in vulnerability to psychopathology. The BAS is viewed as regulating appetitive behavior aimed at acquiring desirable stimuli in the environment and the accompanying emotional experiences of happiness and excitement. A separate behavioral inhibition (or avoidance) system (BIS; Gray, 1972, 1990, 1994) is postulated to control aversive motivational functioning, such as passive avoidance, and regulates the coincident anxious arousal. Models that implicate BAS activity in the development of major depression and bipolar disorder (BPD) are consistent with the clinical phenomenology of these disorders. Indeed, the manic and depressive episodes typical of BPD have been characterized as polar extremes on a continuum of BAS activity (Collins & Depue, 1992), and it has been posited that dysregulations in BAS functioning are a vulnerability factor for mood disorders (Depue & Iacono, 1989; Depue, Krauss, & Spoont, 1987; Depue & Zald, 1993).

To explore these models, researchers have examined BAS activity in clinical and high-risk populations, with diverse assessment strategies emerging from different research traditions. Via electroencephalographic (EEG) indices of cortical activity, decreased left frontal hemispheric activity has been associated with current (Gotlib, Ranganath, & Rosenfeld, 1998; Henriques & Davidson, 1991; Thibodeau, Jorgensen, & Kim, 2006) and lifetime history of depression (Gotlib et al., 1998; Henriques & Davidson, 1990; although see Pizzagalli et al., 2002; and Reid, Duke, & Allen, 1998, for inconsistent findings). This literature is generally consistent with models proposing that activity in left frontal cortical regions (usually measured relative to right) reflects approach motivation and that diminished activity in this region may be a trait marker of depression vulnerability (Davidson, 1998). Little is known about frontal EEG activity in BPD. One study of participants with

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bipolar seasonal affective disorder (Allen, Iacono, Depue, & Arbisi, 1993) reported EEG measures of left frontal hypoactivation during depression and remission. Miller et al. (2002) examined frontal asymmetry in adults with a childhood onset of depressive disorder. Findings showed lower left frontal activity for female patients, while adult men with childhood depression showed an opposite pattern of frontal asymmetry of greater left relative to right activity. These sex differences were most pronounced in participants who subsequently developed BPD or were experiencing depressive symptoms at the time of the EEG assessment. Harmon-Jones et al. (2002) recently reported that college students who scored high on a measure of mania proneness showed increased left frontal activity in response to an anger-eliciting laboratory task. The authors argued that since anger is associated with approach tendencies, it is related to BAS functioning despite its negative emotional valence.

Another literature has used experimental methods to characterize the impact of mood symptoms and disorders on behavior aimed at obtaining rewards. Participants with clinical depression, dysphoria, and elevated depressive symptoms generally fail to modify their behavior to obtain rewards (Henriques & Davidson, 2000; Henriques, Glowacki, & Davidson, 1994). Other than a few studies of neuropsychiatric functioning (Clark, Iversen, and Goodwin, 2001a, 2001b; Murphy et al., 2001), significantly less is known about the performance of patients with BPD on such tasks. Our group recently found that, compared to control participants, patients with BPD showed an increased tendency to make erratic choices during a gambling task (Yechiam, Hayden, Bodkins, O'Donnell, & Hetrick, in press). Ernst et al. (2004) reported that pediatric BPD patients reported greater dissatisfaction than controls when they failed to win during a Wheel of Fortune task and greater satisfaction at not losing. In a sample of undergraduate students, Johnson, Ruggero, and Carver (2005) examined the association between current mood symptoms and performance on a task in which participants pressed a button in response to a light signal for a small monetary reward. Current hypomanic symptoms predicted greater positive affect and expectations for success on future tasks, following receipt of the reward.

Regarding subjective reports of BAS, in an undergraduate sample classified as at risk for mood disorders via the General Behavior Inventory (Depue, Krauss, Spoont, & Arbisi, 1989), higher self-reported BAS activity was correlated with greater manic and fewer depressive symptoms (Meyer, Johnson, & Carver, 1999). In patients with BPD, higher scores on self-reported BAS were unrelated to levels of concurrent manic symptoms but did predict greater manic symptoms over time (Meyer, Johnson, & Winters, 2001).

This review of the literature indicates several gaps in knowledge about the role of BAS activity in BPD. First, very few studies have examined EEG indices thought to reflect BAS activity in this population. Additionally, much of what is known about BAS in BPD comes from analogue samples of risk rather than clinical samples. While this strategy has a number of advantages, including circumventing the issue of the effects of medication and previous episodes of illness on measures of behavior, a complementary characterization of BAS in clinical samples is needed. The methodologies that have been used to measure BAS in BPD to date are also somewhat limited. Surprisingly few studies have used standardized experimental methods to characterize BAS-related processes in mood disorders (Pizzagalli, Jahn, & O'Shea, 2005), especially in BPD. The few studies that have used experimental paradigms have utilized relatively small contingencies or no contingencies at all, which may limit the extent to which motivational systems are successfully activated. Additionally, tasks that measure behavioral responses to reward that use pure, not mixed (e.g., possible reward and loss), conditions are important (Henriques et al., 1994). Psychiatric populations often show evidence of dysregulation in BIS activity (Johnson, Turner, & Iwata, 2003) as well as the BAS. Tasks that elicit behavior that could be motivated by either BAS or BIS activity or a combination of both, as in the case of tasks on which both rewards and losses are possible outcomes, make it difficult to disentangle which of these processes is important.

To address these issues, we examined measures of BAS activity in a sample of patients with BPD and controls using a multimethod assessment approach. We assessed behavioral responses to reward using a card-sorting task. We collected self-reports of BAS activity and EEG measures of cortical activity in frontal brain regions implicated in approach motivation. Depue and Iacono (1989) have characterized BPD as a disorder of BAS dysregulation triggered in response to reward-related cues in the environment. This suggests the importance of examining frontal EEG indices in BPD in the context of experimental manipulations that are likely to elicit BAS activity. We therefore measured cortical activity immediately following a mood induction procedure designed to elicit positive affect and approach motivation.

We expected that BPD patients would show increased left, relative to right, cortical activity in anterior regions only, following a mood induction designed to elicit a positive agentic state (i.e., a mood state characterized by a heightened subjective potency in attaining goals), and that this group would be more responsive to rewards earned during a card-sorting task compared to controls. However, we also expected that considerable heterogeneity could result from variability in clinical status and concurrent mood symptomatology; therefore, we distinguished currently episodic from euthymic BPD participants and also examined the relationship between depressive and manic symptom measures and BAS indices within the BPD group.

Method

Participants

Participants were 59 patients (36 women) with a diagnosis of bipolar I disorder, recruited from local mental health agencies, and 44 nonpsychiatric controls (29 women), recruited via newspaper advertisements and fliers. All participants were interviewed with the Structured Clinical Interview for *DSM–IV* (SCID; First, Spitzer, Gibbon, & Williams, 1996). The clinical interviewers for this project were doctoral- and master's-level psychologists who had completed formal training in the SCID and had several years of experience conducting SCIDs in other research studies. Interrater reliability of our group for the diagnosis of BPD was excellent ($\kappa = 1.00$) in a sample of 26 participants. Control participants were excluded if they met criteria for a lifetime history of any Axis I disorder, and BPD participants were excluded if they had a substance dependence disorder during the 3 months prior to their study participation. Twenty-nine of the BPD patients did not have

a comorbid psychiatric diagnosis. Four had a comorbid diagnosis of an anxiety disorder, and 26 had met criteria for substance dependence prior to the last 3 months before the study assessments. BPD patients with either comorbid diagnosis did not differ from BPD patients without the comorbid condition on any major variables used in the present study.

Bipolar participants were an average of 43 years old (SD = 10.58, range = 21–63 years old) and had an average estimated IQ of 98.63 (SD = 15.61), calculated according to the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). Control participants were an average of 40 years old (SD = 13.17, range = 19–62 years old) and had an estimated IQ of 106.05 (SD = 13.70). While the difference in estimated IQ between the two groups was statistically significant, $t(91) = 2.40$, $p = .02$, both means were well within the average range of intellectual functioning. Most of the control participants (55%) and bipolar participants (69%) were White. Forty percent of the control participants were African American, as was 25% of the patient group. The remaining participants were of other ethnic backgrounds.

Clinical Status

To assess current mood symptomatology, we administered patients two widely used clinician rating scales, the Young Mania Rating Scale (YMRS; Young, Biggs, Ziegler, & Meyer, 1978) and the Montgomery–Asberg Depression Rating Scale (MADRS; Montgomery & Asberg, 1978). Internal consistencies for the YMRS and MADRS were good (see Table 1). BPD patients received a mean score of 14.67 on the YMRS (SD = 12.19, range = 0–48) and 12.86 (SD = 11.91, range = 0–43) on the MADRS. On the basis of all available clinical data, 16 BPD participants were considered euthymic, while the remaining 43 were currently in episode (8 were in a manic episode, 7 were hypomanic, 18 were in a mixed episode, and 10 were in a major depressive episode). Eight of the patients were not currently taking medication for BPD symptomatology, as part of a treatment study "wash-out" period. Five patients' medication status was unknown because of their participation in a treatment study in which clinicians were blind to medication status. The remaining 46 patients were taking an average of 2.35 medications for BPD symptomatology (range = 1–6).

Self-Report

Thirty-nine control and 53 BPD participants completed the BIS/BAS Scales (Carver & White, 1994), which consist of a BIS scale (7 items) and three subscales for BAS that can be summed to create a total BAS scale (13 items). As the BAS subscales were strongly intercorrelated (rs > .40) and analyses of the subscales were redundant with those of the total BAS scale, we present results only for the total BAS scale. Internal consistency (as indexed by coefficient alpha) was acceptable for the BAS and BIS scales (see Table 1).

Behavioral Assessment

As a behavioral measure of reward responsivity, a modified version of the card-sorting task used by Al-Adawi, Powell, and Greenwood (1998) was administered (Durbin, 2000) to 46 BPD and 36 control participants. Participants were given cards similar to regular playing cards but with novel symbols (e.g., stars, houses) in quantities ranging from one to five on each card. Participants were seated at a table facing a game board composed of cards representing each type of symbol and each possible quantity, with spaces for placing sorted cards alongside each.

Eight unique blocks were administered, consisting of two identical trials. Each trial called for participants to sort cards during a 25-s period. Participants were told to sort as many cards as possible by matching cards in the deck by either shape (eight blocks) or quantity (eight blocks) to the cards mounted on the game board. By sorting cards, participants could either win (in eight reward trials) or avoid losing (in eight potential loss trials) money after sorting a minimum amount. Amounts to be won or possibly lost were varied to be either small or large (10 vs. 20 cents; eight trials each), and the criterion amount to be sorted to either begin winning or avoid losing was varied to be either easy or difficult (10 vs. 15 cards; eight trials each). For example, in the first trial (a reward/large amount/easy trial) participants were given

Table 1
Correlations Between Measures of BIS and BAS Activity and Reward Responsivity in Participants With Bipolar Disorder and Controls

Measure	1	2	3	4	5	6	7
1. BIS	.70/.81	−.15	.00	−.09	.21	.25†	.08
2. BAS	.37*	.79/.81	−.23	.11	−.20	.01	.15
3. Sort-RWD	−.21	−.12	.91/.85	.04	.09	−.13	−.39**
4. F4-F3	.02	−.31	−.31	—	.05	.01	.36†
5. IQ	.10	.00	−.24	.04	—	−.13	−.24†
6. MADRS[a]	—	—	—	—	—	.87/—	.27*
7. YMRS[a]	—	—	—	—	—	—	.87/—

Note. Internal consistency estimates (indexed by coefficient alpha) are given on the diagonal for bipolar disorder/control groups. Correlations for participants with bipolar disorder are above the diagonal, and correlations for controls are below the diagonal. Dashes indicate that data in these cells were not calculated or collected. BIS = Behavioral Inhibition System scale; BAS = Behavioral Activation System scale; Sort-RWD = Reward composite scale; IQ = Wechsler Abbreviated Scale of Intelligence estimated IQ; YMRS = Young Mania Rating Scale; MADRS = Montgomery-Asberg Depression Rating Scale.

[a] Correlations with symptom measures are given for the bipolar disorder group only

† $p < .10$. * $p < .05$. ** $p < .01$.

25 s to sort cards to win money. For each card sorted above 10, they won 20 cents per card. Participants also participated in two 25-s baseline sorting trials in which no money was won or lost. The experimenter told the participants the conditions of each trial prior to having them sort cards. Overall, BPD participants won an average of \$9.70 (*SD* = \$5.77) and lost an average of 14 cents (*SD* = \$0.75), while controls won an average of \$10.91 (*SD* = \$6.95) and lost an average of seven cents (*SD* = \$0.22). These amounts were not significantly different. As reward responsivity is the focus of the present study, only trials in which it was possible to win money are considered further.

We averaged the number of cards sorted across trials to create variables reflecting the following conditions: cards sorted to win large amounts of money, cards sorted to win small amounts of money, cards sorted to win in easy conditions, and cards sorted to win in difficult conditions. We created difference scores by subtracting cards sorted for reward under the various conditions from average amounts sorted during the no contingency trials. We then summed the difference scores, treated as scale "items," to create a composite scale, which showed good internal consistency (see Table 1).

Mood Induction Procedure (MIP)

Prior to collecting the EEG data,[1] we administered participants a MIP to elicit positive activation and agentic motivation, affective states linked to BAS activity. The MIP consisted of two 9-min film clips portraying individuals successfully striving against great odds to perform feats of athletic achievement (Morrone, Depue, Scherer, & White, 2000). To confirm that the procedure was effective, we administered a 20-item version of the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988), which asked respondents to indicate the extent to which they were experiencing various mood states "right now, that is, at the present moment," prior to and following the MIP. Pre- and post-MIP ratings of relevant affective descriptors on the Positive and Negative Affect Schedule ("excited," "inspired," and "enthusiastic") were examined with paired *t* tests. Participants rated themselves as significantly more excited, $t(55) = -2.47$, $p = .02$, and more inspired, $t(55) = -4.99$, $p = .00$, after the mood induction. The BPD and control groups did not differ in their susceptibility to the MIP, as indexed by magnitude of change scores on the affective descriptors examined.

EEG

EEG recordings were collected for 60 participants (34 controls). Left-handed participants were excluded from these analyses, which resulted in a final sample size of 23 BPD participants and 27 controls. Participants were seated comfortably in a dimly lit, sound-attenuated, temperature-regulated booth. Following the MIP, resting EEG was recorded over eight 60-s blocks of eyes-open (O) and eyes-closed (C) conditions, presented in one of two counterbalanced orders (OCCOCOOC or COOCOCCO). EEG was recorded from the mid-frontal, anterior temporal, central, and parietal regions from 31 electrode sites, according to the 10–20 system. The average of active sites was used as a reference. Horizontal and vertical electrooculograms were used to monitor ocular artifacts. All impedances were below 10 kΩ. EEG was recorded with a Neuroscan (El Paso, TX) bioamplification and acquisition system at a gain of 1000 and a bandpass of 0.1–200 Hz. EEG recordings were digitized continuously at 1000 Hz. Data were segmented into 60-s O and C blocks, which were then divided into consecutive, overlapping 1,000-ms epochs (50% overlap). The EEG was corrected for ocular artifacts, and epochs containing voltage values of ±150 μV were rejected from the analysis. Power spectra were computed for individual epochs via a fast Fourier transform (Hamming window), and power values were averaged across the epochs.

We computed and transformed alpha power (8–13 Hz) to natural logarithms to address positive skew. To represent asymmetries in regional alpha activity (Harmon-Jones & Allen, 1997; Miller et al., 2002), we computed metrics as the natural logarithm of alpha power at the right recording site minus the left recording site in frontal (ln F4 − ln F3) and posterior (ln P4 − ln P3) regions. Such difference scores have the advantages of increasing statistical power and controlling for individual differences in skull thickness (Coan & Allen, 2004). Since alpha power varies inversely with cortical activity (Davidson, 1988), higher scores on asymmetry metrics calculated in this manner are thought to reflect greater left frontal activity relative to right.

Results

We examined differences between control participants and BPD patients on measures of BAS and related constructs. For these analyses, the BPD group was divided into euthymic and currently symptomatic subgroups. The association between MADRS and YMRS scores and indices of BAS activity was examined within the patient group only. An examination of differences between men and women in the total sample, as well as the patient and control groups separately, showed no significant differences on any of the major variables used in the present study. Eta-square was used as an estimate of effect size and was interpreted according to Cohen's (1988) classification: small effects were greater than or equal to .0099, medium effects were greater than or equal to .0588, large effects were greater than or equal to .1379. Bonferroni tests were used for post hoc multiple comparisons.

Correlations Between Measures of Motivational Systems

Correlations between the BIS/BAS scales, the reward composite from the card-sorting task, and anterior asymmetry scores (averaged across O and C conditions) are presented in Table 1 separately for BPD patients and control participants. Correlations between these measures and MADRS and YMRS ratings are also presented for the patient group alone. Correlations between measures of conceptually similar constructs were generally low and nonsignificant. Self-reported BAS was largely unrelated to other measures of BAS functioning and reward sensitivity. Higher BIS scores were correlated with higher levels of depressive symptoms on the MADRS at the level of a trend. Card sorting under reward

[1] The present study does not report EEG measures of anterior activity collected without a MIP. Unpublished data from our group indicate that no significant group differences were obtained on measures of resting EEG collected without a MIP, although the overall pattern of group differences was similar.

Table 2
Means (and Standard Deviations) of Measures of Self-Reported BIS and BAS, Behavioral Measures of BAS, and Indices of Asymmetry in Regional Cortical Activity

	A	B	C	A–B[a]	B–C[a]	C-A[a]
Self-report						
Mean BIS	19.17 (3.99)	20.56 (4.03)	22.77 (3.48)	−1.10	−2.56[†]	3.65[*]
Mean BAS	40.85 (5.26)	41.56 (5.21)	41.56 (6.06)	−0.41	−0.41	0.82
Card sort task						
Mean no contingency	15.93 (4.74)	16.17 (4.20)	14.43 (3.28)			
Mean sort-RWD	40.64 (16.02)	55.32 (22.12)	40.73 (19.86)	−14.68[*]	14.58[†]	0.10
Alpha asymmetry						
Mean F4-F3	.06 (.15)	.01 (.08)	.19 (.18)	.04	−.17[*]	.13[*]
Mean P4-P3	.06 (.41)	.09 (.27)	−.04 (.27)	−.03	.14	−.11

Note. BIS = Behavioral Inhibition System scale; BAS = Behavioral Activity System scale; A = control participants; B = euthymic bipolar disorder participants; C = symptomatic bipolar disorder participants; sort-RWD = Reward composite scale.
[a] Bonferroni tests of multiple comparisons of group differences.
[†] $p < .10$. [*] $p < .05$.

conditions was unrelated to other measures of motivational system activity. Within the BPD group, manic and depressive symptoms showed a similar pattern of relationships to the card-sorting scale, such that greater symptoms predicted decreased responsivity to reward. Greater manic symptoms were positively associated with greater left anterior cortical activity at the level of a trend.

Self-Report

Means and standard deviations for the BIS/BAS scales are presented in Table 2 for controls and euthymic and symptomatic BPD participants. After data screening to ensure that assumptions of normality and linearity were met, the two bipolar groups (euthymic and symptomatic) were compared to controls on the BIS and BAS scales via multivariate analysis of variance (MANOVA).[2] Results indicated a main effect of group status, Wilks's $\lambda = .83$, $F(4, 184) = 4.62$, $p = .001$, $\eta^2 = .17$. An examination of between-subjects effects revealed that group status had a significant effect only on BIS scores, $F(2, 93) = 9.73$, $p = .000$, $\eta^2 = .17$. Bonferroni tests of multiple comparisons of group differences (see Table 2) showed that control and currently symptomatic BPD participants were significantly different from each other on levels of BIS. Currently symptomatic BPD patients had marginally higher BIS scores than the euthymic patients as well.

Behavioral Assessment

Group means and standard deviations for the composite reward scale are presented in Table 2. Analysis of variance (ANOVA) was used to compare controls and the two BPD groups on the composite scale reflecting responsivity to reward during the card-sorting task. The main effect of group status was significant, $F(2, 79) = 3.56$, $p = .033$, $\eta^2 = .08$. Bonferroni tests showed that euthymic BPD participants sorted more cards to win money than controls and the symptomatic BPD participants.

Cortical Asymmetry

To examine asymmetry in regional activity, we used a repeated measures ANOVA with eyes (open vs. closed) and region (anterior vs. posterior) as within-group variables and sex and group (control, euthymic, and currently ill BPD) as between-groups variables. Since neither the eyes factor nor the sex factor interacted with group, both were dropped from the model. The Group × Region interaction did not reach significance, $F(2, 47) = 1.85$, $p = .16$, $\eta^2 = .07$. However, because we had specific a priori hypotheses regarding anterior asymmetry, we examined regional difference scores using MANOVA. Consistent with our hypothesis, group had a significant effect on anterior asymmetry scores, $F(2, 47) = 4.67$, $p = .014$, $\eta^2 = .17$, while posterior asymmetry scores showed no significant group differences, $F(2, 47) = 0.599$, $p = .554$, $\eta^2 = .02$. Bonferroni tests of group differences (see Table 2) indicated that indices of greater left (relative to right) anterior cortical activity were significantly higher in currently ill BPD participants than in control or euthymic BPD participants.

Discussion

We examined multiple measures of BAS activity in a sample of patients with BPD and control participants. Convergence between methods of measuring putatively similar constructs was weak; accordingly, the evidence for distinct patterns of BAS activity in BPD, relative to controls, differed depending on measurement strategy. Our findings support the use of multiple measures of BAS in investigations of the role of this trait in BPD, as the various assessment modalities we examined appeared to be tapping largely independent processes.

Euthymic BPD patients sorted more cards to win money than both controls and symptomatic BPD patients, consistent with findings that remitted individuals with a history of mania report higher motivation to achieve goals (Johnson, 2005). Greater manic and depressive symptoms were associated with sorting fewer cards during this task. That greater levels of depression were associated with decreased card sorting was not surprising; however, the finding that higher mania was associated with decreased card sorting may initially appear counterintuitive, since mania is often associated with increased engagement in pleasurable activities.

[2] Analyses of group differences on the BAS subscales were nonsignificant ($ps > .45$); data are available on request.

However, this finding is consistent with the notion that severe mania undermines performance (Johnson, 2005). Greater mood symptoms of any kind likely interfere with performance on a demanding task, such as the present one, which required ongoing, sustained effort and concentration. Alternatively, a positive feedback loop may develop as levels of mania rise, influencing the extent to which increasingly more powerful and exciting rewards are needed to sufficiently elicit BAS activity. To maximize the chances of successfully eliciting reward responsivity, the monetary rewards that were attainable by participating in our task were relatively high for a study of this kind. However, the possibility of winning what was still a relatively small amount of money might not have been sufficiently engaging to BPD patients with higher levels of manic symptoms.

Higher self-reported BIS was associated with greater depressive symptoms (consistent with Johnson et al., 2003; Meyer et al., 1999, 2001) and also distinguished currently symptomatic patients from controls. In contrast, we found little evidence that self-reported BAS distinguished control participants from BPD patients, consistent with several other studies finding that self-reports of BAS did not distinguish at-risk or mood-disordered participants from controls (Johnson et al., 2003; Meyer et al., 2001). It has been proposed that the BIS/BAS scales, originally developed for use in undergraduate samples, do not adequately tap the construct of behavioral activation as expressed in clinical samples (Meyer et al., 2001; although see Campbell-Sills, Liverant, & Brown, 2004). This might explain why we failed to find significant correlations between self-reported BAS and EEG indices of anterior asymmetry in the BPD group, in contrast to studies reporting convergence of the BAS scale and anterior cortical asymmetry in college student samples (Coan & Allen, 2003; Harmon-Jones & Allen, 1997). However, we did not find convergence of these measures in our control participants, either.

EEG indices revealed a pattern of greater anterior asymmetry in patients who were currently symptomatic compared to control and euthymic BPD participants. These group differences might have been due largely to the presence of greater mania in the symptomatic group, as the relationship between depressive symptoms and frontal asymmetry scores was minimal. However, it is important to note that most of the symptomatic patients in our sample were experiencing mixed episodes. We do not feel that this compromises the generalization of our findings to other BPD samples, as the extant literature indicates a high co-occurrence of manic and depressive symptoms in most bipolar patients (e.g., Bauer, Simon, Ludman, & Unutzer, 2005). However, future investigations of patients in nonmixed episodes could clarify the relationship between specific phases of BPD and anterior cortical activity.

Our study has a number of strengths, including the use of multiple measures of BAS activity in a sample of BPD patients diagnosed by means of structured clinical interviews. We collected EEG indices of BAS during a relevant motivational/emotional context. However, our study also has some weaknesses. Other than the euthymic group, we did not have a sufficiently large patient sample to examine discrete phases of BPD. Medication usage in the BPD group was heterogeneous, which hampered our ability to look at the specific effects of different medications on measures of BAS. Some medium-sized effects did not reach significance in our EEG analyses, although our sample size was comparable to or larger than samples in many other studies of its kind (see Thibodeau et al., 2006, for a review). We used a relatively lengthy EEG recording period, which has, to our surprise, been linked to smaller effect sizes in adult samples (Thibodeau et al., 2006).

Mood instability in the context of life events may be a robust predictor of relapse of BPD (Aronson & Shukla, 1987), and understanding whether some of this affective instability is accounted for by dysregulated reward processing may have implications for intervention. We plan to examine whether the indices of BAS used in the present study predict course of BPD (Johnson et al., 2000; Meyer et al., 2001); if so, interventions that focus on modulating reactions to reward in everyday life may be indicated, whether pharmacological or cognitive–behavioral (e.g., identifying distorted cognitions, adhering to a strict sleep schedule) in nature. Lam, Wong, and Sham (2001) reported that some BPD patients spontaneously limited goals as a strategy for coping with prodromal mania; furthermore, these strategies appeared to have a positive effect on relapse rates in their sample. It stands to reason that formalized psychosocial interventions geared toward coping with BAS triggers, when deployed in the early stages of mood changes, might similarly help offset full-blown episodes.

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