ASSOCIATIONS OF BIPOLAR TRAITS WITH REWARD AND THREAT SENSITIVITY AND CONDITIONING

by

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Abstract

Bipolar Spectrum Disorders (BSDs) affect 1% of the population and cause significant interpersonal, occupational, and health challenges. Identifying cognitive, affective, and behavioural factors that influence BSD symptoms and related behaviours, consistent with a dimensional approach to psychopathology, may help improve our understanding and treatment of these disorders. Reward and threat sensitivity and learning, for example, are cognitive processes that may be dimensionally related to BSD risk, onset, and course. However, studies exploring reward and threat sensitivity and learning as a function of continuously measured bipolar traits, as opposed to categorical diagnoses or acute symptoms, have mostly employed self-report measures of sensitivity and overlooked classical conditioning. Thus, in this investigation, I explored how bipolar traits in two university student samples related to reward and threat sensitivity and conditioning measured using laboratory tasks. In Study 1, I found that higher self-reported lifetime hypomanic and depressive symptoms significantly predicted sensitivity to incentive reward and a stronger classically conditioned response to a threat-related cue, respectively. In Study 2, I addressed these questions in a larger sample of participants based on three higher-order bipolar traits as predictors of sensitivity and conditioning, variables extracted from measures of lower-order BSD-related traits using principal components analysis. Participants with higher scores for Factor 1, characterized by impulsiveness, low self-control, and low achievement, demonstrated significantly weaker classically conditioned responses to reward- and threat-related cues. Higher Factor 2 scores, indicating greater vulnerability to emotion dysregulation and negative affective responses to stress, significantly predicted greater sensitivity to threat. Finally, higher scores for Factor 3, reflecting a tendency to pursue and

engage in stimulating experiences despite potential risks, significantly predicted greater sensitivity to incentive reward and lower susceptibility to forming classically conditioned responses to threat-related cues. These results indicate that bipolar traits may be meaningfully associated with patterns of reward and threat sensitivity and conditioning, associations which may have important implications for predicting and altering maladaptive levels of bipolar traits.

Lay Summary

This research explored how stable mood traits related to Bipolar Spectrum Disorders (BSDs) influenced participants' sensitivity to potential reward (lottery tickets) and threat (an unpleasant tone), and tendency to associate an unrelated cue with winning a ticket or hearing the tone after they were presented together. I found that participants with hypomania-like traits were more excited about potentially winning lottery tickets than those with lower levels of hypomania-like traits. These participants were also less anxious when looking at the face previously presented with the unpleasant tone. Participants who had higher depression-like traits were more nervous about potentially hearing the tone and when looking at a cue that had previously predicted it. This research showed that stable traits related to BSDs may influence how attractive or aversive people find potential rewards and threat, and how easily they learn from them.

Preface

This thesis is original, unpublished work based on data collected for a doctoral research project in the Department of Human Development at Cornell University [Moore, S.R. (2017). *Sources of individual variability in sensitivity to the environment* (Doctoral dissertation). Retrieved from Cornell's digital repository, eCommons. (doi:10.7298/X44T6GBB).] I was responsible for leading concept formation and data analysis. SR Moore provided all data and was involved in the early stages of concept formation. RM Todd was involved in concept formation throughout the project.

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List of Abbreviations

BAS	Behavioural Activation System
BD I	Bipolar I Disorder
BD II	Bipolar II Disorder
BIS	Behavioural Inhibition System
BIS-15	Short Form of the Barratt Impulsiveness Scale
BSD	Bipolar Spectrum Disorder
BSSS	Brief Sensation Seeking Scale
CS	Conditioned Stimulus
DERS	Difficulties in Emotion Regulation Scale
GBI	General Behavior Inventory
MCAR	Missing Completely at Random
MDD	Major Depressive Disorder
MDE	Major Depressive Episode
MPQ-BF	Multidimensional Personality Questionnaire
NEO-PI-R	Revised NEO Personality Inventory
PCA	Principal Components Analysis
TCI	Temperament and Character Inventory
US	Unconditioned Stimulus
VIF	Variance Inflation Factor

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Dedication

To mom and dad, for your unwavering support and encouragement, which motivate me to do my best every day.

To my sister Shandelle, for your listening ear and enthusiastic reflections regarding theories and research in psychology.

Chapter 1: Introduction

In this investigation, I examined how bipolar traits based on self-report were associated with behavioural measures of reward and threat sensitivity and conditioning in a university student sample. This section begins with a review of Bipolar Spectrum Disorders (BSDs) and their relationships to lifetime mood symptoms and dispositional traits (i.e., temperament, character, and/or personality), followed by a description of previous findings linking BSDs and bipolar traits with altered incentive reward and threat sensitivity and learning. Chapters 2 and 3 describe separate studies of how participants' levels of bipolar traits were related to their performance on tasks measuring sensitivity to varying probabilities of receiving a reward or punishment and susceptibility to developing a classically conditioned response to a reward- or threat-related cue. The fourth and final chapter is a summary of the findings from both studies with my interpretations, recommendations for future research, and conclusions.

1.1 Bipolar Spectrum Disorders

BSDs are a broad class of lifelong, episodic mental disorders that affect approximately 1% of the population (Moreira, Van Meter, Genzlinger, & Youngstrom, 2017). BSDs are often characterized by intense and labile moods, as well as (hypo)manic and depressive episodes. BSDs have been associated with significant individual, interpersonal, and economic costs (Baune & Malhi, 2015; Greenberg, Rosenblum, McInnis, & Muzik, 2014; Kleine-Budde et al., 2014; Merikangas et al., 2007). For instance, individuals with BSDs tend to report difficulty sustaining social relationships, dependence on family members and caregivers to maintain normal functioning, as well as a lower quality of life (Granek, Danan, Bersudsky, & Osher, 2016; Sylvia et al., 2017; Weisenbach et al., 2014). Relative to the general population, individuals with BSDs also have poorer physical health (Young & Grunze, 2013), 15 times the risk of suicide (Chesney,

Goodwin, & Fazel, 2014), and 8-12 years lower life expectancy (Kessing, Vradi, & Andersen, 2015). They also miss more days of work (Kessler et al., 2006) and access significantly more health services and disability benefits (Judd & Akiskal, 2003). Direct per-capita healthcare costs for individuals with BSDs have been estimated to be between US$8,000 to US$14,000 (Kleine-Budde et al., 2014). Evidently, the burden that BSDs place on individuals and society make the psychological processes that underpin them, and interventions that may be informed by this new knowledge, worthy of investigation.

Our understanding of how variations in bipolar traits may influence the sensitivity with which individuals experience rewards and punishments and how easily they begin to associate them with related cues and contexts is incomplete. Yet, these psychological processes may have important implications for how higher bipolar traits may influence thoughts, emotions, motivation, and behaviour (Nees, Heinrich, & Flor, 2015; M. Wessa & Linke, 2009). As background, I detail below the clinical criteria for three BSDs classified in the Fifth Edition of the Diagnostic and Statistical Manual for Mental Disorders (American Psychiatric American Psychiatric Association, 2013), including Bipolar Disorders I (BD I) and II (BD II), and Cyclothymic Disorder, which have been extensively researched and are well-characterized (Grande, Berk, Birmaher, & Vieta, 2016).

1.1.1 Bipolar I Disorder

BD I is diagnosed based on a past or present Manic Episode, defined as 7 or more days of abnormally and persistently elevated, expansive, or irritable mood and higher goal-directed activity or energy for most of the day nearly every day for a week or more (or any duration if hospitalization is necessary). A Manic Episode diagnosis also requires the presence of three or more (four if mood is only irritated) of the following symptoms: (1) inflated self-esteem or

grandiosity, (2) decreased need for sleep, (3) more talkative than normal or pressure to keep talking, (4) flight of ideas or subjective experience that thoughts are racing, (5) distractibility, (6) increase in goal-directed activity or psychomotor agitation, and/or (7) excessive involvement in activities that have high potential for painful consequences. In addition, diagnostic criteria for a Manic Episode include that the individual must exhibit significant functional impairment, unless psychotic features are present, or hospitalization is required. While individuals who meet criteria for BD I often experience one or more Major Depressive Episodes (MDEs) in their lifetime, a past or present MDE is not required for a BD I diagnosis.

1.1.2 Bipolar II Disorder

A BD II diagnosis requires one or more past or current Hypomanic Episodes *and* one or more past or current MDEs. BD II criteria for a Hypomanic Episode parallel those for a Manic Episode, except that the minimum required duration of symptoms is 4 days as opposed to 7, and significant functional impairment, hospitalization, or psychotic features would warrant a Manic, rather than Hypomanic, Episode diagnosis. BD II criteria for a past or present MDE include a period of two weeks or more, most of the day and nearly every day, of depressed mood and/or loss of pleasure accompanied by five or more of (1) depressed mood, (2) diminished interest or pleasure, (3) weight loss or weight gain, (4) insomnia or hypersomnia, (5) psychomotor agitation, (6) fatigue or loss of energy, (7) feelings of worthlessness or excessive or inappropriate guilt, (8) diminished ability to think or concentrate, and/or (9) recurrent thoughts of death, suicidal ideation, suicide attempt, or a specific plan for dying by suicide. Furthermore, these symptoms must have caused an unequivocal change in functioning compared to when the person is not symptomatic that is observable by others.

1.1.3 Cyclothymic Disorder

Cyclothymic Disorder is characterized by mood swings that are less severe than those seen in BDs I and II, including patterns of brief periods of mild depressive and hypomanic symptoms lasting two years or more. Although Cyclothymic Disorder symptoms do not reach the severity or duration of depressive and hypomanic symptoms characterizing a Manic, Hypomanic, or Major Depressive Episode, they may cause clinically significant distress and/or interfere with daily functioning. As pertains to this thesis, it is worth noting that the types, combinations, and severity of symptoms and behaviours classified *categorically* for the purposes of diagnosis (as for BD I, BD II, and Cyclothymic Disorder) may be better characterized as continuous variations in functioning across cognitive, affective, and behavioural domains relevant to the bipolar spectrum. This conceptualization is consistent with a dimensional view of the bipolar spectrum, as reviewed in the next section.

1.2 Dimensional perspectives of Bipolar Spectrum Disorders

A dimensional view of BSDs can help characterize the full range of distinct cognitive, affective, and behavioural domains that have been implicated in these disorders (Henry & Etain, Angst et al., 2003; 2010; Widiger & Samuel, 2005). BSDs are increasingly being described as reflecting patterns of cognitive, affective, and behavioural functioning that exert stable and dynamic influences on mood states, including those related to BSD risk, onset, and maintenance (Henry & Etain, 2010). In past studies examining these relationships, continuous measures of stable vulnerability to bipolar mood states (bipolar traits) have been used in combination with measures of cognition, affect, and behaviour to isolate psychological processes that may enhance our understanding, and the prevention and treatment, of BSDs.

Continuous measures of bipolar traits are often selected because they have been shown to prospectively predict BSD onset (Henry et al., 2008), such as those measuring subsyndromal bipolar mood symptoms (Faedda et al., 2015; Van Meter, Burke, Youngstrom, Faedda, & Correll, 2016). For example, Van Meter et al. (2016) indicated that premorbid BSD-related symptoms, including excessive energy levels, diminished ability to think, indecisiveness, pressured speech, talkativeness, elated mood, academic or work difficulties, insomnia, depressed mood, and over-productive/goal-oriented behaviour were each significant predictors of a BSD diagnosis. The authors reported that excessive energy levels and over-productive and/or goal-oriented behaviour were experienced by 50 and 68 percent (respectively) of participants who were later diagnosed with a BSD. In another study, Faedda et al. (2015) examined clinical diagnostic predictors of BD onset and reported that mood lability, subsyndromal depression, subsyndromal hypomanic symptoms, major depressive disorder (MDD), subsyndromal hypomanic symptoms in MDD, cyclothymic disorder and Bipolar Disorder Not Otherwise Specified, psychotic symptoms in MDD, a psychotic disorder, earlier onset of MDD, lifetime number of depressive episodes, and number of lifetime hypomanic symptoms significantly predicted BSD onset. These findings indicate that a history of subsyndromal bipolar mood symptoms are likely sensitive to individual differences in levels of bipolar traits for identifying those who will develop a BSD (Bottino, Barcelos-Ferreira, & Ribeiz, 2012). However, as the proportion of the population that experiences these symptoms is limited, subsyndromal symptom scales have been less sensitive to variations in non-clinical levels of bipolar traits. Therefore, personality, temperament, and/or character scales have been employed to capture a broader range of individual differences in bipolar traits.

1.3 Dispositional traits associated with Bipolar Spectrum Disorders

Another approach to dimensionally characterizing BSDs is the use of dispositional trait measures (e.g., self-report questionnaires of personality, temperament, and/or character), which may provide a more comprehensive understanding of the stable cognitive, affective, and behavioural dimensions comprising the bipolar spectrum (Markon, Krueger, & Watson, 2005; Savitz & Ramesar, 2006). As detailed below, previous findings indicate that higher neuroticism, openness to experience, novelty seeking, sensation seeking, self-transcendence, impulsiveness, aggression, harm avoidance, and emotional dysregulation, as well as lower extraversion, conscientiousness, agreeableness, and cooperativeness may distinguish individuals with BSDs from individuals without a mental disorder.

1.3.1 Higher-order traits

Several studies have documented higher-order traits (i.e., broad domains of temperament, character, and personality) associated with a BSD diagnosis (Barnett et al., 2011; Costa & McCrae, 1995; Loftus, Garno, Jaeger, & Malhotra, 2008). For instance, Malouff, Thorsteinsson, and Schutte (2005) administered the revised NEO Personality Inventory (NEO-PI-R; Costa & McCrae, 1995) to individuals with a BSD whose moods were euthymic (i.e., a period when clinical criteria for a bipolar mood episode was not met), individuals with BSDs demonstrate higher neuroticism (tendency to experience negative emotions) and openness to experience (imaginative, intellectually curious, nonjudgmental), and lower conscientiousness (sense of purpose, determination), relative to individuals without a mental disorder. In a prospective study, Barnett et al. (2011) showed using the same scale that lower extraversion (sociability, assertiveness, excitability, upbeat nature), conscientiousness, and agreeableness (altruistic, sympathetic, prosocial), as well as high neuroticism and openness, were enduring personality

characteristics of BSDs. Taken together, these studies indicate that higher neuroticism and openness, and lower conscientiousness, are stable traits among individuals with BSDs.

1.3.2 Lower-order traits

1.3.2.1 Novelty and sensation seeking, and self-transcendence

Several studies have reported higher novelty and sensation seeking, as well as self-transcendence, among individuals with BSDs relative to individuals without a mental disorder. One such study was a meta-analysis examining temperament and personality differences between individuals with BSDs and three comparison groups, including siblings of individuals with BSDs, individuals diagnosed with MDD, and control participants without a mental disorder (Zaninotto et al., 2016). In the analyzed studies, individuals with BSDs scored significantly higher than all other groups on three of four subscales on the Novelty Seeking scale of the Temperament and Character Inventory (TCI; Cloninger, Svrakic, & Przybeck, 1998), including Impulsiveness, Extravagance, and Disorderliness. Zaninotto et al. (2016) also reported that participants with a BSD had significantly higher scores on the Self-Transcendence scale and two of three subscales, Self-forgetfulness and Spiritual Acceptance, compared to comparison participants without a mental disorder. Using the Zuckerman-Kuhlman Personality Questionnaire, Xu et al. (2015) found that subscales measuring General Sensation Seeking and Impulsive Sensation Seeking were higher in individuals with BSDs relative to control participants without a mental disorder. Thus, relative to comparison groups, individuals with BSDs have tended to demonstrate higher novelty seeking, self-transcendence, and sensation seeking traits.

1.3.2.2 Impulsiveness

Consistent with the result from Zaninotto et al. (2016) showing an association between higher Novelty Seeking—Impulsiveness on the TCI and a BSD diagnosis, several studies examining trait impulsiveness in BSDs have produced similar results. In these studies, three aspects of impulsiveness were often measured, including attentional (the ability to focus on the task at hand and tendency to shift attention quickly), motor (a tendency to act without forethought; perseverance), and non-planning (a present orientation; failure to consider the future) impulsiveness (Barratt, Patton, & Stanford, 1975; Patton, Stanford, & Barratt, 1995). While findings regarding the specific aspects of impulsiveness related to BSDs were mixed, each was significantly related to BSDs either during periods of euthymic mood or across mood states in one or more previous studies (Holmes et al., 2009; Lombardo et al., 2012; Swann, Lijffijt, Lane, Steinberg, & Moeller, 2009). Thus, research to date suggests that individuals with BSDs exhibit significantly higher attentional, motor, and non-planning impulsiveness than individuals without a mental disorder.

1.3.2.3 Aggression and cooperativeness

Several studies have demonstrated that a BSD diagnosis may be associated with higher aggressiveness and lower cooperativeness than individuals without a mental disorder (Ballester et al., 2014; Di Nicola et al., 2010). For instance, in a longitudinal study assessing whether aggression may be a stable trait in individuals with BSDs, Ballester et al. (2014) found that scores on the Buss-Perry Aggression Questionnaire total scale and five subscales, including Physical Aggression, Verbal Aggression, Anger, Hostility, and Indirect Aggression, discriminated individuals with BSDs from participants in their study who had a non-BSD mental disorder or no mental disorder. Furthermore, cooperativeness, a character trait described by

Cloninger et al. (1998) as the degree to which an individual is socially accepting, empathetic, helpful, compassionate, and pure-hearted in conscience, has been shown in previous studies to be lower in individuals with BSDs relative to control participants (Di Nicola et al., 2010; Zaninotto et al., 2016). In sum, previous research suggests that BSDs may be associated with a tendency towards aggressiveness and low cooperativeness.

1.3.2.4 Emotional dysregulation

Difficulty regulating emotions is a core feature of BSDs (Michèle Wessa & Linke, 2013). One study showed that, despite overall greater effort to spontaneously regulate their emotions, individuals with BSDs were less successful downregulating their emotional response than control participants (Gruber, Harvey, & Gross, 2012). Participants with BSDs have also been found to report greater difficulty controlling their impulses, maintaining efforts towards goals, and accessing emotion regulation strategies while upset, including during periods of euthymia (Becerra et al., 2013). In a more recent study, participants with BSDs, some of whom had clinically elevated hypomanic or depressive symptoms, demonstrated greater difficulty recognizing and accepting negative emotions relative to a non-clinical comparison group (Van Rheenen, Murray, & Rossell, 2015). In terms of stable emotion regulation tendencies, however, impulsive behaviour, difficulty engaging in effective emotion regulation strategies, and maintaining goal-oriented behavior while upset may best characterize emotion regulation patterns in BSDs.

1.4 Sensitivity to incentive reward and threat across the bipolar spectrum

The Behavioural Activation and Inhibition Systems (BAS and BIS, respectively) are psychobiological systems involved in sensitivity to potential reward and punishment and implicated in BSDs (Carver & White, 1994). The BAS is proposed to influence individual

differences in motivational sensitivities, such as sensitivity to incentive reward cues, whereas the BIS is characterized by a tendency to respond to threat events with anxiety or fear (Davidson, 1999; Davidson, Jackson, & Kalin, 2000).

Hypersensitivity to incentive reward is a definitive feature of BSDs and has also been observed in individuals at risk of a BSD (Alloy, Olino, Freed, & Nusslock, 2016; Gruber, 2011; Van der Gucht, Morriss, Lancaster, Kinderman, & Bentall, 2009). For example, self-reported BAS sensitivity has been shown to predict BSD onset a year later (Alloy et al., 2008; Alloy et al., 2012). In addition, previous studies have shown that individuals with BSDs exhibit lower BIS sensitivity during hypomanic episodes and euthymia (Carver & Johnson, 2009; Jones & Day, 2008) and higher BIS sensitivity during depressive episodes (Weinstock, Chou, Celis-deHoyos, Miller, & Gruber, 2018) than non-clinical control participants. Given the associations of self-reported BAS and BIS sensitivity, closely linked to reward and threat sensitivity, with BSDs and their onset, enhanced incentive reward sensitivity and lower sensitivity to threat may also relate to stable bipolar traits, even in individuals who are not living with or at risk of a BSD. In fact, examining how reward and threat sensitivity, and other processes potentially underlying BSDs, are related to bipolar traits in non-clinical participants may help circumvent effects previous mood episodes on the original bipolar spectrum trait structure (Meyer, Johnson, & Carver, 1999; Savitz & Ramesar, 2006; Savitz, Van Der Merwe, & Ramesar, 2008)

Notably, while many studies have examined how self-reported incentive reward and punishment sensitivities relate to BSDs and BSD risk (Alloy & Abramson, 2010; Hamlat, Garro-Moore, Nusslock, & Alloy, 2016; Meyer, Johnson, & Winters, 2001), few have employed behavioural measures of these constructs (Farmer et al., 2006). Among studies that have, several used laboratory tasks that may inadequately parse participants' sensitivity to incentive reward

versus punishment (e.g., the Iowa Gambling Task; Edge, Johnson, Ng, & Carver, 2013). To more objectively assess sensitivity to incentive reward and threat in relation to bipolar traits, more research employing laboratory tasks to measure these constructs is needed.

1.5 Emotional learning in Bipolar Spectrum Disorders

BSDs have been associated with altered emotional learning in several previous studies, although the types of learning assessed have mainly been restricted to probabilistic reinforcement and reversal learning (Dickstein et al., 2010; Gorrindo et al., 2005; Pizzagalli, Goetz, Ostacher, Iosifescu, & Perlis, 2008; Tavares et al., 2008). In these studies, individuals with BSDs have tended to demonstrate poorer acquisition of a response bias towards selecting cues that more frequently resulted in the delivery of a reward relative to control participants (Pizzagalli et al., 2008; Ryu, Ha, Lee, Ha, & Cho, 2017). Furthermore, individuals with BSDs have been shown to select cues that had previously produced one or more significant incentive rewards despite generating lower incentive reward overall (i.e., increased salience of gains; Ryu et al., 2017). In sum, individuals with BSDs may have difficulty integrating past patterns of incentive reward and/or punishment into their decisions to maximize desirable outcome, and this may be particularly true for actions or behaviours that, while ultimately less rewarding, previously produced a substantial incentive reward.

Few studies have examined whether classical conditioning may be altered for individuals with BSDs or in relation to bipolar traits (Lemaire, El-Hage, & Frangou, 2015; Pizzagalli et al., 2008; Ryu et al., 2017). Classical conditioning occurs when a neutral stimulus (CS) is presented with a reward or aversive stimulus or event (US), which elicits a reflexive response, results in the CS eliciting the same response in the absence of the US. In classical conditioning, when a rewarding or punishing stimulus or event is associated with a neutral cue or context (CS), the CS

gains motivational salience, thus facilitating approach or withdrawal behaviour (Mackintosh, 1983). In this way, classical conditioning confers salience to aspects of the environment that may have little intrinsic value or meaning but reliably predict an outcome relevant to our survival (Rescorla, 1988). However, classically conditioned responses to cues predicting rewarding or punishing outcomes can also be maladaptive, as seen in relation to addiction and anxiety (Lissek et al., 2005), where misattributions of salience may motivate or inhibit behaviours in ways that are ultimately unhelpful or even harmful (Nees et al., 2015).

In light of the importance of classical conditioning for psychological functioning and wellbeing (Lissek et al., 2005; Nees et al., 2015), investigating how reward and threat conditioning vary as a function of bipolar traits is warranted. In addition to enhancing our understanding of learning processes related to BSD susceptibility and functioning, these insights may aid in the selection and development of treatments and preventative interventions for BSDs.

1.6 The present investigation

While several lines of evidence lend support to the roles of incentive reward and threat sensitivity and learning in BSDs (Meyer et al., Dutra, Cunningham, Kober, & Gruber, 2015; Gruber, Harvey, & Purcell, 2011; Henry et al., 2008; M'Bailara et al., 2009; 2001; Venn et al., 2004), little is known about how reward and threat sensitivity and classical conditioning may vary as a function of bipolar traits along a continuum from low to high (Meyer et al., 1999). Therefore, the global aim of this investigation was to examine whether continuous measures of bipolar traits in two separate samples of university students significantly predicted incentive reward and threat sensitivity and conditioning.

1.6.1 Study 1

Study 1 was a secondary analysis of pilot data, which included participants' scores on the General Behavior Inventory (GBI; Depue, Krauss, Spoont, & Arbisi, 1989), a self-report measure of bipolar traits (i.e., frequency of bipolar mood states from mid-late adolescence to adulthood). Due to the relatively small sample in this study which limited statistical power, these analyses were treated as exploratory and used inform the hypotheses for Study 2. Therefore, the objective of Study 1 was to first examine how lifetime experiences of bipolar mood symptoms related to measures of incentive reward and threat sensitivity and conditioning, and subsequently use these findings to develop hypotheses for Study 2.

I hypothesized that higher scores on the GBI's Hypomania subscale would predict higher sensitivity to incentive reward (Abler, Greenhouse, Ongur, Walter, & Heckers, 2008; Johnson, Ruggero, & Carver, 2005; Jones & Day, 2008; Meyer, Beevers, Johnson, & Simmons, 2007) and stronger reward conditioning (Pizzagalli et al., 2008), and Depression subscale would predict lower sensitivity to incentive reward (Alloy et al., 2008; Carver & Johnson, 2009; Henriques & Davidson, 2000; Nelson et al., 2013) and weaker reward conditioning (Pizzagalli et al., 2008). I also predicted that GBI Biphasic and Lability scores would be significantly associated with sensitivity to incentive reward (Alloy & Abramson, 2010; Di Nicola et al., 2010; Henry, M'Bailara, Lépine, Lajnef, & Leboyer, 2010; Henry et al., 2008; Urošević, Abramson, Harmon-Jones, & Alloy, 2008).

Regarding threat sensitivity and conditioning, I hypothesized that higher scores on the GBI's Depression subscale (Meyer et al., 2001; Muhtadie & Johnson, 2015; Weinstock et al., 2018), and lower scores on the Hypomania subscale (Jones & Day, 2008), would predict greater threat sensitivity and conditioning (Carver & Johnson, 2009). As I did not have specific

hypotheses regarding potential relationships between lifetime mood lability and threat sensitivity or conditioning, the GBI's Lability subscale was included in these analyses as an exploratory predictor.

1.6.2 Study 2

Study 2 was based on data collected from a large sample of young adult university students who completed self-report and behavioural measures for a study that examined individual differences in environmental sensitivity and emotional learning. The self-report questionnaires included various psychological, behavioural, and environmental variables, including several measures of dispositional traits shown in previous studies to be associated with a BSD diagnosis (see Study 2 Methods). As the GBI was not completed by participants in this study, the available BSD-related measures were used in lieu of a more direct measure of bipolar traits to predict sensitivity and conditioning to incentive reward and punishment. However, I first used principal components analysis (PCA) to extract meaningful higher-order dimensions of bipolar traits from the BSD-related questionnaires completed by this large sample of participants. Once extracted, I formulated hypotheses regarding the relationships of each with the sensitivity and conditioning variables. Then, according to my hypotheses, I entered these component variables into hierarchical regression analyses as potential predictors of reward and threat sensitivity and conditioning.

Chapter 2: Associations of lifetime symptoms of hypomania, depression, and mood lability with reward and threat sensitivity and conditioning (Study 1)

This study was a secondary analysis of pilot data collected in preparation for a larger study examining associations between dispositional traits, early life environmental factors, and environmental sensitivity and emotional learning. These pilot data, but not the larger dataset employed in Study 2, included participants' scores on a measure of bipolar affective traits, the GBI. In a preliminary investigation of how bipolar traits related to sensitivity to reward or threat and classically conditioned responses to their associated cues, I examined whether the GBI's subscales significantly predicted the sensitivity and conditioning variables. I used the results from this study to partly inform my hypotheses for Study 2.

2.1 Methods

2.1.1 Participants and procedures

Sixty-nine young adults studying at Cornell University elected to participate in this study for additional credit in an undergraduate psychology course (demographic characteristics reported in Table 2.1). During a single study visit, participants completed a series of questionnaires and four computer-based tasks measuring reward and threat sensitivity and conditioning (described below).

Table 2.1 Participant characteristics (N=69).

Age M (SD)	N female (%)
19.80 (1.13)	38 (55%)

2.1.2 Measures

2.1.2.1 General Behavior Inventory

The GBI is a 73-item self-report measure of lifetime unipolar and bipolar mood symptoms. The GBI total and subscales can be used to obtain continuous scores (representing levels of bipolar traits) or categorically for identifying individuals who are at risk of a unipolar or bipolar affective condition. Items on the GBI refer to the frequency of respondents' bipolar mood symptoms they can recall in their lifetime, e.g., "as far back as the early teens" (Depue et al., 1981). Items are rated on a 4-point scale, ranging from 1 (never or hardly ever) to 4 (very often or almost constantly), and refer to the intensity, duration, rapid shift, and frequency of respondents' lifetime affective symptoms (Depue et al., 1981). Items on the GBI ask about symptoms that have lasted "several days or more" to distinguish stable patterns of mood functioning that signal BSD risk from more normal short-term variation in mood.

The GBI includes Depression (46 items; max. score of 184), Hypomania (19 items; max. score of 76), Biphasic (8 items; max. score of 32), and Lability (4 items; max. score of 16) subscales. The Depression and Hypomania subscales measure lifetime experiences of low mood/decreased energy and activity and elevated mood/higher energy and activity, respectively, whereas the Biphasic and Lability (consisting of 4/8 Biphasic items) subscales measure the degree to which participants' mood, emotions, irritability, energy, and desire to be around others tend to shift from high to low, as well as perceived sensitivity to pain and pleasure relative to others. For this study, continuous subscale scores were used to avoid information loss (Royston, Altman, & Sauerbrei, 2006).

Mallon, Klein, Bornstein, and Slater (1986) found that all participants in their sample with cyclothymia, 92% with dysthymia, 87% with psychopathology but not an affective disorder,

and 75% of people with non-chronic clinical depression were correctly classified by the GBI. The GBI's Support for the criterion-related validity of the GBI's Hypomania subscale was reported by Klein, Dickstein, Taylor, and Harding (1989) who found that GBI Hypomanic plus Biphasic scores were significantly higher for the 13 participants in their study who met Research Diagnostic Criteria (Spitzer, Endicott, & Robins, 1978) for probable or definite hypomania during a 6-month follow-up period compared to 75 individuals who met criteria for depression but not hypomania during follow-up. An assessment of the GBI's Positive and Negative Predictive Power produced respective values of 87% and 93% (Depue et al., 1989). Thus, the GBI is highly sensitive to aspects of mood and behaviour that characterize BSDs, both continuously (for detecting individual differences in bipolar mood tendencies ranging from non-clinical to clinical) and categorically (for identifying individuals at risk of a BSD).

2.1.3 Sensitivity and conditioning tasks

Participants completed four tasks measuring sensitivity to varying probabilities of reward (monetary incentive) or threat (aversive noise) and the tendency to report excitement or anxiety when presented with a reward- or threat-conditioned cue. All four tasks were completed in the same study session in the following order: (1) incentive reward sensitivity (excitement while anticipating playing for increasing numbers of tickets towards the $100 lottery), (2) sensitivity to an aversive stimulus (anxiety while anticipating varying probabilities of hearing an aversive noise), and (3) reward and (4) threat conditioning (susceptibility to forming a conditioned response to a neutral face [CS] previously paired with a single ticket towards the $100 lottery [reward US] or an aversive noise [aversive US]).

2.1.3.1 Sensitivity to incentive reward

The sensitivity to incentive reward measure was a monetary speeded response task first described by Knutson, Westdorp, Kaiser, and Hommer (2000). For this task, participants were instructed to press a computer key as quickly as possible after they saw a schematic happy face for a chance to win 1-4 tickets towards a $100 lottery. Each trial consisted of 4 seconds of anticipation, followed by the running number of tickets participants had accumulated, then a rating scale ranging from 1-5 with the question, "How excited/enthusiastic/elated do you feel?" After a rating was made, the schematic face appeared, and participants responded by pressing the key. After each key press, participants received feedback indicating whether they won the ticket(s). The outcomes for each trial were fixed such that all participants were "fast enough" or "too slow" on the same number of trails and won the same number of tickets overall, although trial order was randomized across participants. Participants' self-reported excitement about pursuing the incentive reward before feedback was used to measure their threshold for responding to incentive reward specifically associated with incentive motivation.

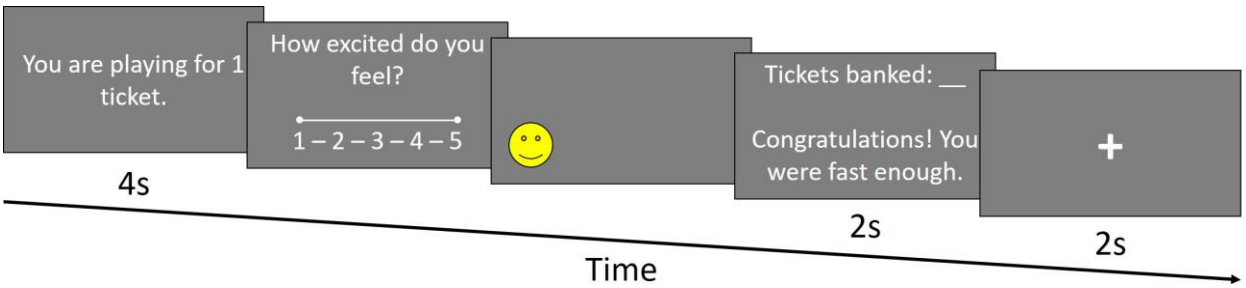

Figure 2.1 Task used to measure sensitivity to incentive reward.

2.1.3.2 Sensitivity to threat

Sensitivity to threat was measured using task described by Herry et al. (2007). Participants were presented with a 0, 25, 50, 75, or 100% probability of hearing an unpleasant

tone and asked to rate how tense/nervous/anxious they felt just before the outcome for that trial. Participants completed 15 trials total (three for each intensity level) in random order.

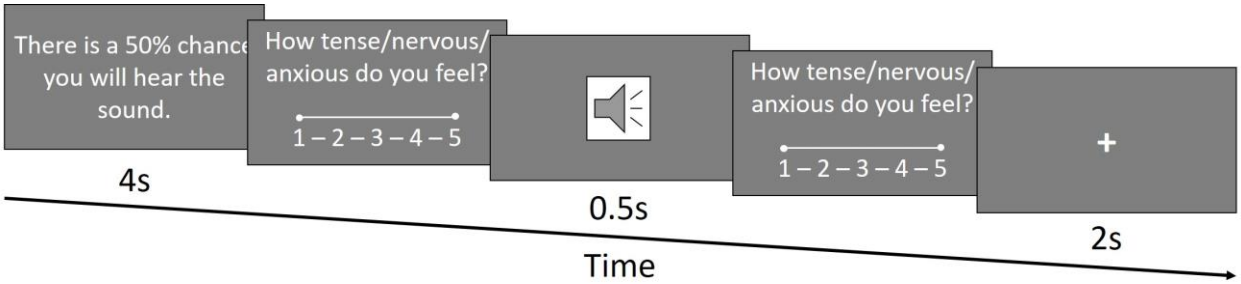

Figure 2.2 Task used to measure sensitivity to threat.

2.1.3.3 Calculation of sensitivity variables

Indices of sensitivity to incentive reward and threat were calculated as participants' average percent change in excitement or tenseness/nervousness/anxiety ratings for each incremental increase in the probability of winning the $100 lottery or hearing the aversive noise, respectively (see Equation 2.1). Thus, sensitivity to incentive reward was measured as the averaged percent increase in excitement ratings from 1-2, 2-3, and 3-4 tickets. Sensitivity to threat was calculated as the averaged percent increase in anxious/nervous/stressed ratings from 0-25, 25-50, 50-75, and 75-100% probability of hearing the noise.

$$Sensitivity = \frac{\left(\frac{Rating_2 - Rating_1}{Rating_1}\right) + \cdots + \left(\frac{Rating_n - Rating_{n-1}}{Rating_{n-1}}\right)}{n-1}$$

Equation 2.1 Calculation of sensitivity to incentive reward and threat variables.

2.1.3.4 Reward and threat conditioning

Participants also completed two classical conditioning tasks that used the same rewarding and aversive stimuli as those for the sensitivity measures. As illustrated in Figure 2.3, the unconditioned stimulus (US; 1 ticket or the aversive noise) was paired with a neutral face (conditioned stimulus; CS+) on a 50% reinforcement schedule. On the 50% of trials when the

CS+ was presented without the emotional stimulus, participants were asked to rate how excited or tense/nervous/anxious they felt (i.e., the conditioned response). Another neutral face (CS-) was presented an equal number of times, but without a paired emotional stimulus, and rated for 50% of trials. CS- ratings were obtained to account for the degree to which the conditioned response was specific to the face paired with the emotional stimulus (CS+), i.e., whether the response generalized to an unpaired human face. Each of the four trial types (CS+ paired, CS+ rated, CS- alone, CS- rated) appeared 10 times in randomized order (40 trials total).

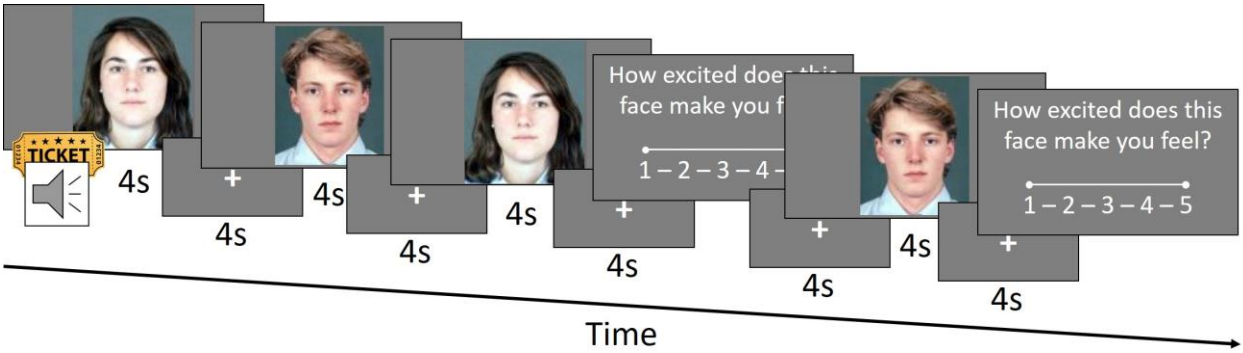

Figure 2.3 Tasks used to measure susceptibility to reward and threat conditioning.

2.1.3.5 Calculation of reward and threat conditioning variables

The incentive reward and threat conditioning variables were calculated in two steps. First, participants' post-baseline ratings for the paired (CS+) and unpaired (CS-) faces (averaged) minus their baseline ratings for each face was calculated to create CS+ and CS- pre-post difference scores. Subsequently, the CS- difference score was subtracted from the CS+ difference score to account for generalization of the conditioned response to an unpaired face. These calculations are represented in Equation 2.2.

Step 1. Baseline CS+/CS- rating minus averaged post-baseline CS+/CS- ratings:

$$CS+/\text{-}\ rating\ difference_{pre\text{-}post} = \frac{Rating_2 + \cdots + Rating_{10}}{10 - 1} - Rating_1$$

Step 2. Departure of post-baseline CS+ ratings from post-baseline CS- ratings:

$$Conditioning\ score = CS+\ rating\ difference_{pre\text{-}post} - CS\text{-}\ rating\ difference_{pre\text{-}post}$$

Equation 2.2 Calculation of incentive reward and threat conditioning variables.

Following my calculations of the reward and threat conditioning variables, I examined the proportion of participants who demonstrated a conditioned response to the CS+ in both conditioning tasks. Here, a conditioning score less than 0.25 (i.e., < 5% increase in CS+ rating from baseline to post-baseline after accounting for CS- ratings) was used as a cut-off to indicate a participant did not develop a conditioned association between the US and CS+.

2.1.4 Data analytic strategy

2.1.4.1 Data screening

All independent and dependent variables were screened to examine their distributional properties and missing data. Histograms and skewness and kurtosis variables were used to evaluate the normality of the independent and dependent variables. Box- and scatter-plots, as well as z-scores (where univariate outliers were defined as values exceeding 3.29 standard deviations from the mean) and Mahalanobis distance, were used to assess for univariate and bivariate outliers. Missing data was examined using Little's MCAR test (Little, 1988).

2.1.4.2 Hierarchical linear regression

To examine the relations of the GBI's bipolar mood subscales with incentive reward and threat sensitivity and conditioning, four hierarchical regression analyses were conducted. As lifetime hypomania symptoms were expected to most strongly relate to reward sensitivity and conditioning (Abler et al., 2008; Jones & Day, 2008; Meyer et al., 2007), the GBI's Hypomania

subscale was the first variable entered in the regression analyses predicting these dependent variables, followed by the Depression subscale in the second step (Nelson et al., 2013; Pizzagalli et al., 2008), and then the Lability subscale in the third and final step (Di Nicola et al., 2010).

In the regression analyses examining threat sensitivity and conditioning as a function of the GBI's Hypomanic, Depression, and Lability scales, the Depression subscale was entered first (Meyer et al., 2001; Muhtadie & Johnson, 2015; Weinstock et al., 2018), then the Hypomania subscale (Jones & Day, 2008; Muhtadie & Johnson, 2015), and finally the Lability subscale (entered as an exploratory predictor in these analyses).

2.1.4.3 Testing the assumptions of hierarchical linear regression

Assumptions of hierarchical linear regression include (1) a linear relationship between dependent and independent variables, (2) multivariate normality, (3) little or no multicollinearity, (4) no autocorrelation, and (5) homoscedasticity. First, to determine whether a linear relationship existed between the independent and dependent variables, plots for the combined independent variables with each dependent variable were examined (Cook, 1977). Multivariate normality of the residuals for the combined predictor variables was determined according to the distributional properties of the predictor variables' unstandardized residuals (i.e., skewness and kurtosis; Joanes & Gill, 1998). Third, multicollinearity was assessed using the Tolerance Statistic and Variance Inflation Factor (VIF) for each predictor variable, where values above 0.2 and below 5 indicated acceptable levels of multicollinearity, respectively (Menard, 1995; Stine, 1995). Fourth, to ensure acceptable levels of autocorrelation among the predictor variables regardless of the dependent variable, I conducted Durbin-Watson tests for each predictor variable in separate regression models with each dependent variable (where a value of 2 indicates an acceptable level of autocorrelation; Durbin & Watson, 1971). Finally, to assess for heteroscedasticity, I examined

the histogram and normal probability plot of residuals and scatter plot of the standardized residuals for each regression analysis.

2.2 Results

2.2.1 Selection and calculation of variables

2.2.1.1 General behavior inventory predictor variables

To facilitate variable selection, correlations of the candidate GBI predictors (the Hypomania, Depression, Biphasic, and Lability subscales) were produced to examine their shared variance and collinearity. As shown in Table 2.3, all GBI subscales were significantly correlated. The strongest subscale correlations were between Biphasic and the Lability subscale ($r = 0.94$, $p < .001$, $N = 69$), Biphasic and the Depression subscale ($r = 0.87$, $p < .001$, $N = 63$), and Depression and the Lability subscale ($r = 0.78$, $p < .001$, $N = 63$), respectively. To prevent multicollinearity in the hierarchical regression analyses, the Biphasic subscale was excluded from the hierarchical regression analyses. Tolerance and VIF values (presented with the results of each hierarchical regression analysis) suggested acceptable levels of collinearity between the GBI's Hypomania, Depression, and Lability subscales.

Table 2.2 General Behavior Inventory total and subscales descriptive statistics, inter-correlations, and internal reliabilities.

GBI scales	Theoretical range	Descriptive statistics		Inter-correlations and internal reliabilities				
		Mean (SD)	N	GBI total	Depressive	Hypomanic	Biphasic	Lability
GBI total	73 – 292	125.38 (35.53)	63	**0.97**				
Depressive	46 – 184	80.62 (25.14)	63	0.98***	**0.97**			
Hypomanic	19 – 76	31.14 (7.90)	69	0.81***	0.70***	**0.87**		
Biphasic	8 – 32	13.48 (4.51)	69	0.91***	0.87***	0.68***	**0.85**	
Lability	4 – 16	6.51 (2.69)	69	0.81***	0.78***	0.59***	0.94***	**0.85**

Note. ***Correlation is significant at the .001 level (2-tailed). Internal reliabilities (Chronbach's α) for the GBI total and subscales appear diagonally in bold.

2.2.1.2 Sensitivity and conditioning variables

Descriptive statistics and inter-correlations between each of the sensitivity and conditioning variables are presented in Table 2.3.

Table 2.3 Sensitivity and conditioning variables' descriptive statistics and inter-correlations.

Sensitivity and conditioning (dependent) variables	Descriptive statistics			Inter-correlations			
	N	*M* (SD)	Range	1	2	3	4
1. Sensitivity to incentive reward (lottery tickets) Avg. % increase in excitement ratings from 1-2-3-4 tickets	69	2.22 (0.83)	0.00 – 4.00	—			
2. Sensitivity to threat (aversive noise) Avg. % increase in anxiety ratings from 0-25-50-75-100% probability of hearing an aversive noise	69	1.25 (0.64)	0.00 – 2.63	.29*	—		
3. Reward conditioning (US = 1 lottery ticket) Increase in excitement ratings from pre- (rating 1) to post-baseline (ratings 2-10, averaged) for CS+, *minus* CS-, faces	67	1.07 (1.10)	-1.22 – 3.33	-.08	-.19	—	
4. Threat conditioning (US = aversive noise) Increase in anxiety ratings from pre- (rating 1) to post-baseline (2-10) for CS+, minus CS-, faces	66	0.53 (1.48)	-2.11 – 3.44	-.08	.12	.17	—

Note. *Correlation is significant at the $p < 0.05$ level.

The incentive reward and threat conditioning variables were assessed in terms of how well participants conditioned to the US during each conditioning task. Based on the established cut-off, 73% of participants conditioned during the reward conditioning task, and 58% of participants conditioned during the threat conditioning task.

2.2.1.3 Data screening

Nine of 69 participants were missing data for the GBI, sensitivity, and/or conditioning variables. Six participants were missing data for one or more of the GBI's Depression subscale items and therefore could not be included in the hierarchical regression analyses (each of which included the Depression subscale as a predictor). Furthermore, two participants were missing both conditioning scores, and one was missing aversive conditioning score. According to the results of Little's MCAR test (Little, 1988), these data were missing completely at random. The GBI Depression and Lability subscale scores, as well as the threat conditioning variable, were positively skewed (skewness statistic/std. error > ±1.96). Sample distributions for the GBI's Hypomania subscale, sensitivity to incentive reward and threat, and reward conditioning were not significantly skewed. Kurtosis for all variables was acceptable (kurtosis statistic/std. error < ±1.96). Box-Cox transformations were performed on all skewed variables to approximate a normal distribution. No univariate outliers were identified for variables included in analyses (defined as >±3.29 standard deviations from the mean; none >2.68).

Nine participants (13% of the total sample) scored above 11 on the Hypomanic plus Biphasic subscales, a cut-off that has been used to identify individuals with a potential bipolar affective condition with 76% sensitivity and 99% specificity (Depue et al., 1989). In addition, 11 participants (16% of total sample; 17.5% of those with valid GBI Depression subscale scores) scored 22 or above on the Depression subscale, used to identify a unipolar affective condition

with 78% sensitivity and >99% specificity. Of these, two participants scored above the cut-off for both conditions.

2.2.2 Hierarchical regression

2.2.2.1 Associations of the GBI's Hypomania, Depression, and Lability subscales with sensitivity to varying probabilities of monetary incentive reward

To test the hypothesis that participants' sensitivity to incentive reward varied significantly as a function of their scores on the GBI's Hypomania, Depression, and Lability subscales, a hierarchical regression analysis was performed. Based on my hypotheses, the Hypomania subscale variable was entered first, followed by the Depression subscale, and then the Lability subscale. Tests of multicollinearity and autocorrelation indicated that levels of each were acceptable (tolerance = 0.497, 0.367, 0.452, for the GBI's Hypomania, Depression, and Lability subscales, respectively; Durbin-Watson = 1.604). The first model tested with the Hypomania subscale alone significantly predicted sensitivity to incentive reward ($R = 0.258$, F [1,60] = 4.272, $p = 0.043$). However, counter to my hypotheses, the models that included depressive and labile mood ($R = 0.269$, F [3,58] = 1.508, $p = 0.222$), traits did not significantly predict sensitivity to incentive reward (see Table 2.4). Thus, in partial support of my hypotheses, the Hypomania subscale significantly predicted sensitivity to incentive reward. It is important to note that achieved power to detect the observed effects, found to be 0.540, 0.467, and 0.400 for Steps 1, 2, and 3 of the regression analysis, was relatively low. Thus, the null results obtained for the models that included the GBI's Depression and Lability subscales may be due, in part, to inadequate power. Interpretations regarding the relationships of Depression and Lability subscales with sensitivity to incentive reward may not be warranted.

Table 2.4 Associations of the GBI's Hypomania, Depression, and Lability subscales with sensitivity to incentive reward (N=62).

	β	*r*	*t*	*p*	sr^2	*VIF*
Step 1						
Hypomania	0.258	0.258	2.067	0.043	0.067	1.000
Step 2						
Hypomania	0.330	0.258	1.892	0.063	0.056	1.933
Depression	-0.104	0.125	-0.595	0.554	0.006	1.933
Step 3						
Hypomania	0.325	0.258	1.811	0.075	0.052	2.011
Depression	-0.120	0.125	-0.575	0.567	0.005	2.723
Lability	0.025	0.136	0.145	0.885	< 0.001	2.213

Note. $R^2 = 0.066$; F (1,60) = 4.272, $p = 0.043$, $f^2 = 0.071$ for Step 1. $\Delta R^2 = 0.006$, F (1,59) = 0.354, p = 0.554, $f^2 = 0.078$ for Step 2. $\Delta R^2 = < .001$, F (1,58) = 0.021, $p = 0.885$, $f^2 = 0.078$ for Step 3.

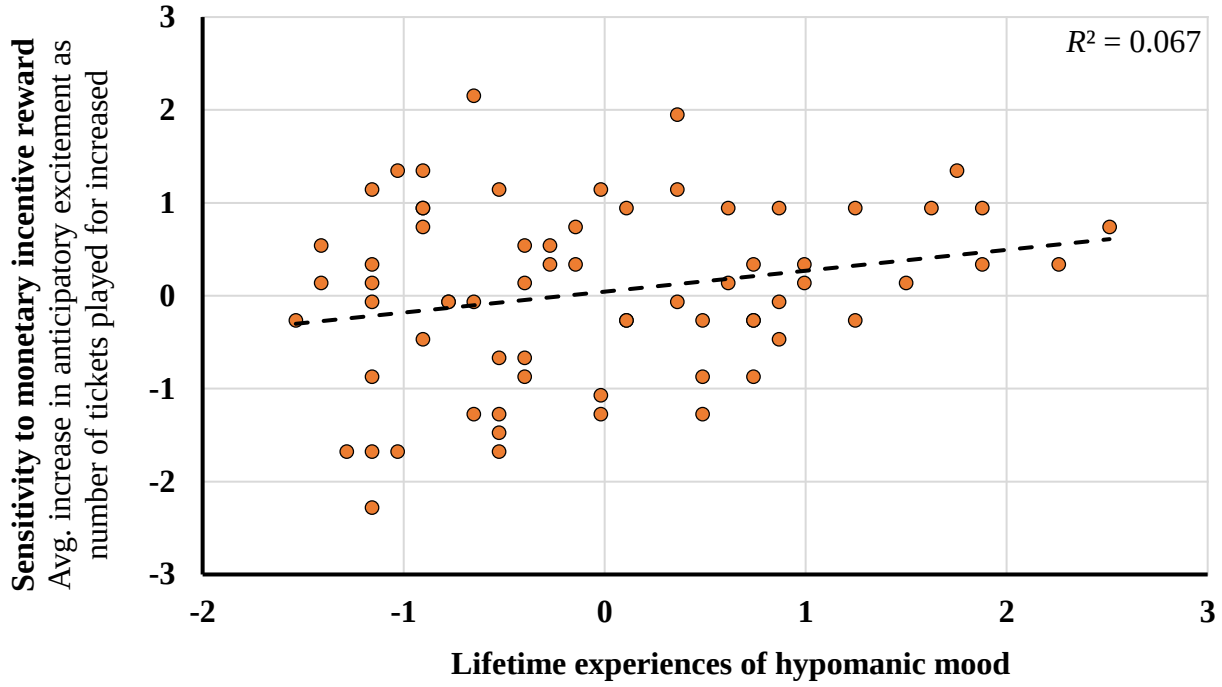

Figure 2.4 The General Behavior Inventory's Hypomania subscale predicted averaged increases in anticipatory ratings of excitement, enthusiasm, and elation from 1-2, 2-3, and 3-4 tickets to be won.

2.2.2.2 Associations of the GBI's Hypomania, Depression, and Lability scores with sensitivity to varying probabilities of hearing an aversive tone

To test the hypothesis that sensitivity to threat would vary as a function of participants' long-standing tendencies to experience depressive, hypomanic, and labile mood states, a hierarchical regression analysis was performed. Based on my hypotheses, the Depression subscale variable was entered first, followed by the Hypomania subscale, and then the Lability subscale. Levels of multicollinearity and autocorrelation were acceptable (tolerance = 0.359, 0.487, 0.444, for the GBI's Depression, Hypomania, and Lability subscales, respectively; Durbin-Watson = 1.741). As can be seen in Table 2.5, results of the hierarchical regression analysis did not support my hypotheses. None of the models, which first included the Depression subscale alone in Step 1 (R = 0.097, F [1,61] = 0.584, p = 0.448), with the Hypomania subscale

entered in Step 2 (R = 0.113, F [2,60] = 0.387, p = 0.681), and then the Lability subscale in Step 3 (R = 0.176, F [3,59] = 0.626, p = 0.601), significantly predicted sensitivity to threat. Once again, the null results may be a consequence of low power afforded by weak associations between the independent and dependent variables and a small sample size. Indeed, achieved power was low for each step of the overall model (0.184 for Step 1, 0.227 for Step 2, and 0.396 for Step 3). Therefore, the results of this analysis were not used to inform my hypotheses in Study 2 or interpreted further.

Table 2.5 Associations of the GBI's Hypomania, Depression, and Lability subscales with sensitivity to threat (N=63).

	β	*r*	*t*	*p*	sr^2	*VIF*
Step 1						
Depression	0.097	0.097	0.764	0.448	0.009	1.000
Step 2						
Depression	0.154	0.097	0.853	0.397	0.012	1.972
Hypomanic	-0.080	0.028	-0.445	0.658	0.003	1.972
Step 3						
Depression	0.275	0.097	1.285	0.204	0.027	2.782
Hypomanic	-0.042	0.028	-0.227	0.821	0.001	2.054
Lability	-0.198	-0.026	-1.049	0.298	0.018	2.252

Note. R^2 = 0.009; F (1,61) = 0.584, p = 0.448, f^2 = 0.009 for Step 1. ΔR^2 = 0.003, F (1,60) = 0.198, p = 0.658, f^2 = 0.013 for Step 2. ΔR^2 = 0.018, F (1,59) = 1.101, p = 0.298, f^2 = 0.032 for Step 3.

2.2.2.3 Associations of the GBI's Hypomania, Depression, and Lability subscales with reward conditioning

To examine whether susceptibility to reward conditioning varied as a function of three variables, the GBI's Hypomania, Depression, and Lability subscales, a hierarchical regression analysis was performed. Lifetime hypomanic symptoms were expected to account for the largest amount of variance in participants' tendency to report feelings of excitement when viewing a neutral cue that had previously been paired with a cue signaling incentive reward (ticket towards $100 lottery), followed by lifetime depressive symptoms, and then labile mood. Therefore, the Hypomania variable was entered first, followed by Depression, and then Lability. Tests of multicollinearity and autocorrelation indicated that low levels of multicollinearity and autocorrelation were present (tolerance = 0.488, 0.356, 0.440, for the GBI's Hypomania, Depression, and Lability subscales, respectively; Durbin-Watson = 1.597). Results of the hierarchical regression did not support the research hypothesis. The best fitting model included the GBI's Hypomania subscale alone (R = 0.097, F [1,59] = 2.162, p = 0.147), i.e., the models that included the GBI's Hypomania and Depression subscales (R = 0.113, F [2,58] = 1.257, p = 0.292) or all three GBI subscales (R = 0.176, F [3,57] = 1.822, p = 0.153) did not significantly predict reward conditioning. Achieved power to detect an effect in the first, second, and third steps of the regression analysis was 0.313, 0.268, and 0.473, respectively. Again, the null results may have been due to low achieved power, suggesting that the interpretations and conclusions based on these findings were not warranted. The results were therefore not used to inform hypotheses for Study 2.

Table 2.6 Associations of the GBI's Hypomania, Depression, and Lability subscales with reward conditioning (N=61).

	β	*r*	*t*	*p*	sr^2	*VIF*
Step 1						
Hypomanic	-0.188	-0.188	-1.470	0.147	0.035	1.000
Step 2						
Hypomanic	-0.266	-0.188	-1.471	0.147	0.036	1.974
Depression	0.111	-0.076	0.612	0.543	0.006	1.974
Step 3						
Hypomanic	-0.325	-0.188	-1.795	0.078	0.052	2.051
Depression	-0.085	-0.076	-0.403	0.688	0.003	2.811
Lability	0.328	0.061	1.694	0.096	0.046	2.271

Note. $R^2 = 0.035$; F (1,59) = 2.162, $p = 0.147$, $f^2 = 0.036$ for Step 1. $\Delta R^2 = 0.006$, F (1,58) = 0.375, $p = 0.543$, $f^2 = 0.044$ for Step 2. $\Delta R^2 = 0.046$, F (1,57) = 2.87, $p = 0.096$, $f^2 = 0.095$ for Step 3.

2.2.2.4 Associations of the GBI's Depression, Hypomania, and Lability subscale scores with threat conditioning

A hierarchical regression analysis was performed to test the hypothesis that participants' tendencies to form a classically conditioned response to a threat-related cue was a function of three variables, the GBI's Depression, Hypomania, and Lability subscales, a hierarchical regression analysis was performed. Based on my hypotheses, the Depression subscale variable was entered first, followed by the Hypomania subscale, and then the Lability subscale was entered in a third and final step as an exploratory predictor. Tests of multicollinearity and

autocorrelation indicated that low levels of multicollinearity and autocorrelation were present (tolerance = 0.355, 0.483, 0.440, for the GBI's Depression, Hypomania, and Lability subscales, respectively; Durbin-Watson = 1.809). Results of the hierarchical regression analysis provided partial confirmation of my hypotheses. The best fitting model included the Depression subscale only (R = 0.366, F [1,58] = 8.971, p = 0.004). Prediction remained significant for the models that included the GBI's Depression and Hypomania subscales (R = 0.385, F [2,57] = 4.946, p = 0.010) and all three predictors combined (R = 0.390, F [3,56] = 3.346, p = 0.025). However, the addition of the Hypomania and Lability subscales did not significantly improve prediction (see *Note* below Table 2.7). Achieved power to detect an effect was 0.851 for Step 1, 0.801 for Step 2, and 0.761 for Step 3. The power achieved in this analysis supports the finding that higher scores on the GBI's Depression subscale, but not the Hypomania or Lability subscales, significantly predicted the degree to which participants showed a classically conditioned response to a neutral cue previously paired with an aversive noise.

Table 2.7 Associations of the GBI's Hypomania, Depression, and Lability subscales with threat conditioning (N=60).

	β	*r*	*t*	*p*	sr^2	*VIF*
Step 1						
Depression	0.366	0.366	2.995	0.004	0.134	1.000
Step 2						
Depression	0.483	0.366	2.803	0.007	0.118	1.988
Hypomanic	-0.166	0.174	-0.965	0.339	0.014	1.988
Step 3						
Depression	0.425	0.366	2.057	0.044	0.064	2.816
Hypomanic	-0.185	0.174	-1.044	0.301	0.016	2.069
Lability	0.095	0.296	0.523	0.603	0.004	2.275

Note. $R^2 = 0.134$; F (1,58) = 8.971, $p = 0.004$, $f^2 = 0.155$ for Step 1. $\Delta R^2 = 0.014$, F (1,57) = 0.931, $p = 0.339$, $f^2 = 0.174$ for Step 2. $\Delta R^2 = 0.004$, F (1,56) = 0.274, $p = 0.603$, $f^2 = 0.179$ for Step 3.

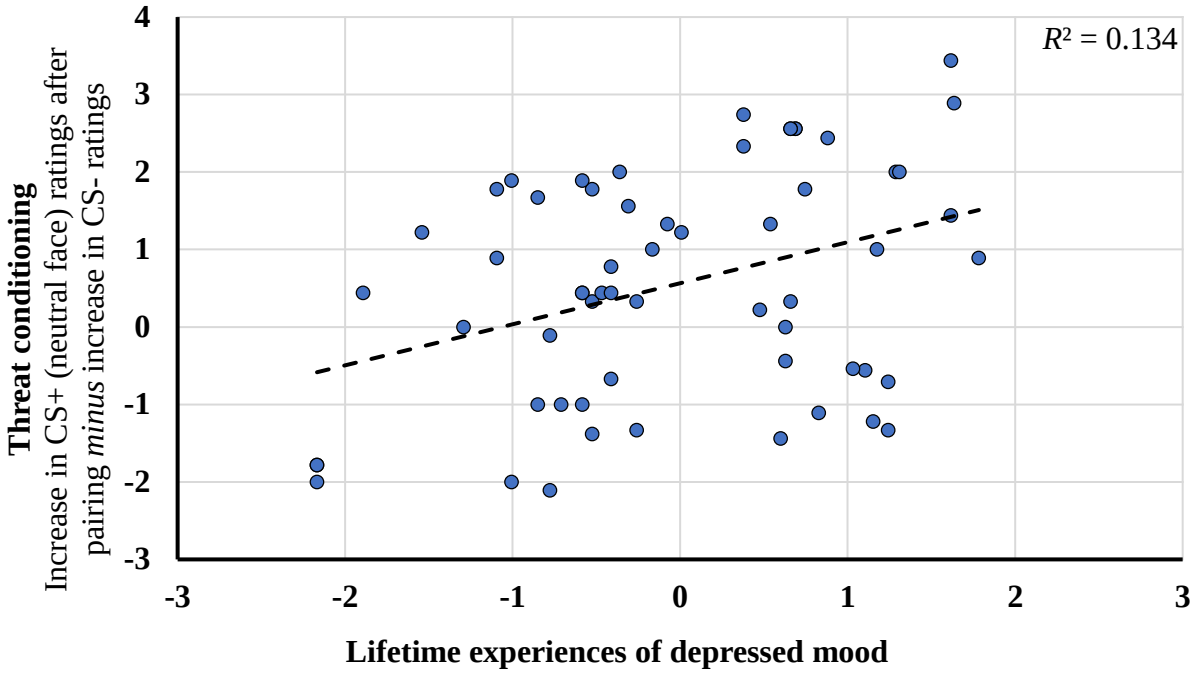

Figure 2.5 The Depression subscale predicted threat conditioning scores calculated as the difference between participants' averaged post-baseline CS+ anxiety ratings and their baseline CS+ rating *minus* that of the CS-.

In summary, in partial support of my hypotheses, the GBI's Hypomania subscale predicted sensitivity to incentive reward, indicating that participants who endorsed higher levels of lifetime hypomanic symptoms had a greater average percent increase in their anticipatory ratings of excitement, enthusiasm, and elation with each incremental increase in the number of tickets to be won. Furthermore, participants who reported higher levels of lifetime depressive symptoms had significantly higher self-reported tenseness, nervousness, and anxiety in response to a neutral face that had been paired with an aversive cue.

Counter to my hypotheses, none of the GBI's subscales—Hypomania, Depression, or Lability—predicted sensitivity to threat or susceptibility to reward conditioning in a young adult university student population. However, these null findings may have been attributable to low achieved power. Due to the limitations of the small sample size in this study, I next turned to an

examination of higher-order bipolar traits, extracted from stable measures of BSD-related traits in a larger sample of young adult university students.

Chapter 3: Associations of higher-order bipolar traits with reward and threat sensitivity and conditioning (Study 2)

Study 2 involved an analysis of data from a large university student sample of young adults who completed self-report measures of dispositional traits previously shown to characterize individuals with BSDs, as well as the sensitivity and conditioning tasks described in Study 1. For the current study, the BSD-related scales were used to extract higher-order bipolar traits and examine their potential links with reward and threat sensitivity and conditioning reward and threat sensitivity and conditioning. As noted in Objectives, analysis results from Study 1 were intended, in part, to inform my hypotheses for Study 2. Therefore, the observed associations of the GBI's Hypomania and Depression subscales with sensitivity to incentive reward and threat conditioning, respectively, were used to inform my hypotheses regarding how the factors extracted using PCA would relate to these dependent variables (see Principal components analysis subsection of the Results).

3.1 Methods

3.1.1 Research design

This study also involved a secondary analysis of data, this time collected for a larger study that examined how individual differences in various psychological and social factors (e.g., personality, temperament, and early life environment) related to environmental sensitivity and emotional learning.

3.1.2 Participants and procedures

This study included 506 young adults enrolled at Cornell University who elected to participate for course credit. Research ethics approval was obtained from the university's

Institutional Review Board and all participants provided informed consent. Participants ranged in age from 18-31 and 65% were female (see Table 3.1). They first completed an online survey including demographic questions and self-report scales, and subsequently visited the laboratory to complete the sensitivity and conditioning tasks.

Table 3.1 Participant characteristics (N=506).

Age M ± SD (Range)	N female
19.96 ± 2.02 (18-31)	324 (65%)

3.1.3 Measures

3.1.4 Self-report questionnaires

3.1.4.1 Multidimensional Personality Questionnaire-Brief Form

The Multidimensional Personality Questionnaire-Brief Form (MPQ—BF; Patrick, Curtin, & Tellegen, 2002) includes 155 of the original scale's 300 items, including 12 items for each of the 11 primary trait scales and 9 additional items to index the validity of participants' item responses (Tellegen & Waller, 2008). The MPQ—BF's primary trait scales include Wellbeing (positive disposition), Stress Reaction (negative disposition), Achievement and Social Potency (agency), Social Closeness (communion), Alienation (estrangement), Aggression (confrontation), Control (impulsivity reversed), Harm Avoidance (sensation seeking reversed), Traditionalism (from conventionality to rebellious nonconformity), and Absorption (propensity for imaginative and self-involving experiences; responsiveness to engaging stimuli). The MPQ-BF was developed based on data collected from large independent samples of mixed-gender community participants ranging in age from 18-70. Chronbach's alpha coefficients for these scales, computed from a normative sample of 1,350 participants, ranged from .75 to .84.

3.1.4.1.1 Subscale selection

Many studies that have examined patterns of stable BSD-related traits using self-report questionnaires administered either the TCI (Cloninger et al., 1998; Engstrom, Brandstrom, Sigvardsson, Cloninger, & Nylander, 2004), a relatively comprehensive measure of dispositional trait scales with several facet subscales, or the NEO-PI-R (Costa & McCrae, 1995), which measures higher-order personality domains. Although these scales were not administered to participants in the current study, the BSD-related dispositional traits measured by the TCI and NEO-PI-R correspond closely to those measured by the MPQ-BF (Markon et al., 2005; Rushton & Irwing, 2009, 2011). Thus, based on dispositional traits shown to characterize individuals with BSDs using the TCI and NEO-PI-R (Loftus et al., 2008; Lozano & Johnson, 2001; Markon et al., 2005; Nery et al., 2008; Rushton & Irwing, 2009; Zaninotto et al., 2016), I selected five corresponding MPQ-BF subscales as candidate items for the extracted PCA components, including Absorption, (low) Achievement, (low) Control, Stress Reactivity, and (low) Social Closeness. Consistent with previous reports of elevated trait aggressiveness in individuals with BSDs (Ballester et al., 2014; Buss & Perry, 1992), I also selected the MPQ-BF's Aggression subscale for inclusion in the PCA.

3.1.4.2 Short Form of the Barratt Impulsiveness Scale

The short form of the Barratt Impulsiveness Scale (BIS-15) is a self-report measure of impulsivity that includes 15 of the original 30 items included in the original scale (Barratt et al., 1975). The BIS-15 has demonstrated good reliability and validity and a three-factor structure representing attentional impulsiveness (inability to pay attention or concentrate), motor impulsiveness (acting without thinking), and non-planning impulsiveness (a lack of futuring or forethought; Patton et al., 1995; Spinella, 2007).

3.1.4.3 Brief Sensation Seeking Scale

The Brief Sensation Seeking Scale (BSSS; Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002) is a revised version of the Sensation Seeking Scale (Zuckerman, Kolin, Price, & Zoob, 1964). The BSSS consists of 8 items measuring thrill and adventure seeking, disinhibition, experience seeking, and boredom susceptibility (two per subscale). It has good validity and reliability (Zuckerman, 2007), and higher scores have been shown to be elevated in individuals with BSDs (Bizzarri et al., 2007; Brocke, Beauducel, John, Debener, & Heilemann, 2000). It has been found to be significantly associated with the TCI's Novelty Seeking subscale (McCourt, Gurrera, & Cutter, 1993), shown in several previous studies to be elevated for individuals diagnosed with a BSD, relative to those without a mental disorder (Zaninotto et al., 2016).

3.1.4.4 Difficulties in Emotion Regulation Scale

The DERS includes six subscales measuring (1) difficulties concentrating and accomplishing tasks when experiencing negative emotions (GOALS), (2) difficulties with self-control (e.g., impulses, emotions) when upset (IMPULSE), (3) non-acceptance reactions to one's distress (NONACCEPT), (4) a tendency to attend to and acknowledge emotions (AWARE), (5) belief that there is little that can be done to regulate emotions effectively (STRATEGIES), and (6) the extent to which individuals know (and are clear about) the emotions they experience (CLARITY). The DERS has demonstrated high internal consistency, good test-retest reliability, and adequate construct and predictive validity (Gratz & Roemer, 2004). The GOALS, IMPULSE, and STRATEGIES subscales were included in the PCA for this study.

3.1.5 Sensitivity and conditioning tasks

The tasks used in this study differed from those described in Study 1 in a few ways. First, self-report rating scales for "How excited do you feel?" and "How tense/anxious/nervous do you

feel?" ranged from 0-100 in this study (in Study 1, the response range was 1-5). Second, the threat conditioning task included 28 trials with 7 CS+ unpaired with rating, 7 CS+ paired without rating, 7 CS- with rating, and 7 CS- without rating (compared to 10 trials each in Study 1). The incentive reward task included four conditions each consisting of 10 trials, as in Study 1. Finally, for the calculation of the sensitivity to incentive reward and threat variables in the current study, participants' ratings (0-100) were adjusted to be anchored at 1 to eliminate divisions by 0 (for the step $Rating_n - Rating_{n-1} / Rating_{n-1}$).

3.1.6 Data analytic strategy

Analyses for the current study included (1) PCA with parallel analyses to extract higher-order bipolar traits from self-report questionnaires measuring dispositional traits and (2) hierarchical regression analysis to examine whether the higher-order bipolar traits significantly predicted reward and threat sensitivity and conditioning.

3.1.6.1 Variable calculations and data screening

To ensure that most participants conditioned during the conditioning tasks, I assessed whether participants' conditioning scores (calculated as described in Study 1 Methods) represented at least a 5% increase in rating the conditioned stimuli (CS+) after controlling for potential confounds related to biased ratings of the CSs at baseline and changes in ratings unrelated to conditioning over time. Therefore, an average increase of 5% or more following the initial CS+ rating trial (after controlling for the equivalent increase for the CS-) was used to indicate that a participant conditioned during the task.

All variables included in the analyses for this study were assessed for missing data, distribution normality, and univariate and multivariate outliers. Normality of the independent and dependent variables was examined using visual inspection of histograms and skewness and

kurtosis values. Variables with skew or kurtosis values were more than ±1.96 times their standard error were transformed using the Box-Cox method (Kim, 2013). Box-plot and z-scores (where univariate outliers were defined as values exceeding 3.29 standard deviations from the mean; Field, 2013) were used to assess for univariate outliers, and Mahalanobis distances (Mahalanobis, 1936) were used to assess for multivariate outliers.

3.1.6.2 Principal components analysis with parallel and reliability analyses

To establish the higher-order structure of dispositional traits previously associated with BSDs in this participant sample, I conducted PCA with the 13 identified BSD-related trait variables (i.e., the BSSS total score, six of 11 MPQ-BF primary trait scales, three of six DERS subscales, and all three BIS-15 subscales). The number of components retained was determined using parallel analysis with 5000 permutations of the raw dataset using a PCA approach (Horn, 1965; Wood, Akloubou Gnonhosou, & Bowling, 2015), the scree plot (Cattell, 1966) and each component's eigenvalue (Kaiser, 1960). As the extracted components were expected to correlate (Field, 2013), the component matrix was rotated using an Oblique method (Direct Oblimin). I used Haitovsky's test to assess multicollinearity (Haitovsky, 1969) and reliability analysis to examine the internal consistency of the trait scales that comprised each component (Chronbach's α).

3.1.6.3 Hierarchical regression analyses

Regression analyses in this study were conducted according to the same procedures used in Study 1, except that the components extracted using PCA were used in the prediction of the sensitivity and conditioning variables. Thus, my hypotheses for these analyses are presented with at the end of the Principal components analysis section.

3.2 Results

3.2.1 Variable selection, calculation, and screening

3.2.1.1 Calculation of sensitivity and conditioning variables

Sensitivity and conditioning variables were calculated as described for Study 1. Based on the cut-score to suggest a participant showed a conditioned response during the tasks used to measure reward and threat conditioning in this study (i.e., a conditioning score of 5 or more), 61% of participants who completed the reward conditioning task, and 67% who completed the threat conditioning task, successfully conditioned.

Descriptive statistics and inter-correlations for the sensitivity and conditioning variables are presented in Table 3.2.

Table 3.2 Sensitivity and conditioning variable descriptive statistics and inter-correlations.

Dependent variables included in the regression models	Descriptive statistics		Inter-correlations			
	N	*M* (SD), Range	1	2	3	4
1. Sensitivity to incentive reward (lottery tickets) Avg. % increase in excitement ratings from 1-2-3-4 tickets	498	58.24 (22.92), 0.00 – 99.67	—			
2. Sensitivity to threat (aversive noise) Avg. % increase in nervousness ratings from 0-25-50-75-100% probability of hearing an aversive noise	502	41.77 (21.20), 0.00 – 96.00	.30***	—		
3. Reward conditioning (US = 1 lottery ticket) Increase in excitement ratings from pre- (rating 1) to post-baseline (ratings 2-10, averaged) for CS+, *minus* CS-, faces	501	13.87 (21.05), -4.07 – 4.85	.21***	.11*	—	
4. Threat conditioning (US = aversive noise) Increase in nervousness ratings from pre- (rating 1) to post-baseline (2-7) for CS+, minus CS-, faces	499	18.29 (27.82), -3.89 – 4.13	.18***	.21***	.32***	—

Note. ***$p < 0.001$; *$p < 0.05$.

3.2.2 Data screening

Prior to my analyses, I examined patterns of missing data and distributional properties for the independent and dependent variables. Eight participants were missing one or more BIS-15 subscale scores and eighteen were missing one or more sensitivity and/or conditioning scores. The results of a missing value analysis indicated these scores were missing completely at random (MCAR; Little's MCAR test). All personality measures, except for the BIS-15 Non-planning subscale and the BSSS, had skewness and/or kurtosis values exceeding ±1.96 times their standard error. Scores for these variables were transformed to approximate a normal distribution using the Box-Cox method (Box & Cox, 1964). Finally, five univariate outliers, defined as scores greater than ±3.29, were identified for DERS-IMPULSE subscale scores (z-scores ranging from ±3.30 to 3.72) and one for MPQ—BF Control subscale (z-score = -3.52). Once normalized, standard scores for these variables were within the range of 2.78 SDs from the mean.

3.2.2.1 Principal components analysis

Following an initial parallel analysis and PCA including the 13 scales selected for inclusion, I found that two scales, Aggression and Social Closeness, had communalities below 0.4. As recommended by Field (2013), I removed these variables from the model and re-ran the analysis with the remaining 11 items. The second parallel analysis indicated that three components should be extracted (a scree plot of the parallel analysis results is presented in the Appendices, Figure B.1). Therefore, I re-ran the PCA with Direct Oblimin rotation and three factors specified for extraction. The obtained eigenvalues (Kaiser, 1960) and scree plot (Cattell, 1966) also suggested the data were best represented by 3 components (see Appendices, Figure B.2). Communalities were above .5, with an average of .61, indicating that the derived factor structure accurately reflected the data structure (Stevens, 2012). The Kaiser-Meyer-Olkin

statistic was 0.78, indicating good sampling adequacy (Hutcheson & Sofroniou, 1999). A Haitovsky's x_H^2 value of 19.05 suggested acceptable levels of co-linearity between components. Correlations between all item values produced from the PCA and the raw data values were above 0.6, supporting their inclusion in the analysis. Reliability between items for each component (Chronbach's alpha) were also acceptable, as shown in Table 3.3. Thus, variables representing the three extracted components (presented graphically in Figure 3.1) were carried forward to the hierarchical regression analyses.

Table 3.3 Principal components analysis results with internal reliabilities and inter-correlations of the extracted components (N=498).

	Rotated factor loadings		
Item	Factor 1	Factor 2	Factor 3
Non-planning	**0.82**	0.11	-0.13
Control	**-0.78**	0.13	-0.08
Motor	**0.66**	-0.02	0.27
Achievement	**-0.65**	-0.05	**0.58**
Attentional impulsiveness	**0.54**	0.30	0.22
Access to strategies	-0.04	**0.88**	0.04
Impulsivity when upset	0.12	**0.79**	0.02
Stress reactivity	-0.07	**0.77**	0.08
Goal pursuit when upset	0.00	**0.73**	-0.11
Absorption	0.02	0.15	**0.73**
Sensation seeking	0.35	-0.13	**0.63**
Eigenvalues	3.29	2.14	1.33
% of variance	29.93	19.44	12.12
Chronbach's α	0.74	0.82	0.54
Inter-correlations			
Factor 1	-		
Factor 2	.158***	-	
Factor 3	.139**	.047	-

Note. Factor loadings over .40 appear in bold. ***$p < 0.001$; **$p < .01$.

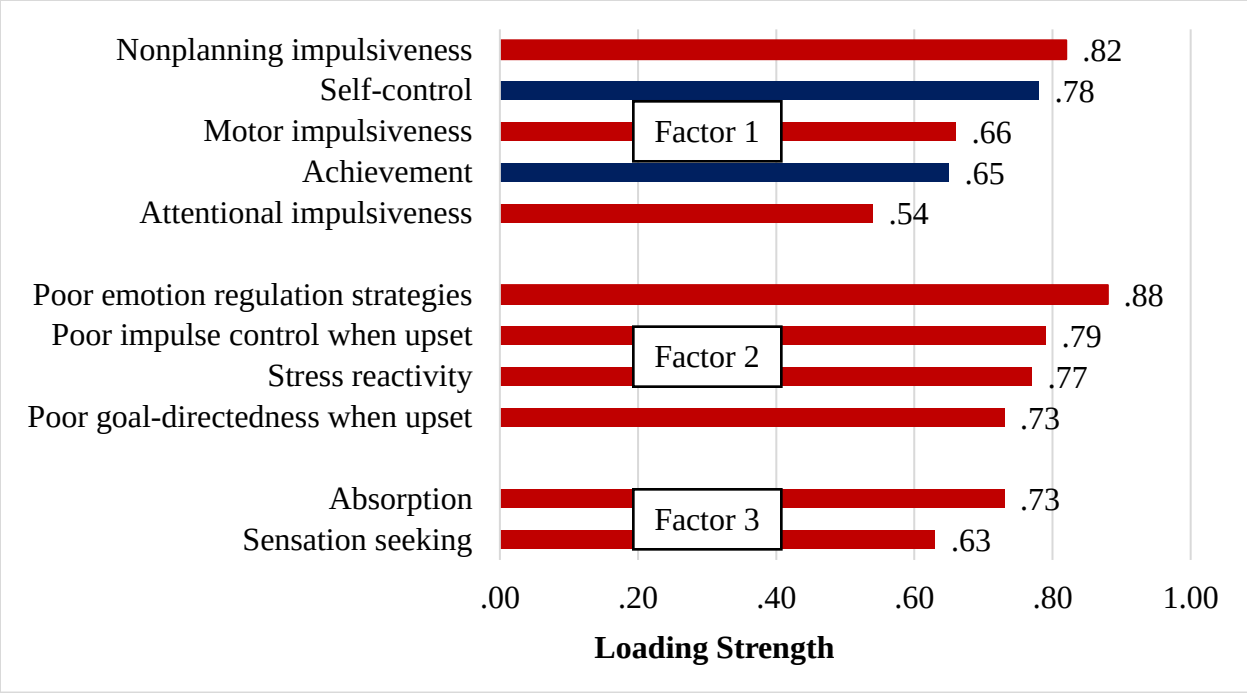

Figure 3.1 Item loadings for the three extracted principal components labelled Factor 1 ('executive dyscontrol'), Factor 2 ('distress susceptibility'), and Factor 3 ('heedless engagement').

The three components' constituent scales, shown in Figure 3.1, reflected impulsiveness, low control, and low achievement for Factor 1 ('executive dyscontrol'); difficulties regulating emotions and high stress reactivity for Factor 2 ('distress susceptibility'); and sensation seeking and absorption for Factor 3 ('heedless engagement'). Factor 1 ('executive dyscontrol') was interpreted as reflecting difficulties recruiting executive functions to guide thoughts and actions and low goal-oriented motivation and behaviour, Factor 2 ('distress susceptibility') as sensitivity to and a negative interpretation of unpleasant emotions, and Factor 3 ('heedless engagement') as attraction to novel, fascinating, and/or exciting stimuli, experiences, and ideas and a tendency to engage deeply with them despite potential risks.

Of the three extracted components, Factors 1 ('executive dysfunction') and 3 ('heedless engagement') are likely to best reflect the GBI's Hypomania subscale. In terms of face validity

alone, the Hypomania subscale on the GBI contains items measuring physical restlessness and hyperactivity, as well as poor sustained attention (Depue et al., 1981), attributes which overlap with those measured by the motor and attentional impulsiveness subscales of the BIS-15 (respectively; Spinella, 2007) and the MPQ-BF's Control subscale (Patrick et al., 2002). Items on the Hypomania subscale resembling those comprising the Factor 3 ('heedless engagement') refer to excitement and engagement in novel, mischievous, destructive, risky, shocking, and/or potentially unlawful activities, consistent with the BSSS (Hoyle et al., 2002). Lastly, the Hypomania subscale asks about respondents' sensitivity to sensory stimuli, i.e., how vividly or intensely they experience sensations, consistent with the MPQ-BF's Absorption subscale (Patrick et al., 2002).

Previous research has linked these dispositional traits to reward and threat sensitivity and conditioning. For instance, Mardaga and Hansenne (2007) found that higher scores on the TCI's Novelty Seeking subscale (a construct related to sensation seeking; McCourt et al., 1993) significantly predicted greater reward responsiveness and lower threat sensitivity as measured using the BIS/BAS scales. Another study showed similar results using a behavioural measure of sensitivity to reward and loss, wherein greater sensation seeking, as well as impulsivity, significantly predicted less sensitivity to reward/loss magnitude (Bornovalova et al., 2009). Thus, consistent with the findings from Study 1 showing the GBI's Hypomania subscale predicted greater reward sensitivity, and with findings from previous research, it was hypothesized that higher scores on Factors 3 ('heedless engagement') and 1 ('executive dyscontrol') would significantly predict greater sensitivity to incentive reward (respectively), measured as participants' anticipatory excitement levels as a function of incremental increases in the probability of winning a $100 lottery. I also hypothesized based on the findings of Bornovalova

et al. (2009) that Factors 3 (‘heedless engagement’) and 1 (‘executive dyscontrol’) would significantly predict lower sensitivity to threat, measured as participants’ average levels of tenseness, nervousness, and anxiety as a function of incremental increases in the probability that they will hear an aversive noise. Since the GBI’s Hypomania subscale was not significantly associated with either conditioning variable, Factors 1 (‘executive dyscontrol’) and 3 (‘heedless engagement’) were entered as exploratory variables into these analyses.

The Factor 2 (‘distress susceptibility’) component contains scales measuring emotion regulation strategies and stress reactions related to the GBI’s Depression subscale in terms of item content and previous research. For example, a study of individuals with BSDs which directly investigated how higher GBI’s Depression subscale scores related to participants’ responses on the DERS total and subscales (Van Rheenen et al., 2015). The authors showed that higher depressive traits significantly predicted higher scores on the ‘difficulties accessing emotion regulation strategies’ subscale, which was the highest loading item on the Factor 2 (‘distress susceptibility’) component extracted from the PCA.

Therefore, I hypothesized that higher scorers on the Factor 2 (‘distress susceptibility’) component would demonstrate significantly greater tendency to develop a classically conditioned response to a threat-related cue, as shown for the GBI’s Depression subscale in Study 1. As the Depression subscale did not show a significant relationship to reward conditioning, I hypothesized based on previous research that Factor 2 (‘distress susceptibility’) would be negatively associated with reward conditioning (Ochsner & Gross, 2007; Pizzagalli et al., 2008). I also hypothesized that this higher-order bipolar trait would significantly predict less reward sensitivity, considering evidence that depressive symptoms and emotion regulation difficulties predict reduced reward responsiveness on the BIS/BAS scales (Markarian, Pickett, Deveson, &

Kanona, 2013). Finally, as a tendency to have difficulty regulating emotions has been significantly associated with threat sensitivity in BSDs (Weinstock et al., 2018), I hypothesized that higher Factor 2 (‘distress susceptibility’) scores would significantly predict greater sensitivity to threat.

3.2.3 Hierarchical regression analyses

3.2.3.1 Associations of Factors 1 (‘executive dyscontrol’), 2 (‘distress susceptibility), and 3 (‘heedless engagement’) with sensitivity to varying probabilities of monetary incentive reward

To test the hypothesis that sensitivity to incentive reward is a function of Factors 1, 2, and 3, a hierarchical multiple regression analysis was performed. Based on my hypotheses, the Factor 3 (‘heedless engagement’) variable was entered first, followed by Factor 2 (‘distress susceptibility’), and then Factor 1 (‘executive dyscontrol’). Tests of multicollinearity and autocorrelation indicated that low levels of multicollinearity and autocorrelation were present (tolerance = 0.980, 0.978, 0.96, for Factors 3, 2, and 1, respectively; Durbin-Watson = 2.00). Results of the hierarchical regression analysis provided partial support for my hypotheses. While the combination of all three predictors indicated a significant model ($R = 0.134$, F [3,486] = 2.983, $p = 0.031$), the best fitting model entered into the regression analysis as potential predictors of sensitivity to incentive reward included only the Factor 3 (‘heedless engagement’) variable ($R = 0.108$, F [1,488] = 5.805, $p = 0.016$). Power to detect the effects obtained in the significant model with the Factor 3 (‘heedless engagement’) variable used to predict sensitivity to incentive reward was 0.677. Thus, the component I characterized as Factor 3 (‘heedless engagement’), which was extracted with the greatest weight from scales measuring absorption and sensation seeking traits, predicted sensitivity to incentive reward, suggesting that seeking

excitement while discounting risk and keeping open to new and novel experiences may together promote higher sensitivity to incentive reward.

Table 3.4 Results of the regression analysis predicting sensitivity to incentive reward as a function of Factors 1 ('executive dyscontrol'), 2 ('distress susceptibility'), and 3 ('heedless engagement') (N=490).

	β	*r*	*t*	*p*	sr^2	*VIF*
Step 1						
Factor 3 ('heedless engagement')	0.108	0.108	2.409	0.016	0.012	1.000
Step 2						
Factor 3 ('heedless engagement')	0.112	0.108	2.482	0.013	0.012	1.002
Factor 2 ('distress susceptibility')	-0.076	-0.071	-1.692	0.091	0.006	1.002
Step 3						
Factor 3 ('heedless engagement')	0.115	0.108	2.528	0.012	0.013	1.020
Factor 2 ('distress susceptibility')	-0.073	-0.071	-1.597	0.111	0.005	1.023
Factor 1 ('executive dyscontrol')	-0.024	-0.019	-0.525	0.600	0.001	1.041

Note. $R^2 = 0.012$; F (1,488) = 5.805, $p = 0.016$ for Step 1. $\Delta R^2 = 0.006$, F (1,487) = 2.861, $p = 0.091$ for Step 2. $\Delta R^2 = 0.001$, F (1,486) = 0.275, $p = 0.600$ for Step 3.

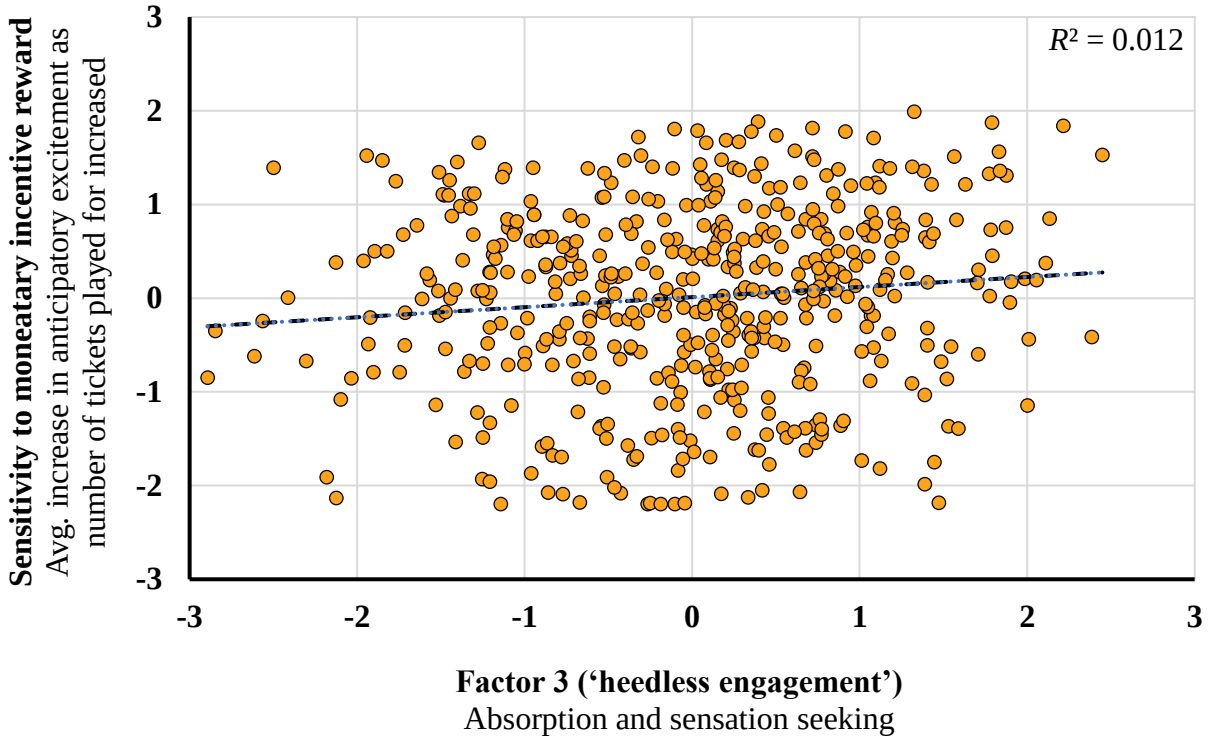

Figure 3.2 Factor 3 ('heedless engagement') significantly predicted averaged increases in anticipatory ratings of excitement, enthusiasm, and elation as the number of potential tickets to be won increased.

3.2.3.2 Associations of Factors 1 ('executive dyscontrol'), 2 ('distress susceptibility), and 3 ('heedless engagement') with sensitivity to varying probabilities of hearing an aversive tone

To test the hypothesis that sensitivity to threat is a function of three higher-order bipolar traits, Factors 1 ('executive dyscontrol'), 2 ('distress susceptibility), and 3 ('heedless engagement), a hierarchical regression analysis was performed. Based on my hypotheses generated from Study 1 results and previous literature, Factor 2 ('distress susceptibility'; emotion regulation difficulties and stress reactivity) was entered first, followed by Factor 3 ('heedless engagement'; absorption and sensation seeking), and then Factor 1 ('executive dyscontrol'; impulsiveness, [low] control, and [low] achievement). Low levels of multicollinearity and

autocorrelation were observed (tolerance = 0.974, 0.98, 0.958, for Factors 2, 3, and 1, respectively; Durbin-Watson = 1.851). Results of the hierarchical regression analysis provided partial support for my hypotheses. The combination of all three predictors indicated a significant model ($R = 0.253$, F [3,490] = 11.169, $p < .001$). Despite this, the best fitting model predicting sensitivity to varying probabilities of hearing an aversive tone was Factor 2 (‘distress susceptibility’) alone ($R = 0.243$, F [1,492] = 30.91, $p < 0.001$). With an alpha level of 0.05, sample size of 494, and the effect sizes obtained, achieved power was >0.999 in Step 1, 0.999 in Step 2, and 0.999 in Step 3. Thus, the component I characterized as Factor 2 (‘distress susceptibility’), reflecting high levels of negative affect combined with difficulties managing unpleasant emotions, predicted threat sensitivity, suggesting that this bipolar trait dimension is measuring a disposition that is more highly related to responsivity to increasing levels of threat than the Depression subscale as measured in on the GBI for Study 1.

Table 3.5 Results of the regression analysis predicting sensitivity to varying probabilities of hearing an aversive noise as a function of Factors 1 (‘executive dyscontrol’), 2 (‘distress susceptibility’), and 3 (‘heedless engagement’) (N=494).

	β	*r*	*t*	*p*	sr^2	*VIF*
Step 1						
Factor 2 (‘distress susceptibility’)	0.243	0.243	5.560	0.000	0.059	1.000
Step 2						
Factor 2 (‘distress susceptibility’)	0.244	0.243	5.568	0.000	0.060	1.003
Factor 3 (‘heedless engagement’)	-0.017	-0.005	-0.398	0.691	0.000	1.003
Step 3						
Factor 2 (‘distress susceptibility’)	0.254	0.243	5.747	0.000	0.063	1.026
Factor 3 (‘heedless engagement’)	-0.008	-0.005	-0.189	0.850	0.000	1.021
Factor 1 (‘executive dyscontrol’)	-0.069	-0.030	-1.550	0.122	0.005	1.044

Note. $R^2 = 0.059$; F (1,492) = 30.91, $p < 0.001$, $f^2 = 0.063$ for Step 1. $\Delta R^2 = < .001$, F (1,491) = 0.159, $p = 0.691$, $f^2 = 0.063$ for Step 2. $\Delta R^2 = 0.005$, F (1,490) = 2.403, $p = 0.122$, $f^2 = 0.068$ for Step 3.

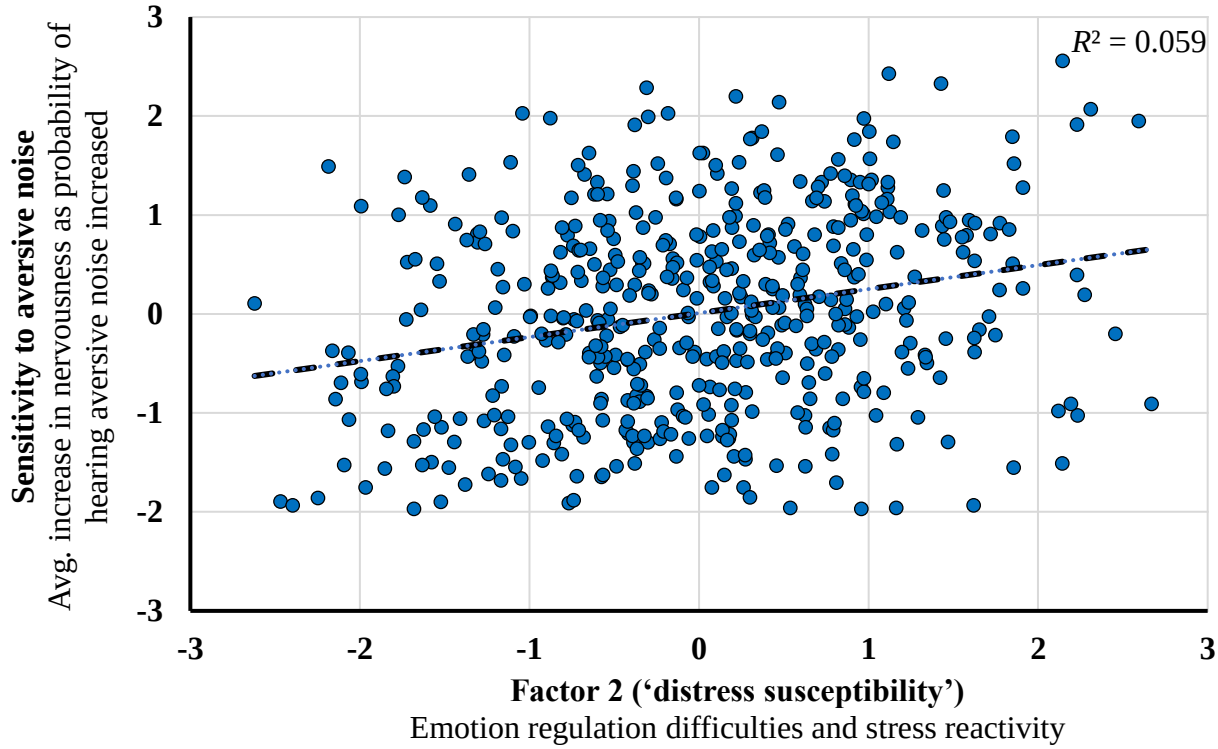

Figure 3.3 Factor 2 ('distress susceptibility') predicted greater averaged increases in self-reported tenseness, nervousness, and anxiety for each incremental increase in the probability of hearing an aversive noise.

3.2.3.3 Associations of Factors 1 ('executive dyscontrol'), 2 ('distress susceptibility), and 3 ('heedless engagement') with reward conditioning

To test the hypothesis that reward conditioning is a function of three variables, the Factor 1 ('executive dyscontrol'), Factor 2 ('distress susceptibility'), and Factor 3 ('heedless engagement') dimensions, a hierarchical regression analysis was performed. According to my hypotheses, the Factor 3 ('heedless engagement') variable was entered first, followed by Factor 2 ('distress susceptibility'), and then Factor 1 ('executive dyscontrol'). Tests of multicollinearity and autocorrelation indicated that low levels of multicollinearity and autocorrelation were present (tolerance = 0.981, 0.976, 0.960, for Factors 3, 2, and 1, respectively; Durbin-Watson = 2.049). While the combination of all three predictors indicated a significant model (R = 0.150, F

[3,489] = 3.733, p = 0.011), my hypotheses were only partially supported. Only the third and final predictor added to the model, Factor 1 (‘executive dyscontrol’), significantly improved prediction of reward conditioning (ΔR^2 = 0.022, F [1,489] = 11.068, p = 0.001). Achieved power for this significant result given an alpha level of 0.05, sample size of 493, and f^2 effect size of 0.02 was 0.80. Thus, Factor 1 (‘executive dyscontrol’), which comprised measures of self-control, planning, motor inhibition, and achievement negatively predicted participants’ tendencies to associate a neutral cue with incentive reward after it was paired with a rewarding stimulus.

Table 3.6 Results of the regression analysis predicting reward conditioning as a function of Factors 1 (‘executive dyscontrol’), 2 (‘distress susceptibility’), and 3 (‘heedless engagement’) (N=493).

	β	*r*	*t*	*p*	sr^2	*VIF*
Step 1						
Factor 3 (‘heedless engagement’)	-0.016	-0.016	-0.359	0.720	< 0.001	1.000
Step 2						
Factor 3 (‘heedless engagement’)	-0.016	-0.016	-0.359	0.720	< 0.001	1.002
Factor 2 (‘distress susceptibility’)	0.001	0.000	0.022	0.983	< 0.001	1.002
Step 3						
Factor 3 (‘heedless engagement’)	0.004	-0.016	0.080	0.936	< 0.001	1.020
Factor 2 (‘distress susceptibility’)	0.023	0.000	0.515	0.607	0.001	1.024
Factor 1 (‘executive dyscontrol’)	-0.152	-0.148	-3.327	0.001	0.022	1.042

Note. $R^2 < 0.001$; F (1,491) = 0.129, $p = 0.720$, $f^2 = 0.00$ for Step 1. $\Delta R^2 < 0.001$, F (1,490) < .001, $p = 0.983$, $f^2 < 0.01$ for Step 2. $\Delta R^2 = 0.022$, F (1,489) = 11.068, $p = 0.001$, $f^2 = 0.023$ for Step 3.

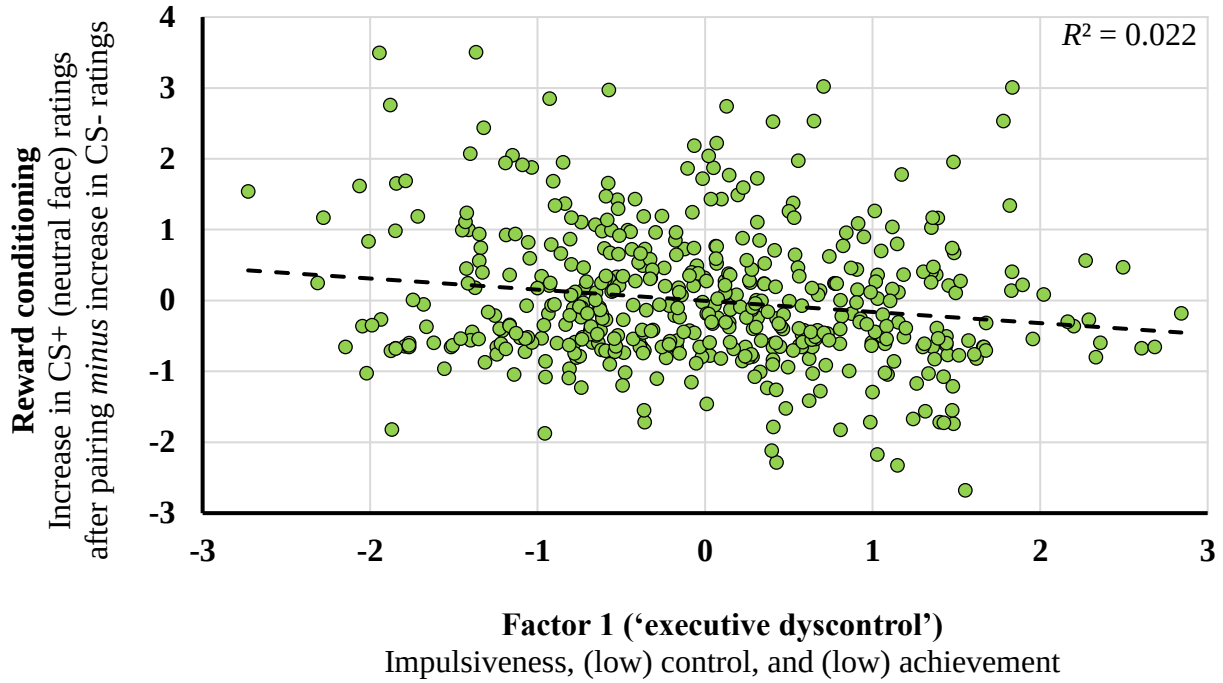

Figure 3.4 Factor 1 ('executive dyscontrol') dimension predicted lower reward conditioning.

3.2.3.4 Associations of Factors 1 ('executive dyscontrol'), 2 ('distress susceptibility), and 3 ('heedless engagement') with threat conditioning

To test the hypothesis that threat conditioning is a function of three dimensions of bipolar traits, Factor 1 ('executive dyscontrol'; impulsiveness, [low] control, and [low] achievement), Factor 2 ('distress susceptibility'; emotion regulation difficulties and stress reactivity), and Factor 3 ('heedless engagement'; absorption and sensation seeking), a hierarchical regression analysis was performed. Based on my hypotheses, Factor 2 ('distress susceptibility') was entered first, followed by Factor 3 ('heedless engagement'), and then Factor 1 ('executive dyscontrol') dimensions. Levels of multicollinearity and autocorrelation were acceptable (tolerance = 0.975, 0.981, 0.959, for Factors 2, 3, and 1, respectively; Durbin-Watson = 2.064). Results of the hierarchical regression analysis provided partial support for my hypotheses. The combination of all three predictors indicated a significant model (R = 0.167, F [3,487] = 4.63, p = 0.003);

however, the model only became significant after the addition of the Factor 3 (‘heedless engagement’) ($\Delta R^2 = 0.011$, F [1,488] = 5.372, $p = 0.021$) and Factor 1 (‘executive dyscontrol’) $\Delta R^2 = 0.014$, F [1,487] = 7.023, $p = 0.008$) variables. Given an alpha level of 0.05 and sample size of 491, achieved power for the two significant models was 0.64 for Step 2, and 0.93 for Step 3. Thus, Factor 3 (‘heedless engagement’) and Factor 1 (‘executive dyscontrol’) negatively predicted propensity for threat conditioning, suggesting that both higher-order bipolar traits accounted for unique variance in participants’ tendencies to attribute tenseness, nervousness, and anxiety to a neutral cue after it was paired with an aversive noise.

Table 3.7 Associations of Factors 1 (‘executive dyscontrol’), 2 (‘distress susceptibility’), and 3 (‘heedless engagement’) with threat conditioning (N=491).

	β	*r*	*t*	*p*	sr^2	*VIF*
Step 1						
Factor 2 (‘distress susceptibility’)	0.053	0.053	1.182	0.238	0.003	1.000
Step 2						
Factor 2 (‘distress susceptibility’)	0.058	0.053	1.295	0.196	0.003	1.002
Factor 3 (‘heedless engagement’)	-0.104	-0.102	-2.318	0.021	0.011	1.002
Step 3						
Factor 2 (‘distress susceptibility’)	0.077	0.053	1.690	0.092	0.006	1.026
Factor 3 (‘heedless engagement’)	-0.089	-0.102	-1.971	0.049	0.008	1.019
Factor 1 (‘executive dyscontrol’)	-0.121	-0.121	-2.650	0.008	0.014	1.042

Note. $R^2 = 0.003$; F (1,489) = 1.398, $p = 0.238$, $f^2 = 0.003$ for Step 1. $\Delta R^2 = 0.011$, F (1,488) = 5.372, $p = 0.021$, $f^2 = 0.014$ for Step 2. $\Delta R^2 = 0.014$, F (1,487) = 7.023, $p = 0.008$, $f^2 = 0.029$ for Step 3.

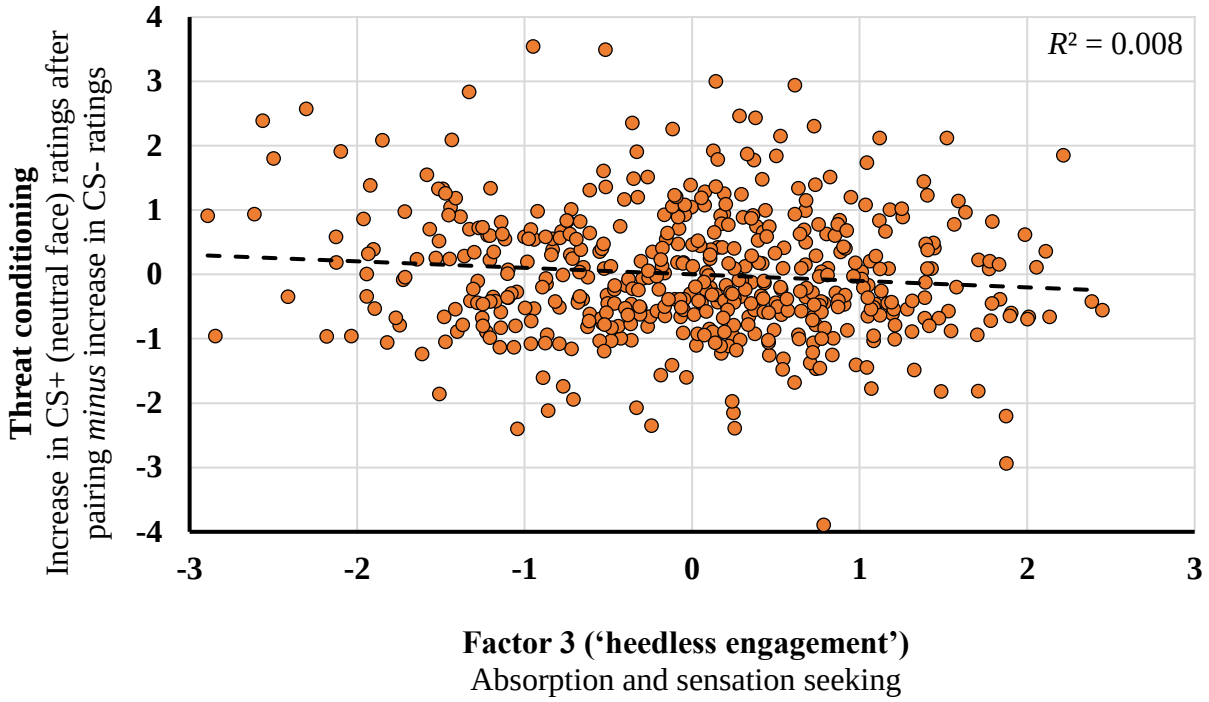

Figure 3.5 Higher Factor 3 ('heedless engagement') scores predicted lower threat conditioning scores calculated as the difference between participants' averaged post-baseline CS+ tense/nervous/anxious ratings and their baseline CS+ rating *minus* that of the CS-.

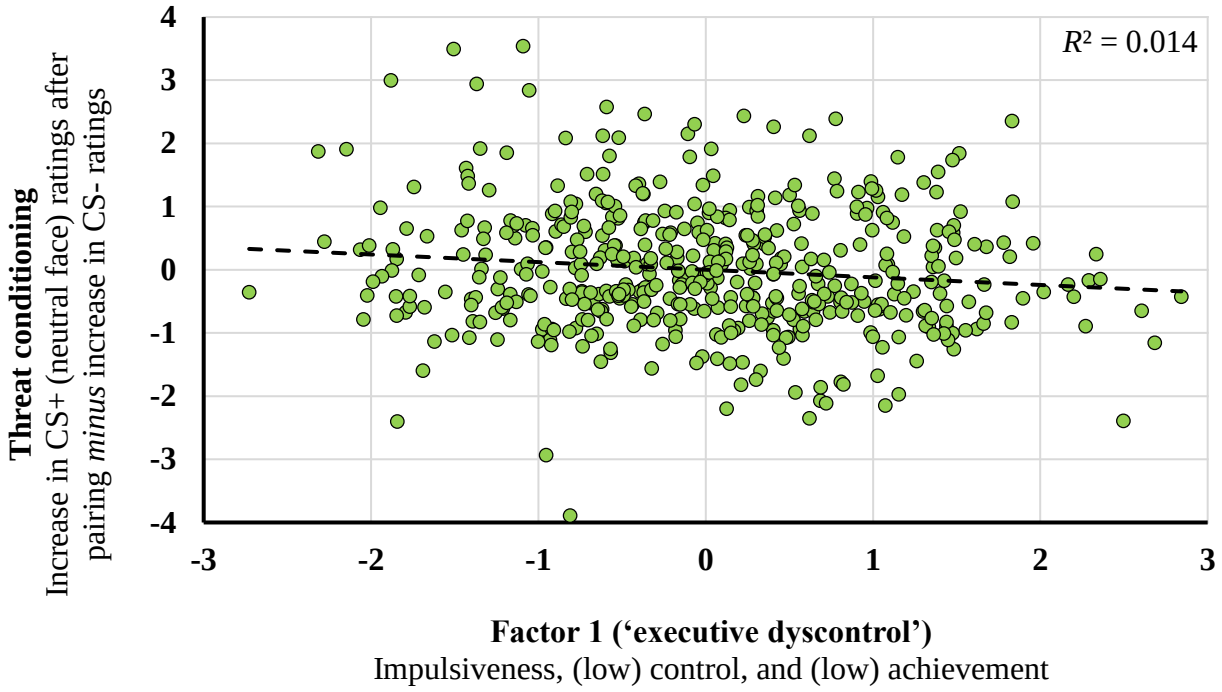

Figure 3.6 Factor 1 ('executive dyscontrol') predicted threat conditioning scores calculated as the difference between participants' averaged post-baseline CS+ tenseness/nervousness/anxiety ratings and their baseline CS+ rating *minus* that of the CS-.

Chapter 4: Discussion

Reward and threat sensitivity and conditioning have been investigated in relation to several mental disorders, including anxiety (Hyman & Malenka, 2001; Lissek et al., 2005), addiction (Hyman, 2005), MDD (Hägele et al., 2015; Sherdell, Waugh, & Gotlib, 2012; Vrieze et al., 2013), and BSDs (Duek, Osher, Belmaker, Bersudsky, & Kofman, 2014; Pizzagalli et al., 2008). Despite research demonstrating a significant role of reward and threat sensitivity and learning in BSDs, few of these studies have used behavioural measures to capture sensitivity, nor have they explored how bipolar traits relate to classical conditioning. Therefore, this investigation was undertaken to improve our understanding of how sensitivity to the anticipation of rewarding or punishing stimuli, and vulnerability to developing classically conditioned responses to reward- and threat-related cues, varied as a function of bipolar traits ranging broadly from low to high.

4.1 Study 1: Associations of lifetime symptoms of hypomania, depression, and mood lability with reward and threat sensitivity and learning

In partial support of my hypotheses, higher scores on the Hypomania subscale of the GBI significantly predicted sensitivity to incentive reward, and the Depression subscale significantly predicted greater threat conditioning. Although no other significant effects were observed in this study, insufficient power may have precluded the detection of smaller effects.

4.1.1 Lifetime hypomanic mood symptoms significantly predicted sensitivity to incentive reward

I hypothesized that higher scores on the GBI's Hypomania subscale would predict higher sensitivity to incentive reward (Abler et al., 2008; Johnson et al., 2005; Jones & Day, 2008; Meyer et al., 2007) and stronger reward conditioning (Pizzagalli et al., 2008), as well as lower

threat sensitivity and conditioning (Carver & Johnson, 2009; Jones & Day, 2008; Muhtadie & Johnson, 2015). In partial support of my hypotheses, higher Hypomania subscale scores significantly predicted greater increases in anticipatory excitement as a function of incremental increases in the number of tickets being played for during the reward sensitivity task. Thus, in this relatively small university student sample, the GBI's Hypomania subscale showed a significant positive association with an individual's responsiveness to a cue signaling incentive reward. These results also support the interpretation that, given the associations of goal striving and achievement with BSD onset (Alloy et al., 2012), higher responsivity to prospective incentive rewards varies as a function of hypomanic mood traits, even in the non-clinical range.

4.1.2 Lifetime depressive mood symptoms predicted stronger classically conditioned responding to threat-related cues

Higher depressive trait scores significantly predicted the formation of stronger conditioned responding to a threat-related cue, as indicated by a greater increase in self-ratings of tenseness, nervousness, and anxiety in response to a neutral face after it was paired with an aversive noise, relative to the increase in participants' ratings in response to a neutral face that was not paired with the aversive stimulus. These findings suggest that individuals with a history of greater depressive mood symptoms may demonstrate greater depth in processing of aversive cues and their associated contexts (Rescorla, 1988), and in turn, individuals with the lowest levels of past depressive symptoms may demonstrate more shallow processing of aversive cues and their associated contexts. One relevant study of cognitive processing of emotional material in MDD by Levens and Gotlib (2010) showed evidence of increased retention of negative material in working memory for participants with MDD relative to control participants. This bias for retaining negative material may partly explain the results obtained in this study, whereby

greater retention of cues and contexts related to past negative experiences over the course of associative learning may facilitate the formation of classically conditioned associations involving a punishing stimulus (Hamilton & Gotlib, 2008). Overall, the finding that depressive traits were associated with greater susceptibility to threat conditioning may suggest a potential psychological process related to, and perhaps facilitated by, enhanced attentional processing, working memory, and short and long term memory for negative stimuli (Mogg, Bradley, & Williams, 1995; Murphy et al., 1999; Watkins, Vache, Verney, & Mathews, 1996).

My hypotheses that the GBI's Depression subscale would be associated with reward sensitivity and conditioning were not supported, despite a large body of research linking MDD and depressive symptoms to blunted incentive reward sensitivity and altered incentive reward learning (Alloy et al., 2016; Shankman et al., 2013; Sherdell et al., 2012; Shumake, Barrett, & Gonzalez-Lima, 2005; Vrieze et al., 2013). As noted in the Results section of Study 1, the null findings may have been attributable to low power. However, the null findings may also reflect a difference in incentive reward sensitivity across mood states, whereby individuals currently experiencing MDEs or sub-clinically elevated depressive symptoms may demonstrate blunted incentive reward sensitivity, but these changes may not be observed during subsyndromal periods (Alloy et al., 2008). This may be especially true for individuals who, in addition to higher levels of lifetime depressive symptoms, also report higher levels of lifetime hypomanic symptoms, as these individuals would be expected to exhibit stable incentive reward hypersensitivity (Carver & Johnson, 2009).

4.2 Interim summary and interpretation

In Study 1, I found that the GBI's Hypomania and Depression subscales (measuring frequency of these symptoms and related behaviours since high school age) significantly

predicted excitement during the anticipation of increasing chances of winning a monetary reward, and susceptibility to feeling nervous, anxious, and tense when presented with an initially neutral cue after it had been paired with an aversive noise, respectively. These findings, while exploratory, suggest that the tasks used in this study to measure sensitivity to incentive reward and threat conditioning can be useful for examining how reward and threat sensitivity and conditioning vary as a function of bipolar traits. Once again, however, these findings must be interpreted cautiously given the small sample. Thus, Study 2 was conducted to further investigate potential links between bipolar traits and the sensitivity and conditioning variables examined in Study 1.

4.3 Study 2: Associations of higher-order bipolar traits with reward and threat sensitivity and learning

The overall objective for Study 2 was to examine whether higher-order bipolar traits, extracted from dispositional trait scales shown in previous studies to distinguish individuals with BSDs from comparison groups, were related to reward and threat sensitivity and conditioning. For this study, I first analyzed the component structure of 13 BSD-related trait scales to form higher-order constructs representing higher-order bipolar traits. Three higher-order trait dimensions were extracted using PCA, including Factor 1, ‘executive dyscontrol’ (impulsiveness, control [negative loading], and achievement [negative loading] scales); Factor 2, ‘distress susceptibility’ (emotion regulation difficulties and stress reactivity); and Factor 3, ‘heedless engagement’ (absorption and sensation seeking). I then used these components to investigate how reward and threat sensitivity and conditioning varied as a function of higher-order bipolar traits.

4.3.1 Factor 1 (‘executive dyscontrol’) predicted weaker reward and threat conditioning

Counter to my hypotheses, participants with higher scores on Factor 1 (‘executive dyscontrol’) demonstrated significantly weaker conditioning to the reward- and threat-related cues. These findings may be explained by certain lower-order traits captured by Factor 1 (‘executive dyscontrol’) which may hinder the formation of classically conditioned responses, such as lower tendencies towards attentiveness, reflectiveness, and attempting to anticipate events (Dayan, Kakade, & Montague, 2000). Thus, higher scores on Factor 1 (‘executive dyscontrol’) may reflect less engagement in cognitive processes relevant to the formation of conditioned responses (e.g., executive resources; Hur, Iordan, Berenbaum, & Dolcos, 2016), deficits which may explain its significant negative association with reward and threat conditioning.

Importantly, conditioned cues are known to elicit physiological responses that may “prepare” an organism to approach or avoid the associated outcome (Carter & Tiffany, 1999). Consequently, individuals with reduced conditioning to, and attention towards (Dayan et al., 2000), reward- or threat-related cues and contexts may not experience the same level of motivation to obtain rewards and avoid threat or harm as would individuals with greater conditioning susceptibility. This proposition is consistent with the *negative* loading of the MPQ-BF’s Achievement subscale on Factor 1 (‘executive dyscontrol’), suggesting that individuals with lower levels of this higher-order trait may be less likely to be ambitious, perfectionistic, and persistent, or to enjoy effort, challenging tasks, and working hard (Patrick et al., 2002). To reiterate, Factor 1 (‘executive dyscontrol’) was related to weaker classical conditioning for both conditioning tasks, suggesting an overall tendency to form weak classically conditioned associations.

4.3.2 Factor 2 (‘distress susceptibility’) predicted enhanced sensitivity to threat

As predicted, Factor 2 (‘distress susceptibility’) was significantly associated with sensitivity to threat, such that individuals with a greater tendency to have trouble regulating their emotions and negative emotions in response to stress were also more tense, nervous, and anxious when anticipating varying probabilities of hearing an aversive noise during the sensitivity to threat task. This finding extends several previous studies showing that greater emotion regulation difficulties are associated with higher scores on questionnaires measuring sensitivity to aversive stimuli and events (Balconi, Falbo, & Conte, 2012; Meyer et al., 2001; Muhtadie & Johnson, 2015) as well as BSD psychopathology (Jylhä et al., 2010). Another scale that loaded significantly onto Factor 2 (‘distress susceptibility’) was the MPQ-BF’s Stress Reactivity subscale, also shown to predict self-reported sensitivity to aversive stimuli and events (Caseras, Avila, & Torrubia, 2003). This study therefore extends existing literature suggesting that difficulties regulating negative emotions and stronger reactions to stress potentiate experiences of tenseness, nervousness, and anxiety during the anticipation of threat. Thus, for individuals with bipolar traits and BSDs, developing strategies that attenuate stress reactivity and help with regulating unpleasant emotions, and applying them in situations of potential punishment or harm, could help attenuate the unpleasant psychological and emotional sequelae of heightened threat sensitivity (Kim, Miklowitz, Biuckians, & Mullen, 2007; Malkoff-Schwartz et al., 1998).

My hypothesis that higher Factor 2 scores (‘distress susceptibility’; indicating a greater tendency towards stress reactivity and emotion regulation difficulties) would predict higher levels of threat conditioning was not supported. One potential explanation is that, when considered from the view that stronger conditioning indicates deeper processing of the US with its surrounding cues and context (Bouton & Moody, 2004), weaker threat conditioning may

suggest avoidance of the US and other related information (Hur et al., 2016). The finding could also be explained by the fact that my measure of conditioning measured the acquisition of a conditioned response to the CS+ that distinguished it from CS-. Previous research has shown that individuals with Generalized Anxiety Disorder, who demonstrate maladaptive levels of stress reactivity and emotion regulation difficulties (Salters-Pedneault, Roemer, Tull, Rucker, & Mennin, 2006), show generalized classical conditioning whereby cues that resemble a CS+ tend to elicit the same response, even though that particular cue (i.e., the CS-) was never itself paired with the US (Lissek et al., 2014). Thus, two potential explanations for the lack of association between Factor 2 ('distress susceptibility') and the measure of threat conditioning used in this study include (1) avoidance of the US and/or CS+, or (2) generalized conditioning to both the CS+ and the CS-, as opposed to weaker acquisition of the conditioned response. Therefore, further investigation is warranted regarding the relations of dispositional traits reflecting vulnerability to stress reactivity and emotion regulation difficulties to classical conditioning to threat-related cues.

4.3.3 Factor 3 ('heedless engagement') predicted enhanced sensitivity to incentive reward and weaker classical conditioning to a threat-related cue

Results from this study showed that Factor 3 ('heedless engagement'), primarily derived from absorption (openness to unusual experiences and elevated imaginative involvement) and sensation seeking (a tendency to engage in exciting activities involving risk), was a statistically significant predictor of greater sensitivity to incentive reward and lower susceptibility to classically conditioned responding to a threat-related cue. Concerning the relationship between Factor 1 ('heedless engagement') and incentive reward sensitivity, the combination of absorption and sensation seeking traits may reflect captivation and engagement with positive or attractive

environmental and mental (e.g., ideas, imagery) stimuli, consistent with previous findings of higher positive rumination exhibited by individuals with BSDs (Gruber, 2011).

With regard to conditioning, it is noteworthy that, while sensation seeking is evidently a measure of pursuing rewarding experiences at the potential expense of harm (Zuckerman et al., 1964), higher absorption traits may also be related to engaging in stimulating experiences with the potential for negative consequences (Sirois, 2014), such as problematic internet use (Cole & Hooley, 2013; Garris, Ahlers, & Driskell, 2002). Taken together, these findings are in line with previous research associating higher sensation seeking with less sensitivity to reward/loss magnitude (Bornovalova et al., 2009), which could be explained by the joint influences of enhanced sensitivity to incentive reward and insensitivity to cues predicting risk of negative consequences (as found in this study). This insensitivity to reward/loss magnitudes, as reported by Bornovalova et al. (2009), has also been reported in relation to BSDs, using similar measures of sensitivity to potential reward and loss (e.g., Pizzagalli et al., 2008). Thus, the finding that Factor 3 (‘heedless engagement’) predicted enhanced sensitivity to reward, and lower susceptibility to threat conditioning, may help explain this prioritization of rewarding or stimulating experiences over potential risks, as reported in individuals with BSDs (Mason, O'Sullivan, Montaldi, Bentall, & El-Deredy, 2014).

4.4 General discussion

In summary, the findings from this investigation highlight that specific bipolar traits in predominantly non-clinical samples may show unique associations with sensitivity to incentive reward and threat, as well as differences in susceptibility to forming classically conditioned responses to reward- and threat-related cues. In both studies, I found that stable hypomania-related traits (i.e., the GBI’s Hypomania subscale in Study 1 and the PCA variable labeled Factor

3 [‘heedless engagement’] in Study 2) significantly predicted sensitivity to incentive reward. While the association between hypomanic traits and incentive reward sensitivity is consistent with existing literature (e.g., Van Meter & Youngstrom, 2015), the association of Factor 3 (‘heedless engagement’) with incentive reward sensitivity is intriguing because it may characterize more specifically the psychological and behavioural correlates of stable incentive reward hypersensitivity among individuals with elevated bipolar traits. Thus, a tendency to be allured by fascinating, exciting, or mysterious stimuli and experiences, and engage in deeper and more elaborate ideation (Hoyle et al., 2002; Patrick et al., 2002), may describe aspects of the bipolar spectrum dispositional trait profile related to incentive reward hypersensitivity. Furthermore, this particular dimension was associated with weaker threat conditioning, a relationship that may be attributable to sensation seeking items on the BSSS that measure tolerance of risk in favour of exciting or novel experiences (Bornovalova et al., 2009).

Regarding depression-related traits, I found in Study 1 that scores on the GBI’s Depression subscale significantly predicted threat conditioning but not sensitivity to threat, whereas findings for Factor 2 (‘distress susceptibility’) showed the opposite pattern, such that higher scores for this factor (extracted from scales measuring emotion regulation difficulties and stress reactivity) predicted greater sensitivity to threat but was not related to threat conditioning. Two relevant studies, which included participants diagnosed with unipolar depression (Abler, Erk, Herwig, & Walter, 2007) or a BSD (Kim et al., 2007), showed that depressive symptom scores were significantly associated with conditioning to aversive cues and that poorer emotion regulation strategies were predictive of higher emotional responding (Abler et al., 2007; Kim et al., 2007). As these studies showed an association between depressive symptoms and conditioning to aversive cues, it may be beneficial in future studies to disentangle the relative

contributions of trait versus state depression to the association with threat conditioning. Thus, the results indicate that the Depression subscale and Factor 2 (‘distress susceptibility’) may be distinguishable by their differential associations with classical conditioning and sensitivity to harm, processes which may be important contributors to maladaptive levels of bipolar traits.

4.5 Limitations

A primary limitation of this study was the small sample in Study 1 which did not contribute adequate power to reliably detect smaller associations between some of the bipolar traits and sensitivity and conditioning variables. Despite this shortcoming, adequate power was achieved for two of four analyses conducted in Study 1 to detect effects with potentially meaningful implications. Another limitation is the correlational design used in both studies, which precluded the examination of the stability of bipolar traits in the samples. Moreover, participants in these studies did not complete state measures of bipolar depressive or hypomanic symptoms; thus, mood state at the time of testing was not controlled for. However, given that both studies were based on university student samples likely comprised mostly of young adults without a mental disorder, symptom levels may be expected to resemble those found in the general population. Another limitation of the current study was that several of the trait variables I included in the PCA to extract higher-order bipolar traits were not directly associated with a BSD diagnosis in previous studies but were instead significantly associated with other such personality trait scales demonstrating these relationships. Nevertheless, the face validity of the included scales suggested substantial convergence with the BSD-related scales, and consideration of the significant associations observed between the higher-order bipolar traits and behavioural measures of incentive reward and harm, which overlapped to an extent with the

bipolar symptom trait findings, suggest that meaningful higher-order bipolar traits were extracted from the PCA.

4.6 Future directions

Studies examining associations of bipolar traits with reward and threat sensitivity and conditioning in more representative participant samples are needed to assess how these psychological processes vary as a function of bipolar traits accounting for age, education, and other demographic characteristics. Further, additional research to clarify the independent and joint contributions of the candidate higher-order bipolar traits reflecting 'executive dyscontrol' (impulsiveness, low control, and low achievement) and 'heedless engagement' (absorption and sensation seeking) to lower tendencies to associate neutral and aversive cues would be beneficial, as this may be an example of combined traits that negatively influence functioning, such as discounting of delayed relative to immediate risks (Bornovalova et al., 2009).

It may be worthwhile to consider how the findings presented here could inform future research to identify specific psychological processes underlying or perpetuating maladaptive levels of bipolar traits, as they may be tractable targets for BSD prevention and intervention. For example, social and circadian rhythm therapies or behavioural activation may help attenuate levels of incentive reward sensitivity that are maladaptively high (Alloy, Nusslock, & Boland, 2015) or low (Craske, Meuret, Ritz, Treanor, & Dour, 2016), respectively. Furthermore, mindfulness-based treatments (Garland, Farb, R. Goldin, & Fredrickson, 2015; Roemer, Williston, & Rollins, 2015) and antidepressant medications (e.g., selective serotonin reuptake inhibitors; Anderson et al., 2007; Cools et al., 2005; Cools, Roberts, & Robbins, 2008; Muhtadie & Johnson, 2015) could improve toleration of distress for individuals more sensitive to potential negative consequences (e.g., threat of harm), and interventions informed by conditioning

principles could help to address maladaptive patterns of reward or aversive associative learning (Craske et al., 2008). Thus, the research presented here raises important questions about how sensitivity to reward and threat, and classical conditioning involving reward and threat, may help improve intervention selection and development to benefit individuals with, or at risk of, a BSD.

4.7 Conclusions

This investigation was undertaken to examine how self-reported bipolar traits in two university student samples of young adults related to reward and threat sensitivity and conditioning. These indices of sensitivity and learning were individually associated with measures of lifetime bipolar mood symptoms and higher-order bipolar trait variables extracted from measures of BSD-related dispositional traits. The findings suggest that reward and threat sensitivity and conditioning may be involved in the maintenance of stable bipolar traits and may inform future research of whether altering these processes could attenuate maladaptive levels of bipolar traits.

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Appendices

Appendix A

A.1 Supplementary Tables (Study 1)

Table A.1 Durbin-Watson test results indicating the degree of autocorrelation for the GBI's Hypomania, Depression, and Lability subscales independently predicting each dependent variable.

Independent variables	Durbin-Watson values from individual analyses			
	Incentive reward		Threat	
	Sensitivity	Conditioning	Sensitivity	Conditioning
Hypomania subscale	1.394	1.835	1.570	1.255
Depression subscale	1.562	2.032	1.731	1.470
Lability subscale	1.565	2.038	1.743	1.394

Appendix B

B.1 Supplementary Figures (Study 2)

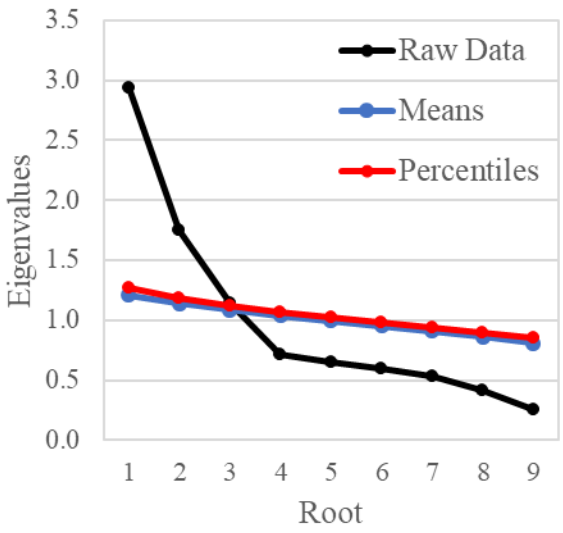

Figure B.1 Scree plot of eigenvalues produced using parallel analysis.

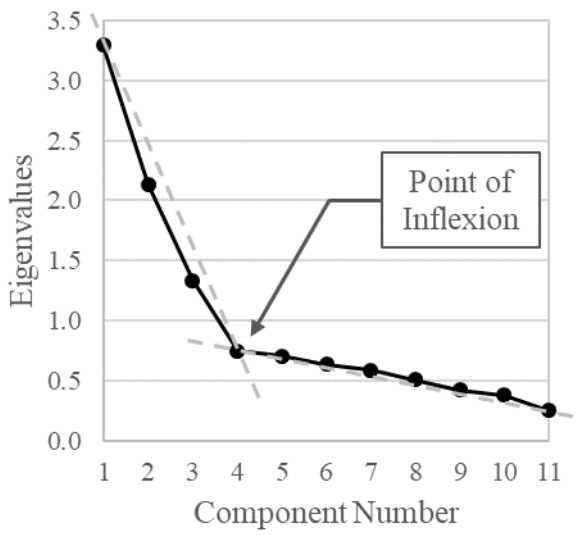

Figure B.2 Scree plot of eigenvalues produced using principal components analysis.