The Behavioral Activation System and Mania

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Abstract

For over two decades, theorists have suggested that mania relates to heightened sensitivity of the behavioral activation system (BAS). In this article, we review a burgeoning empirical literature on this model, drawing on both cross-sectional and prospective studies. As evidence has emerged for this model, we argue that it is time to consider more specific aspects of BAS sensitivity in this disorder. We review evidence that bipolar disorder relates to an increased willingness to expend effort toward reward and to increases in energy and goal pursuit after an initial reward. We conclude by considering the strengths and weaknesses of this literature, with an eye toward future directions and implications for treatment.

Contents

INTRODUCTION

Behavioral activation system (BAS): neurobiologically based system involved in guiding approach toward reward-relevant stimuli

This article reviews evidence concerning the behavioral activation system (BAS) in bipolar disorder. We begin by defining bipolar disorder and the BAS. We then review a series of studies that indicate that bipolar disorder is characterized by elevated BAS sensitivity and that elevations in BAS sensitivity are prospectively related to the onset of disorder and to a more severe course of mania after onset.

BAS can be thought of as an umbrella construct that encompasses many more specific processes that may have separable neurobiological underpinnings. Although some facets of BAS do not appear to be related to bipolar disorder, others do. These include placing high value on reward and reward-related goals, difficulties in reversing responses to previously rewarded cues, and sustained effort toward goals after an initial success. These various manifestations of BAS hypersensitivity do not appear to be merely epiphenomena of illness, as they are often well documented among at-risk populations. Several of these properties also appear to be related to the course of manic symptoms over time.

Despite the development of this body of work, several important issues remain unaddressed. In our conclusion, we consider some of these issues and point out ways in which better understanding in those areas could have substantial clinical implications.

DEFINING BIPOLAR DISORDER

The *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) diagnostic criteria define bipolar I disorder by the presence of at least one lifetime manic episode (Am. Psychiatr. Assoc. 2000). Mania, in turn, is defined by a distinct period of elevated or irritable mood accompanied by a set of symptoms including decreased need for sleep, increased psychomotor activation, extreme self-confidence, pressured speech, racing thoughts, and pursuit of rewarding activities without attention to risks. To meet criteria, symptoms must interfere with functioning and either last one week or require hospitalization. A milder form of the disorder, bipolar II disorder, is defined by episodes of both hypomania and major depression. Although hypomania is defined by the same symptoms as those involved in mania, their severity is not sufficient to interfere with functioning. A third form of the disorder, cyclothymia, is defined by rapid and chronic fluctuations between

manic and depressive symptoms, in which neither the highs nor lows become intense enough to be diagnosed as full-blown episodes. Although some forms of the disorder are defined in part by experiences of depression, this article focuses primarily on the experience of mania. It is estimated that in the United States, 1% of the population meets criteria for bipolar I disorder and that about 5% of the population meets criteria for the full spectrum of bipolar disorders, though rates may be lower in other countries (Merikangas et al. 2011).

The consequences of mania complicate the study of BAS among people with bipolar I disorder. Given that manic episodes can severely disrupt finances, employment, and relationships, heightened pursuit of reward-related goals could simply reflect a desire to compensate for the damage of previous manic episodes. Further, antipsychotic medications, which are frequently prescribed as antimanic drugs, dampen neural responses to reward receipt (Abler et al. 2008). These difficulties highlight the importance of studying BAS among those who are at risk for mania but have not yet experienced a manic episode. In line with this, a large body of work has examined persons with high scores on the General Behavior Inventory (GBI; Depue et al. 1989) or the Hypomanic Personality Scale (HPS; Eckblad & Chapman 1986), two instruments that measure subsyndromal mania symptoms that are prospectively and robustly associated with risk for developing bipolar disorder. This review considers findings relating BAS sensitivity to mania in both diagnosed and at-risk samples.

DEFINING BAS SENSITIVITY

Over the past 20 years, several theorists have proposed that manic symptoms are tied to a biologically based system variously referred to as the behavioral activation system, behavioral facilitation system, behavioral approach system, or the approach motivation system (Alloy & Abramson 2010, Depue & Iacono 1989, Fowles 1988, Gray 1990). The BAS is postulated to guide approach toward reward-relevant stimuli, in which the goal is to move toward something desired. To do so, BAS functions include a broad range of affective and cognitive processes in support of goal-directed behavior.

It is helpful to differentiate among the inputs to, the outputs of, and the sensitivity of the BAS. Inputs to the BAS are stimuli that serve as cues for goal-directed behavior, such as incentive cues in laboratory settings or life events involving goal salience or goal attainment. Outputs are the manifestations of engaged BAS activity. As one would expect of a broadband system, increases in BAS activity yield many different outputs including motor activity, energy, confidence, and interest and pleasure in rewards. It has been argued that sociability and exploration are also indicators of a heightened activation of this system (Depue & Iacono 1989).

In addition to considering the inputs to and outputs of the BAS, it is important to consider its sensitivity or individual differences moderating the intensity of BAS outputs for a given level of BAS input. Given the same input cues, high BAS sensitivity is reflected in more output. As a metaphor, consider allergies. A person who is highly allergic to pollen (sensitive) will manifest symptoms (output) in the context of pollen to a greater degree than a person who is less allergic. It is important to consider both BAS sensitivity and inputs (cues of incentive) as predictors of BAS output. Some articles, including our own, have referred to BAS sensitivity as reward sensitivity.

One commonly used measure of BAS sensitivity is Carver & White's (1994) BAS scale. Carver & White (1994) wrote self-report items based on several prior statements of how BAS sensitivity should be manifested in overt behavior and subjective experience. The result was three empirically derived factors assessing different manifestations of BAS sensitivity, which are conceptually and empirically distinct from manifestations of threat sensitivity. The BAS subscales capture motivation to pursue goals (Drive), the tendency to respond to rewarding outcomes with energy and enthusiasm (Reward Responsiveness), and the tendency to pursue positive experiences without regard

BAS sensitivity: multifaceted individual difference influencing the intensity of BAS outputs for a given level of BAS input

BAS outputs: manifestations of BAS engagement including motor activity, arousal, elation, and confidence

BAS inputs: stimuli that serve as cues for goal-directed behavior

to potential threats or costs (Fun Seeking). Some research differentiates among BAS subscales; other research blends them into an index. Where researchers described effects for specific BAS subscales, we summarize those findings. Some researchers have examined how bipolar disorder relates to the Sensitivity to Reward scale (Torrubia et al. 1995), which is intended to capture the impulsive pursuit of rewards; as such, this scale is most closely parallel with the BAS Fun-Seeking subscale.

The BAS subscales have been found to relate to a range of affective and behavioral measures of BAS sensitivity (Carver & White 1994). BAS scores have been found to relate to a propensity for setting more approach goals (goals of moving toward something) as opposed to avoidance goals (goals of moving away from something) (Jones et al. 2007) and to valuing approach goals (Alloy et al. 2009). BAS scores predict high arousal positive affect during goal pursuit (Heponiemi et al. 2003) but also responses after receiving a reward, including affect (De Pascalis et al. 2010, Germans & Kring 2000), confidence (Meyer et al. 2010), and neural activity (Beaver et al. 2006, Van den Berg et al. 2011). The BAS scales have also demonstrated excellent test-retest reliability over a two-year period (Brown 2007). In sum, a basic literature provides a conceptual framework for understanding differences in BAS sensitivity. More pragmatically, techniques are available for measuring BAS sensitivity.

EVIDENCE FOR THE BAS HYPERSENSITIVITY MODEL

Depue & Iacono (1989) initiated the wave of interest in relations between BAS and bipolar disorder by drawing on clinical observations. They noted that BAS outputs correspond closely to manic symptoms, including mood change, inflated self-esteem, increased sociability, increased goal-directed activity, and excessive involvement in pleasurable activities. Within their model, mania occurs when the outputs of BAS are sufficiently high.

We begin by considering evidence that mania and BAS outputs both yield similar clinical manifestations, including activity, exploration, and anger. Then we turn to more direct studies examining elevations in BAS sensitivity among those prone to mania and whether the BAS hypersensitivity model might help us understand the course of mania over time.

BAS Outputs Correspond with Key Manic Symptoms

As noted above, Depue and Iacono initially described overlap between symptoms of mania and BAS outputs. Several lines of work indicate that BAS outputs strongly parallel mania symptoms. One body of work has focused on energy and activation; other work has examined anger, a key symptom of mania with a less apparent connection to BAS activity.

Initiation of locomotor activity is believed to be one of the major functions of the BAS (Depue & Iacono 1989). Mania is also highly correlated with activity. In early studies using actigraphy (motion meters), motor activity levels corresponded tightly to changes in manic symptoms over a several-day observation period (Wehr & Wirz-Justice 1982). Increased activation also appears to be a major prodromal symptom of mania: In a study that included hourly actigraphy measures of motor activity and observational ratings of mania, increases in activity were an excellent signal of impending manic shifts (Wehr & Wirz-Justice 1982). Indeed, it has been argued that activation might be a more reliable diagnostic criterion than mood state changes (Akiskal & Benazzi 2005). Accordingly, activity and energy are proposed as cardinal symptoms of mania in the upcoming DSM-5 (Am. Psychiatr. Assoc. 2010).

Drawing from animal research on the open field test, Perry and colleagues (2009) use an assessment paradigm called the human behavioral pattern monitor to test activity and exploration in bipolar disorder. Participants are asked to wait for 15 minutes in a furnished room that has no chairs. Colorful and tactile objects are placed throughout the room. A ceiling camera

is used in addition to actigraphy monitors to quantify levels of activity and exploration, two dimensions that are widely used in animal research. Persons who are manic display highly elevated activity and exploration levels compared to healthy controls or to persons with schizophrenia (Perry et al. 2009). Hence, using a range of tests, it appears that mania is related to greater activity and exploration, which could be conceptualized as indices of high BAS output.

Another defining feature of mania and an important clinical concern is anger. Several epidemiological studies have now found that bipolar disorder is related to highly elevated rates of physical fighting (Corrigan & Watson 2005) and violent offending (Casiano et al. 2008). Although some might assume that BAS activity would lead only to positive affect and positive engagement, extensive evidence suggests that anger can be a response to thwarted goals, particularly approach-related goals (Carver & Harmon-Jones 2009). Thus, elevated BAS sensitivity can increase the propensity for anger in such circumstances (Carver 2004). It appears that elevations of BAS sensitivity could help explain the anger that is observed in bipolar disorder.

On the whole, then, both clinical observations and descriptive research suggest that mania often involves symptoms that represent outputs of the BAS system. These include not just positive affect, activation, and exploration, but also anger.

BAS Sensitivity Is Elevated in Bipolar Disorder

These observations set the stage for a series of more direct empirical studies of BAS sensitivity in bipolar disorder. An initial study followed people with bipolar I disorder until they achieved symptom remission and then assessed them using the BAS scale (Meyer et al. 2001). Persons with bipolar I disorder had high BAS Drive and Fun-Seeking scores compared to normative levels. Salavert and colleagues (2007) observed a parallel finding, in that those with bipolar I disorder obtained higher scores on the Sensitivity to Reward scale (Torrubia et al. 1995) than did healthy controls. Several studies have also indicated that those with bipolar spectrum disorder obtain higher scores on the BAS Drive and Fun-Seeking scales than did healthy controls (Alloy et al. 2008, 2009). Within a group of undergraduates, persons with high BAS scores were more likely to have a lifetime history of bipolar spectrum disorders than were those with medium BAS scores (Alloy et al. 2006).

Conceptually similar findings have been obtained using methods other than self-report. For example, Sutton & Johnson (2002) found that risk for mania (HPS score) was correlated with psychophysiological reactivity to positive pictures (Meyer et al. 1999). Hayden and colleagues (2008) found that bipolar I disorder was related to elevations of BAS sensitivity on a behavioral measure (described below), though they did not find elevations on the total BAS scale (subscales were not reported).

The relation of symptom status and BAS sensitivity is somewhat complex. Cross-sectional studies have found that high BAS Drive and Fun-Seeking scores, as well as Sensitivity to Reward scales, among those with bipolar disorder are correlated with manic symptom severity (Alloy et al. 2008, 2009; Salavert et al. 2007; Van der Gucht et al. 2009). Such correlations, though, could reflect a tendency for high BAS scores to drive mania, could reflect a tendency for mania symptoms to inflate BAS scores, or could indicate that a third variable contributes to elevations in both BAS and mania levels.

Longitudinal analyses are needed to disentangle these possibilities. One study that used such longitudinal analyses examined whether BAS sensitivity levels were elevated only when manic symptoms were present or stayed constant while mania fluctuated (Meyer et al. 2001). This study followed 59 bipolar I participants over an average of 20 months and examined within-subject correlations of BAS scores with symptom interviews in a mixed-effects model. BAS scores remained constant while mania

fluctuated. BAS Drive and Fun-Seeking scores were elevated compared to normative data even among those who were fully recovered (Meyer et al. 2001). These findings indicate that mania does not lead to artifactually elevated BAS scores.

Further evidence that such elevations are not just the result of current symptoms comes from studies showing that BAS sensitivity levels are elevated before onset among those at risk for the disorder, as indicated by HPS scores (Applegate et al. 2009, Carver & Johnson 2009, Fulford et al. 2008, Johnson & Carver 2006, Jones et al. 2007, Jones & Day 2008, Mansell et al. 2008, Meyer et al. 1999, Meyer & Hofmann 2005). It does not appear, then, that elevated BAS levels are an epiphenomenon of symptom levels.

Other research has clarified that the greater reported BAS sensitivity in mania does not appear to be part of a general hypersensitivity to all valenced cues. For example, mania does not appear to be related to elevations in threat sensitivity (Alloy et al. 2006, 2008, 2009; Meyer et al. 2001; Salavert et al. 2007). Rather, scores on a measure of threat sensitivity appear to be related to the severity of depression within bipolar disorder (cf. Alloy et al. 2008, 2009; Meyer et al. 2001).

Despite the large number of positive studies, three researchers have reported mixed or null findings. One found that bipolar disorder was related to higher scores on a behavioral measure of BAS but not the BAS self-report scale (Hayden et al. 2008), one found elevated BAS only for those with manic symptoms (Van der Gucht et al. 2009), and one study found that a small sample of bipolar persons (n = 20) did not differ from control participants on BAS scores (Jones et al. 2006b). It is worth noting that each of these studies tested participants who were taking mood-stabilizing medications yet did not incorporate analyses to consider the blunting effects of antipsychotic medications on BAS sensitivity (Abler et al. 2008). These cross-study discrepancies suggest that control over medications may be an important methodological issue when testing clinical samples. Of course, many other factors could contribute to cross-study differences, and we return to issues of generalizability in our conclusions. On the whole, though, studies provide evidence that BAS scores are stably elevated among persons with bipolar disorder and those at risk for the disorder when this issue is addressed.

BAS Sensitivity Is Prospectively Related to the Onset and Course of Mania

According to theory, greater BAS sensitivity would promote higher BAS outputs when BAS inputs were encountered, resulting in the emergence of manic symptoms. We now turn to evidence from longitudinal studies that BAS sensitivity is prospectively related to more severe manic symptoms among those diagnosed with the disorder as well as to shifts to a more severe form of disorder and to initial onset of disorder.

Two studies of persons diagnosed with bipolar I disorder have found that elevated BAS scores predict increases in manic symptoms as measured using structured symptom severity interviews. In the first, BAS Reward Responsiveness scores were prospectively related to increases in manic symptoms, controlling for baseline symptoms, over a three-month period (Meyer et al. 2001). In the second, Sensitivity to Reward scores were prospectively related to greater risk of manic than depressive episodes over an 18-month follow-up period (Salavert et al. 2007).

Similar findings have emerged among persons diagnosed with bipolar spectrum disorders (bipolar II disorder and cyclothymia). Alloy and her colleagues have conducted a longitudinal two-site study to examine BAS scores as predictors of symptoms and episodes among those diagnosed with bipolar spectrum disorder. Students ages 18 to 24 completed a diagnostic interview, symptom severity scales, and the BAS scale at baseline and then completed diagnostic and symptom severity follow-up interviews every four months for an average of 2.75 years. High total BAS scores and high Reward Responsiveness subscale scores were both related to shorter time to the occurrence

of hypomanic or manic episodes among the first 136 participants (Alloy et al. 2008). These findings were replicated in an extended sample of 195 participants followed for an average of 3.18 years (Alloy et al. 2009). Recent analyses of 201 persons followed over an average of 4.5 years found that high BAS Fun-Seeking scores predicted greater likelihood of developing bipolar I disorder among those diagnosed initially with bipolar II disorder and of developing bipolar II disorder among those diagnosed initially with cyclothymia (Alloy et al. 2011a,b).

Alloy and colleagues have also conducted research to prospectively examine whether BAS sensitivity could predict the onset of bipolar spectrum disorders among students ages 14 to 19 with no mood disorder diagnosis at baseline. Students who scored above the 85th percentile on both the BAS Total and the Sensitivity to Reward scales (Torrubia et al. 1995) (high-BAS; $n = 171$) were compared with those who scored in the 40th to 60th percentile on both scales (moderate-BAS; $n = 119$). When followed for an average of 12.8 months, persons in the high-BAS group were three times more likely than those in the moderate-BAS group to develop a bipolar spectrum disorder (12.9% versus 4.2%) (Alloy et al. 2011a). As with the cross-sectional findings, BAS scales have not been found to predict the onset of depressive episodes over time (Alloy et al. 2008, 2009; Meyer et al. 2001; Salavert et al. 2007).

Overall then, prospective findings indicate that BAS sensitivity is related to the onset of bipolar spectrum disorder, the transition from cyclothymia to bipolar II disorder, the transition from bipolar II disorder to bipolar I disorder, and a more severe course of manic symptoms among those who are diagnosed with bipolar I disorder. These effects do not appear to be artifacts of baseline symptoms in that analyses consistently included baseline mania levels as a covariate. There is some discrepancy between the cross-sectional and prospective findings, in that Drive and Fun-Seeking scales are consistently related to mania in cross-sectional analyses, but longitudinal studies have varied in whether Fun-Seeking or Reward Responsiveness scores are more predictive of increases in manic symptoms over time.

Summary of Evidence Concerning BAS Sensitivity

The BAS sensitivity model was initially based on the idea that manic symptoms seemed to correspond to BAS outputs. Over the years, research has validated these clinical observations in noting that this system relates to anger, energy, and exploration, each of which is a key aspect of mania. In more direct tests, the BAS sensitivity model has substantial cross-sectional and prospective support. With few exceptions, findings suggest that elevated BAS sensitivity is present among those diagnosed with bipolar I disorder and bipolar spectrum disorders as well as those at risk for the disorder by virtue of subsyndromal symptoms. Several studies suggest that elevated BAS sensitivity can be documented during well periods among those with bipolar disorder. BAS sensitivity is related to the onset of bipolar spectrum disorder, the intensification of bipolar spectrum disorders to more severe forms of disorder, and among those diagnosed with bipolar I disorder, more severe manic symptoms.

SPECIFIC COMPONENTS OF BAS SENSITIVITY IN BIPOLAR DISORDER

Although often treated as a unified system, the BAS appears to comprise a set of dissociable mechanisms. One way to parse these mechanisms is to consider the time course of incentive pursuit. A simple division is between the availability and pursuit of an incentive versus its attainment (reward). Before a reward is obtained, BAS sensitivity can influence the reward's valuation or desirability. This motivational property is captured by the term "wanting" (Berridge 2007). Greater BAS sensitivity may be linked to greater wanting.

Several processes are important to consider after a reward is obtained. First, there is an immediate hedonic response to it, which is

captured by the term "liking." Second, learning occurs that changes subsequent responses to stimuli associated with the reward. BAS sensitivity can influence this learning in two ways. One is the speed with which a person learns which stimulus is paired with reward. Another is the person's ability to shift responses when a formerly rewarded stimulus is no longer paired with reward (response reversal). Beyond hedonic and learning responses, attaining reward promotes satiety—once a reward is successfully obtained, there is a normative tendency to reduce approach motivation. It is increasingly clear that other psychopathologies, such as eating disorders and addictions, can involve a failure of satiety such that the person may sustain high BAS output levels even after attaining reward (Flagel et al. 2009, Nasser et al. 2005). Below, we consider evidence that mania entails a failure of this mechanism such that heightened BAS output levels (energy, arousal, confidence, and goal pursuit) are sustained after reward receipt.

We consider these separate components of the BAS in this section, noting from the outset that relatively little research has directly examined these constructs. Nonetheless, we consider the available evidence on how those prone to mania perform on measures of reward valuation, initial hedonic responses to reward, learning, and satiety responses to reward compared to healthy controls.

Reward Valuation (Wanting)

Across studies, risk for mania as indexed by the HPS scale has been correlated with a tendency to set approach goals as opposed to avoidance goals (Jones et al. 2007, Meyer et al. 2004) and to perceive approach scenarios as more enticing (Meyer et al. 2007). More broadly, people with bipolar disorder report valuing goal attainment and seeing this attainment as of central importance to self-worth (Alloy et al. 2009; Fulford et al. 2009; Lam et al. 2001, 2004; Scott et al. 2000; Wright et al. 2005). This overvaluation of goals does not appear to be a consequence of manic episodes in that it has been observed among those who have experienced only subsyndromal symptoms of mania (Morrison et al. 2003) and is not influenced by fluctuations in affective states from mood inductions (Wright et al. 2005). Hence bipolar disorder and mania risk appear to be related to a stable tendency to value achieving goals.

How broad is this tendency to value reward? In the animal literature, one of the clearest ways to measure reward valuation is to consider what costs an organism would endure to obtain rewards. Costs might involve expenditure of energy or the possibility of sustaining a loss. There is evidence that willingness to endure different costs can be behaviorally and neurally distinct (Wallis 2007). We first consider paradigms that have assessed the willingness to sustain risk of loss in exchange for the prospect of reward. Then we review studies that are consistent with a willingness to expend more energy to accomplish difficult goals.

Sensitivity to loss during reward pursuit. Several tasks have been used to assess whether persons with bipolar disorder will tolerate the potential for loss in the pursuit of reward. The most common approach uses gambling tasks such as the Iowa Gambling Task (Bechara et al. 1994) and the Cambridge Gambling Task (Rogers et al. 1999). These tasks are designed to measure sensitivity to the possibility of losing money while attempting to pursue monetary rewards.

During manic episodes, people with bipolar disorder display an increased willingness to take risks on the Iowa Gambling Task (cf. Adida et al. 2011, Clark et al. 2001) and the Cambridge Gambling Task (cf. Rubinsztein et al. 2006) compared to controls. Here, though, we focus on findings during remission. These findings have been mixed. One large study suggested that euthymic persons with bipolar disorder make riskier decisions than do healthy controls (Jollant et al. 2007), and another large-scale study observed risky decision-making among persons with bipolar disorder compared to controls, regardless of whether they were euthymic, manic, or depressed (Adida

et al. 2011). In contrast to this evidence for risky decision-making, findings of other studies have indicated that euthymic people with bipolar disorder do not differ from healthy controls in their performance on the Iowa Gambling Task (Clark et al. 2002, Martino et al. 2011, Yechiam et al. 2008) or on a Wheel of Fortune task (Ernst et al. 2004) compared to healthy controls. Two other studies failed to find elevated risk taking among bipolar participants even when positive mood inductions were administered before the Cambridge Gambling Task (Roiser et al. 2009) or the Iowa Gambling Task (Clark et al. 2001). On the whole, then, findings have not consistently indicated that risky decision-making can be observed among those with bipolar disorder once they are euthymic.

Beyond gambling tasks, the Balloon Analog Risk Task has been used as an index of willingness to risk losing money in pursuit of monetary reward (Lejuez et al. 2002). In this task, participants press a button repeatedly to inflate a balloon—the larger the balloon, the greater the reward. The task involves risk, though, in that inflating the balloon too many times can cause the balloon to pop, and consequently no money is won for that round. In a study of bipolar participants with and without alcohol abuse as compared to healthy controls, only the participants with comorbid bipolar disorder and alcohol abuse differed from controls on the number of popped balloons (Holmes et al. 2009).

Taken together, findings provide only mixed evidence that persons with remitted bipolar disorder differ from others in their willingness to risk losses in the pursuit of rewards. The pattern casts doubt on the idea that those with a history of mania are willing to tolerate losses to gain larger rewards.

Willingness to expend effort to gain reward. Another index of reward valuation is willingness to expend effort in the pursuit of the reward. Effort-based decision-making is a widely used paradigm for assessing motivation to attain rewards in animal research (Salamone et al. 2009). Most typically, an animal is presented with a choice between an easily obtained but small reward as compared to a larger reward that requires more work (e.g., more lever presses, a steeper ramp, or a barrier to climb over). This behavioral paradigm has been shown to be highly sensitive to biological manipulations of the BAS system. For example, manipulations that increase dopamine levels or activity of the nucleus accumbens have been found to enhance willingness to choose the high-effort/high-reward choice over the low-effort/low-reward choice (Salamone et al. 2009). Hence effort-based decision-making has been well validated in animal research as a measure of behavioral activation.

Several studies have examined how people with bipolar disorder mobilize effort toward goals that are difficult to obtain. In laboratory studies, people diagnosed with bipolar disorder expend more effort in conditions involving reward. This willingness to expend effort appears to be specific to reward conditions and is not observed in conditions without reward. For example, Hayden and colleagues (2008) found that when given an opportunity to earn a reward, people with bipolar I disorder completed a card sorting task faster than did healthy controls. These group differences did not emerge in the nonreward condition.

Harmon-Jones and colleagues (2008) hypothesized that people diagnosed with bipolar disorder would sustain effort and remain engaged as tasks became more difficult if the task involved reward as opposed to punishment. In testing this hypothesis, they used left frontal cortical activation (as measured by electroencephalography) to index task engagement. When presented with anagrams of varying difficulty levels (easy, medium, difficult) and a chance to either win money if solved correctly ("reward" trial) or lose money if solved incorrectly ("punishment" trial), people with bipolar disorder showed greater relative left frontal cortical activation while preparing for the difficult reward trials but not for the difficult punishment trials and not for the medium or easy reward trials. These findings suggest that people with bipolar disorder work harder and sustain effort longer given challenging

opportunities to earn reward. Similar findings regarding sustained engagement in the face of challenge have emerged in a study of students at high risk for mania as defined by high GBI scores (Harmon-Jones et al. 2002).

In sum, greater reward valuation in the form of willingness to expend effort has been found at a behavioral and a psychophysiological level among persons with bipolar disorder. Willingness to expend effort toward difficult-to-obtain rewards appears to be the only index of reward valuation that has been consistently related to bipolar disorder during remission.

A fair amount of evidence from self-report scales also indirectly supports this idea of willingness to expend effort among persons diagnosed with bipolar disorder. Johnson & Carver (2006) developed a self-report measure termed the WASSUP (Willingly Approached Set of Statistically Unlikely Pursuits) to capture ambitions to pursue highly difficult-to-attain life goals. Across studies, people diagnosed with bipolar disorder endorse highly ambitious life goals (Alloy et al. 2011a, Carver & Johnson 2009, Johnson et al. 2011). The goals do not appear to be a compensation for the bipolar diagnosis in that risk for mania as measured with the HPS also correlates with high WASSUP scores (Fulford et al. 2008, Gruber & Johnson 2009, Johnson & Carver 2006, Johnson & Jones 2009). These ambitions also do not appear to be an artifact of manic symptoms in that this profile is observed even after adjusting for current mood symptoms (Fulford et al. 2008, Gruber & Johnson 2009, Johnson & Carver 2006, Johnson & Jones 2009).

Implications of willingness to expend effort toward goals. High goal setting is strongly associated with success (Sitzmann & Ely 2011). Accordingly, we have reviewed elsewhere the idea that one might expect that the pattern of high goal setting and willingness to expend effort observed among those with bipolar disorder might contribute to heightened accomplishment (Johnson 2005). There is some evidence that premorbid levels of accomplishment are high for those who develop bipolar disorder (MacCabe et al. 2010). One goal for future research would be to examine how these accomplishments relate to goal setting.

Although ambitious goal setting might have positive consequences, early evidence also suggests that ambitious goal setting at baseline is prospectively related to a worse course of mania over time. In longitudinal analyses, self-reported emphasis on achieving goals was related to subsequent increases in manic symptoms (Alloy et al. 2009, Francis-Raniere et al. 2006). Another study found that highly ambitious WASSUP goals for achieving fame and wealth were related to increases in manic symptoms (Johnson et al. 2011). It seems, then, that high goal setting may be important for understanding the course of mania over time.

Taken together, it appears that compared to healthy controls, people prone to mania will expend more effort toward reward pursuit and stay more engaged as tasks become more difficult. Relatedly, they will pursue highly ambitious life goals. Although it is possible that this profile helps explain a tendency toward premorbid accomplishment, it may also contribute to a more severe course of mania over time.

Initial Hedonic Response to Success (Liking)

In studies of initial responses to reward, one well-studied component is the initial hedonic response, which has been labeled "liking" (Berridge 2007). The most common measure of liking in humans is simply the subjective experience of pleasure in response to a reward, measured using affective ratings. Several studies have failed to document that people with bipolar disorder report a greater increase in happiness than do controls in response to success feedback in careful laboratory paradigms. For example, in one study people with bipolar disorder did not report a significantly greater increase in happiness than did healthy controls on measures taken just after receiving (false) positive feedback or winning on gambling tasks (Farmer et al. 2006, Roiser et al. 2009). In another study, people with bipolar disorder compared to healthy controls did not show greater increases in happiness

or psychophysiological reactivity after viewing happy film clips (Gruber et al. 2008). The available evidence does not seem to indicate that bipolar disorder is related to an elevated hedonic response to a positive stimulus.

Learning

Reward learning is most commonly assessed using probabilistic learning tasks (Frank et al. 2004). In typical probabilistic learning tasks, participants are presented with one of two stimuli on each trial, and a reward may or may not follow the stimulus presentation. The stimulus that is more frequently followed by a reward is termed the richly rewarded stimulus. Reward learning is indexed by the number of trials before participants learn to select the richly rewarded stimulus.

There is little evidence that mania relates to this sort of learning. Effects on probabilistic reward learning were not found among euthymic children with bipolar disorder (Dickstein et al. 2010, Gorrindo et al. 2005) or in unmedicated adults diagnosed with bipolar depression (Roiser et al. 2009). Contrary to hypotheses, one study found that adults with bipolar disorder were actually slower to develop a bias toward the richly reinforced stimulus than were healthy controls (Pizzagalli et al. 2008), although the deficit was particularly apparent among those who were experiencing anhedonic symptoms of depression. These findings provide no support for an association between mania and enhanced reward learning. One caveat is that the studies did not control for general speed of learning or neuropsychological deficits.

Researchers have also used response reversal paradigms to study sensitivity to changing contingencies once associations are established. In these tasks, participants first learn that a given stimulus is associated with reward. In a second phase, contingencies are changed without warning so that the stimulus that previously was richly rewarded is no longer rewarded. The number of times that a participant continues to choose the formerly rewarded stimulus is used as an index of difficulty adjusting to the response reversal. Though showing no difference in initial acquisition, people with bipolar disorder have shown deficits on response reversal during periods of remission (Dickstein et al. 2010, Gorrindo et al. 2005) and depression (Roiser et al. 2009).

The few available findings do not indicate that persons with bipolar disorder learn to associate stimuli with rewards more quickly than others do. However, findings do suggest that people with bipolar disorder show deficits compared to healthy controls in adjusting their behavior to face changing contingencies after initial learning. Specifically, they continue to choose previously rewarded stimuli that are no longer associated with reward.

Lack of Satiety in Responses to Success: Prolonged Affect, Overly General Confidence, and Increased Energy

Within bipolar disorder, several paradigms have been used to examine responses to reward other than initial hedonic response. These studies have examined the duration of the hedonic response as well as changes in confidence, energy, and arousal after success. To examine these variables, researchers have used laboratory tasks, experience sampling, and self-report to understand cognitive and behavioral response to success. Evidence from these paradigms suggests that people with bipolar disorder respond intensely in a variety of ways to goal progress.

To begin, it appears that affective responses to success may last longer for people with bipolar disorder compared to healthy controls. Farmer and colleagues (2006) used false success feedback during a Go-No Go task as a way to induce positive affect among euthymic bipolar individuals ($n = 15$) and controls ($n = 19$). That is, after a practice block with no monetary reward, participants were given positive feedback that their performance was very fast. Self-rated happiness was measured four times over the course of the task, once before the mood induction, and three times afterward. Bipolar participants and controls reported similar increases in positive mood just

after receiving the positive feedback. Group differences were observed, though, in the duration of this increase in positive mood. By the final rating, the mean happiness score of the control group had returned to baseline, whereas the mean score in the bipolar group remained elevated. Hence, mania proneness may be more related to the duration of reward response than to its initial affective intensity.

Other studies indicate that bipolar disorder is related to overly general increases in confidence after success. For example, after success on a skill-based task, persons with a history of mild manic symptoms seem more confident about their likely performance on chance tasks. In a first study of this phenomenon, Stern & Berrenberg (1979) recruited a sample of students with subsyndromal mania symptoms and a control group and provided them with high, medium, or low success feedback on an ability-based task. They were then asked to predict how accurately they would be able to guess the outcome of a coin toss. Students with subsyndromal mania symptoms were more confident than controls about their performance in predicting coin tosses, but only after receiving success feedback.

Meyer and colleagues (2010) extended this work to show that doing well on a chance-based task seemed to inspire overly general confidence among those at risk for bipolar disorder. Their study included a condition involving positive feedback about a chance-based task (dice rolling) and a condition involving positive feedback about an ability-based task (an intelligence task). Whereas most people gained confidence after positive feedback on an IQ task, a similar gain after positive feedback on the dice-rolling task was distinct to the high HPS persons.

To refine understanding of these shifts in confidence, we created a self-report scale to assess different ways in which confidence might increase after success. Persons at risk for mania, as indicated by HPS scores, endorsed greater shifts in confidence in response to a specific success than did those with lower HPS scores. Mania risk was particularly related to upward generalization—defined by an overly large leap in confidence. Persons prone to mania endorsed items such as "if someone praises the way I express something, I think I can write a book" (Eisner et al. 2008). These findings have been replicated in a cross-national study of risk for mania (Johnson & Jones 2009). Surges of confidence after success, then, appear to be present among those at risk for disorder.

Beyond confidence, it appears that those with bipolar disorder may also experience increases in energy and effort after success compared to other people. One model of how people handle their many simultaneous life tasks is that they shift from one to another as they make enough progress on the first to attend to the second (Carver & Scheier 1998). One study asked people to name three goals they were pursuing and to rate their progress and efforts toward these goals three times a day for 21 days. Multilevel modeling revealed an overall tendency for people to react to unexpectedly high progress toward a goal by reducing effort toward it in the next time block. People with bipolar disorder, however, did this significantly less than healthy controls. These results suggest that people with bipolar disorder experience greater mobilization—more energy and activation—in response to goal progress compared to controls (Fulford et al. 2010).

In parallel to these findings, Wright and colleagues (2008) reported that among people diagnosed with bipolar disorder, those with a more severe history (characterized by a greater number of manic episodes) remained in a highly activated state for longer after daily successes than did those with a milder history. More specifically, those with bipolar disorder showed more sustained responses on the Behavioral Engagement scale, which is designed to assess energy, excitement, confidence, and lively thought.

One might expect that increases in confidence and energy would promote a willingness to take on difficult tasks, and findings of one laboratory task are consistent with this idea. In one study, researchers gave participants (sham) success feedback and then asked them to choose the difficulty level for an upcoming eye-hand

task. People at high risk for bipolar disorder chose a more difficult task for themselves than did those at low risk (Johnson et al. 2005, 2008).

In sum, there is some evidence that people with bipolar disorder and those at risk for disorder respond differently to goal progress and success feedback than do other people. Whether measured by self-reports or laboratory paradigms, mania proneness appears related to longer-lasting excitement, confidence, energy, and goal pursuit in response to success.

Implications of lack of satiety. Many of us might wish for prolonged pleasure, spikes in confidence, and renewed energy and effort after experiencing success and goal progress. Despite the allure of these experiences, it is worth noting that they are defining symptoms of mania. Other evidence suggests that these experiences can also be harbingers of onset. That is, increased energy and involvement in goal pursuit are related to longitudinal increases in manic symptoms (Lozano & Johnson 2001), as are overly confident views of the self (Lam et al. 2005, Lee et al. 2010).

Several studies have now examined responses to major life events that involved attaining goals, such as becoming married or graduating from college. For people diagnosed with bipolar I disorder, such events predict longitudinal increases in manic symptoms over the next several months, controlling for baseline symptoms (Johnson et al. 2000, 2008). Life events involving goal attainment also predict longitudinal increases in hypomanic symptoms among persons diagnosed with bipolar spectrum disorders (Nusslock et al. 2007). In contrast, negative life events do not directly predict changes in mania over time (Johnson et al. 2008).

Given that hypomania is related to setting high goals, one might ask whether the symptoms are driving the success rather than unfolding as a consequence of the success. Studies on this topic have taken care to minimize this possibility. Life events that appeared to have been generated by symptoms were excluded from analyses, and effects emerged after controlling for baseline symptoms. Further, rates of life events involving goal attainment do not appear elevated in bipolar spectrum disorder (Urosević et al. 2010).

For people diagnosed with bipolar disorder, increases in confidence and involvement in goal pursuit after an initial success may form the first part of a spiral toward manic symptoms. Given that these symptoms seem to emerge after success, it is perhaps not surprising that life events involving goal attainment can precede increases in manic symptoms.

SUMMARY AND FUTURE DIRECTIONS

Over the past 15 years, a substantial number of studies have accrued on the BAS sensitivity model of bipolar disorder. The model has attained support across populations of persons at risk for the disorder, those with bipolar spectrum diagnoses, and those with bipolar I disorder. Support has been attained for two aspects of the model: that BAS sensitivity is elevated among people prone to mania and that BAS sensitivity is related to the course of mania. It does not appear that these effects are secondary to subsyndromal symptoms, severity of illness, or age, although it is important to consider medications as a potential suppressor of these effects. Support has come from self-reports of BAS sensitivity and from behavioral paradigms. Perhaps most importantly, evidence suggests that BAS sensitivity is longitudinally related to the onset of bipolar spectrum disorder, the switch to more severe forms of disorder, and the course of mania within those diagnosed with bipolar I disorder. Indeed, with the growing body of evidence, BAS hypersensitivity has been proposed as a potential endophenotype for bipolar disorder (Hasler et al. 2006).

Although relatively few studies have been conducted on this issue, data suggest a profile in which distinct facets of BAS sensitivity are and are not related to bipolar disorder. Certain facets of BAS have not been linked to bipolar disorder. People with bipolar disorder do not appear to be faster to learn stimulus-reward associations, nor do they appear to have a stronger

immediate hedonic response to receiving reward. During periods of remission, those with this disorder do not appear to be more willing to tolerate losses to attain reward.

Other facets of BAS do seem to relate to bipolar disorder. Once a stimulus is associated with reward, people with bipolar disorder are slow to realize changes in contingencies and continue to choose a previously rewarded response. Regarding reward valuation, people with bipolar disorder report being invested in goal pursuit and they show a willingness to expend greater effort to pursue rewards, even during remission. After rewards, people with bipolar disorder exhibit slower return of mood state to baseline, along with greater confidence and energy. Several of these components of BAS have been found to be related to a more severe course of mania over time.

This pattern does not suggest that it is fruitful to try to define deficits in terms of pregoal attainment versus postgoal attainment. Bipolar disorder seems to be related to a heightened state of behavioral engagement (BAS output) during reward pursuit and after receipt of reward. The pattern suggests that the manifestations of BAS sensitivity in bipolar disorder are best characterized as motivational in nature rather than hedonic (Krauss et al. 1992).[1] They are about wanting more than they are about liking. People who are prone to mania appear to want more intensely than do other people, and they continue to want even after attaining a reward.

Underlying Mechanisms That Might Guide the Profile of BAS Dysregulation in Bipolar Disorder

Are there fundamental underlying mechanisms that might account for this pattern? What mechanisms underlie satiety that might be disrupted among those prone to mania? What mechanisms underlie wanting? The biology of the latter phenomenon has been intensively studied and has been differentiated from biological processes guiding other BAS components, such as initial hedonic responses to reward or learning reward prediction errors (Berridge 2007).

Animal research suggests that willingness to engage in effort toward reward—often referred to as "incentive salience" within that literature—is facilitated by dopaminergic neurons in the core of the nucleus accumbens that are phasically activated by incentive cues (Salamone et al. 2009). We briefly describe here some parallels between biological processes affecting incentive salience and those regarding mania. In particular, we highlight evidence deriving from two of the major methods for amplifying the activity of the biological incentive salience system—amphetamine administration and dopamine transporter knockout. Both techniques lead to behavioral profiles that are similar to that of mania.

Animal research has found that a single dose of amphetamine increases activity of the nucleus accumbens and enhances willingness to expend effort toward reward (Carlezon & Thomas 2009). One advantage of this technique is that it can be applied in humans. In humans, typical measures of the normative response to amphetamine consist of three symptoms of mania—activity levels, elevated mood, and faster speech (Strakowski et al. 1996, 1997). People with bipolar disorder have a greater subjective sensitivity to amphetamine than do controls (Anand et al. 2000). Correspondingly, the dopamine precursor, L-Dopa (Murphy et al. 1973), other dopamine manipulations (Anand et al. 1999), and deep brain stimulation of the nucleus accumbens (Kulisevsky et al. 2002) can trigger episodes of mania.

Increased sensitivity to amphetamines generally occurs with repeated exposure. This phenomenon of sensitization is frequently used as a window into the incentive salience system. It involves increased sensitivity of dopamine receptors in the nucleus accumbens (Berridge 2007), increased activation of structures

[1]Other affective dysregulation may be present in bipolar disorder (Gruber 2011). Our point here is strictly concerning the nature of responses to incentive and reward.

downstream from the nucleus accumbens (such as the ventral pallidum) to incentive cues (Tindell et al. 2005), and greater willingness to expend effort to obtain rewards (Wyvell & Berridge 2001). An indirect hint of the relationship between bipolar disorder and amphetamine sensitization came from a study of first-episode psychosis. Though controls show increased sensitivity with each dose of amphetamine, persons with first-episode psychosis, including those with mania-related psychosis, do not show a change in sensitivity with repeated doses of amphetamine (Strakowski et al. 1997). One possibility is that the dopamine receptors in the nucleus accumbens are already sensitized, perhaps through exposure to endogenously produced dopamine. Further work on the relationship between amphetamine sensitization and bipolar disorder is needed.

Once released, dopamine transporter (DAT) is the primary mechanism for clearing dopamine from the synaptic cleft. DAT knockout (DAT-KO) transgenic mice do not produce DAT; as a result, they show 300 times the duration of extracellular dopamine increases compared to normal mice (Jones et al. 1998). Behaviorally, DAT-KO mice show a heightened willingness to expend effort toward reward but do not differ from other mice in their ability to learn reward associations or in their liking in response to reward stimuli (Berridge 2007, p. 422).

In a separate line of work, researchers have used mice with several different manipulations of dopamine function as animal models of mania, including DAT-KO mice (Young et al. 2010b), DAT knockdown mice (Perry et al. 2009), and mice treated with GBR 12909, a specific DAT inhibitor (Young et al. 2010a). Whereas previous animal models of mania focused strictly on hyperactivity and responses to antimanic drugs, DAT models provide a closer match to manic profiles in that the animals also show distinct patterns of locomotion and investigatory behavior (Perry et al. 2009).

In summary, methods used to amplify the activity of the incentive salience system, including amphetamine administration and techniques that reduce DAT function, lead to mania-like profiles in both humans (amphetamine) and mice (DAT). Although caution must be urged in drawing conclusions about etiology on the basis of medication effects, pharmacological evidence is consistent in showing that medications used to treat mania have direct effects on energy and willingness to expend effort toward reward (Salamone et al. 2005, Wise 2004). These medications also diminish effects of amphetamines and sensitization (Dencker & Husum 2010).

Shortcomings in the Body of Research

Despite the burgeoning evidence in support of this model, a surprising number of issues and potential confounds have not been considered. These issues are important whether one is considering general models of BAS or more specific models of its components. We turn to those now in hopes of suggesting directions for future research.

This discussion has given little consideration to bipolar depression other than to note that BAS scores are not consistently correlated with bipolar depression in either cross-sectional or prospective research. It does appear that even minor symptoms of depression will suppress self-reported BAS sensitivity (Meyer et al. 2001). Considerable research indicates that BAS sensitivity, as measured using self-report or electroencephalography laterality, is low among those experiencing unipolar depression (Harmon-Jones & Allen 1997) and that self-reported BAS is related to the course of recovery from unipolar depression (Kasch et al. 2002). On the other hand, in a recent comprehensive review, Treadway & Zald (2011) argued that the critical facet of BAS sensitivity in unipolar depression may be a lowered willingness to expend effort to gain reward, a conclusion that is remarkably parallel to our thesis that heightened willingness to engage in effort toward reward is related to mania proneness. One possibility is that bipolar disorder, with its highs and lows, involves major fluctuations in willingness to engage in effort toward

reward. Examination of this possibility will require studies of effort-based decision-making across mood phases in bipolar disorder.

There is also a major gap in our understanding of how various features of the disorder can influence BAS sensitivity. We have noted above that failures to replicate have not considered the potential role of medications. The life experiences of those with this severe disorder might be another key variable to consider. Sadly, people with bipolar disorder experience high rates of bankruptcy, divorce, unemployment, and homelessness. Very little is known about how such experiences influence BAS sensitivity, goal setting, or reactivity to success. We recently found that life ambitions remained extremely high for attaining popular fame even after multiple hospitalizations (Johnson et al. 2011), but this area of investigation remains ripe for consideration.

We have also not provided information about how this system might relate to other risk factors for mania. To date, one of the best-documented risk factors for mania is circadian disruption and sleep deprivation (Murray & Harvey 2010). Experimental studies indicate that sleep deprivation can precede the onset of manic episodes (Colombo et al. 1999), and the *Clock* gene has now been replicated as relevant for bipolar disorder (Benedetti et al. 2010, Shi et al. 2008). *Clock* knockout mice have been used as a mouse model of mania (Roybal et al. 2007). Sleep and circadian disruption appear to be important aspects of mania risk.

Intriguingly, there is considerable evidence that sleep and BAS sensitivity systems are closely tethered. Sleep deprivation leads to an increase in dopamine levels in the nucleus accumbens (Volkow et al. 2008b). Sleep enhances prefrontal cortical control over responses to positive stimuli (Gujar et al. 2011). *Clock* knockout mice show heightened BAS sensitivity (Roybal et al. 2007). There is a need for research that jointly considers the role of BAS sensitivity and the circadian system in the course of mania (Jones et al. 2006a).

Another problem in the current literature is that few studies of BAS sensitivity have included psychiatric comparison groups. This is of concern given that BAS sensitivity is elevated in many externalizing conditions (Johnson et al. 2003). Indeed, one of the initial appeals of the BAS model was the possibility that this dimension operated as a transdiagnostic risk factor (Fowles 1988). Substance abuse has been related to heightened BAS sensitivity as measured using the BAS scales (Johnson et al. 2003), increased sensitivity of the D2 receptors guiding responsivity to amphetamines and sensitization (Volkow et al. 2008a), and a failure to diminish reward seeking after initial reward receipt (Flagel et al. 2009). The overlap between bipolar disorder and substance abuse, not just in BAS sensitivity levels but also in the dysregulation of specific components of BAS sensitivity, is striking. At one level, one might expect this overlap, given the high rates of alcohol and substance abuse in bipolar disorder (Kessler et al. 2005) and the evidence for overlapping genetic contributions (Johnson et al. 2009). Nonetheless, it is important to conduct transdiagnostic studies to further understand the commonalities and the distinctions. It seems likely that this work will need to consider specific components of BAS sensitivity to be able to differentiate disorders.

A final set of gaps relates to the attempt to consider BAS hypersensitivity as an endophenotype of bipolar disorder. If BAS sensitivity is to help us understand how the genes for this disorder are expressed as a vulnerability trait, we will need a better understanding of the biological underpinnings of this system. For example, there is still a fair amount that is unknown about the heritability of BAS sensitivity. BAS sensitivity is heritable in other animals (cf. Ogden et al. 2004). Studies of the heritability of BAS sensitivity in humans have used widely varied self-report measures and have yielded estimates of heritability ranging from 27% to 82% (Bogdan & Pizzagalli 2009). None of those studies have used the Carver & White (1994) BAS scale or behavioral measures that have distinguished those with bipolar disorder from controls (Bogdan & Pizzagalli 2009). Better understanding of the heritability of

different components of the reward system is needed.

Candidate gene studies of reward have focused on genes involved in dopamine function, including dopamine receptors such as DRD2 and DRD4, DAT, and COMT, an enzyme involved in dopamine breakdown. Polymorphisms in the genes relevant for dopaminergic transmission have been linked to differences in neural responses to reward (Dreher et al. 2009) and self-reported BAS scores (Reuter et al. 2006). In humans, it has been difficult to identify genetic polymorphisms that are robustly and consistently related to bipolar disorder, but modest associations of bipolar disorder with polymorphisms in the dopamine transporter gene (*SLC6A3*) and dopamine receptor D4 gene (*DRD4*) have been observed (Craddock & Sklar 2009). There is a need for studies that include relevant measures of genes and neuroimaging along with behavioral measures of the various facets of BAS sensitivity and goal dysregulation within bipolar disorder.

Beyond these approaches, family history data on BAS sensitivity and bipolar disorder could also be helpful. We were able to identify only one study of BAS sensitivity among children of bipolar parents, and that study did not find that the offspring had higher BAS self-report scores than did children of non-mood-disordered parents (Jones et al. 2006b). Findings of that study, though, are limited by the small sample size (25 at-risk offspring).

Overall, many key questions regarding BAS sensitivity in bipolar disorder have not been answered. Chief targets for future research include more precisely describing the nature of BAS hypersensitivity in bipolar disorder; understanding the role of depression, life history, and medication in influencing BAS sensitivity; integrating BAS sensitivity with other risk factors for bipolar disorder; and clarifying the transdiagnostic roles played by aspects of BAS sensitivity. Further, if BAS hypersensitivity is to be considered as an endophenotype, much more attention must be given to the biological underpinnings of this system in bipolar disorder.

CLINICAL IMPLICATIONS

Despite the need for future research, the BAS hypersensitivity model has achieved a fair amount of support, and some specificity has begun to emerge in our understanding of the biological and psychological mechanisms involved. We believe it will be important for future research to consider the best ways for those with bipolar disorder to cope with these processes. Most people do not have to think about how to regulate their engagement in goal pursuit. As a result, little is known about the best ways to down-regulate such states.

In an effort to begin to address this question, a recent study (Edge et al. 2011) used a questionnaire to determine whether those with bipolar disorder limit their exposure to rewarding circumstances as a way to prevent mania. Of particular interest was whether people learn to use these strategies as they face the serious repercussions of disorder. The questionnaire was administered to a sample with extensive symptom histories. On average, the 59 persons in the sample had experienced 9.4 manic episodes and 1.7 hospitalizations for mania. Persons with bipolar I disorder were asked whether they used strategies to avoid major rewards in life in domains such as romantic relationships, friendships, and promotions, or having children or pursuing an educational program. More than three-quarters of participants reported using one of these reward-limiting strategies to avoid mania.

These reward-limiting strategies may have important costs. In that sample, the extent to which people reported engaging in these strategies was correlated with poorer interviewer-rated functioning, on the Global Assessment of Functioning scale, $r = -0.32$. Prospective research is needed to disentangle the directionality of this relationship and to determine whether a third variable is involved.

Given the possibility that limiting rewards will potentially limit quality of life, it would seem important in clinical interventions to consider whether people with bipolar disorder can learn strategies to enhance control once they

are engaged in highly rewarding activities and begin to experience prodromal symptoms of mania. Behavioral calming strategies that require less cognitive control appear to be helpful (Lam 2009, Lam et al. 2001). Many people with bipolar disorder endorse reducing goal pursuit and activity levels and engaging in calming activities (Lam et al. 2001). Use of these coping strategies has been found to be related to less mania in an 18-month follow-up period (Lam et al. 2001). These early findings suggest that it might be helpful to teach coping strategies.

We have used the goal regulation concept to develop a mania prevention manual (Johnson & Fulford 2009). Within the treatment, we differentiate facets of goal dysregulation that appear to be involved in bipolar disorder: high goal setting, overreactivity to success and failure, surges of confidence, and excessive engagement in goal pursuit. For each potential process, we begin by teaching clients what is known about this domain and by assessing whether the particular process seems relevant for that given individual. Where such processes appear to be involved in mania genesis, though, we do not assume that a person will immediately want to change. That is, high goals are inspiring, and bursts of confidence are exciting. Rather than assuming that clients will be motivated to change these processes, our manual involves motivational interviewing to help the client consider the advantages and disadvantages of potential changes. For those who want to change, we then use cognitive behavioral strategies to promote better control over these processes. In an open trial, the program led to significant reductions in manic symptoms and overly ambitious goals over time, with effect sizes for mania that were substantially larger than those obtained with psychoeducation. Others have also suggested the utility of drawing from our understanding of the BAS to develop treatments (Nusslock et al. 2009). On the whole, it is our hope that the BAS sensitivity model will continue to provide insights that will help to refine treatment.

SUMMARY POINTS

1. The sensitivity of the BAS system appears to be elevated for those with bipolar disorder and those at risk for the disorder.
2. Sensitivity of the BAS system has been shown to predict the onset of disorder, the switch from milder to more severe forms of disorder, and the course of mania after onset.
3. The BAS is an umbrella term that captures a wide range of components.
4. Some facets of the BAS do not appear related to bipolar disorder.
5. People with bipolar disorder appear to be willing to expend effort toward reward.
6. Bipolar disorder also appears related to greater engagement of the BAS during reward pursuit and after reward receipt, as manifested in increased energy, confidence, and goal pursuit.

FUTURE ISSUES

1. How does bipolar disorder relate to specific components of the BAS?
2. How do medication, life experiences, and illness severity influence BAS levels in bipolar disorder?

3. What are the distinct features of the BAS among those with bipolar disorder compared to those with other disorders?
4. What biological mechanisms can explain dysregulation of the BAS in bipolar disorder?

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