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Respiratory Sinus Arrhythmia and Emotion Regulation in Emerging Adults at Risk for Bipolar Disorder

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Defense Date: April 9th, 2018

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Abstract

Bipolar Disorder (BD) is a chronic and serious psychological disorder associated with difficulties regulating emotions. However, few studies have examined potential psychophysiological features of individuals at risk for BD and whether they may be associated with self-reported emotion regulation difficulties. The present investigation employed a multi-modal experimental approach to examine one putative psychophysiological indicator of emotion regulation – respiratory sinus arrhythmia (RSA) – in response to with emotion eliciting films and in association with and regulation strategies among emerging adults at either high risk (HR; \( n = 31 \)) or low risk (LR; \( n = 29 \)) for BD. Participants completed a baseline diagnostic visit and returned to the laboratory for a second visit to complete a standardized emotion elicitation film task where their physiological reactivity was assessed and self-reported trait emotion regulation strategies were measured. Results indicated that the HR group exhibited smaller decreases in RSA reactivity compared to the LR group across all films. No group differences emerged for either heart rate or skin conductance measures. Within the HR group, tonic RSA (i.e., during the resting baseline) was correlated with increased trait reappraisal. This investigation underscores the potential utility of physiological information in identifying individuals early on who may be at risk for mood disturbance.

Keywords: Mania; Bipolar Disorder; Risk; Respiratory Sinus Arrhythmia; Emotion Regulation; Rumination; Suppression; Reappraisal
Respiratory Sinus Arrhythmia and Emotion Regulation in Emerging Adults at Risk for Bipolar Disorder

Emotion regulation difficulties are common and central to psychopathological disorders (e.g. Gross & Jazaieri, 2014; Aldao, Gee, De Los Reyes, & Seager, 2016; Aldao, Nolen-Hoeksema, & Schweizer, 2010). To date, the literature has largely emphasized the dysregulation of negative emotions (e.g., du Pont, Welker, Gilbert, & Gruber, 2016). Although important, this leaves an empirical gap with respect to chronic and pervasive disorders, such as bipolar disorder (BD), that feature difficulties with, or dysregulation of, positive emotions (e.g., Gruber, 2011; Gruber, Dutra, Hay, & Devlin, 2014; Watson & Naragon-Gainey, 2010). Therefore, it is important to investigate disorders of positive emotion dysregulation such as BD. This is particularly important for emerging or young adults who are at risk for developing BD and where early identification of potential processes – such as emotion regulation -- could provide a window into preventative treatment (e.g., Correll et al., 2007; Miklowitz & Chang, 2008). The present investigation adopted a multi-modal experimental approach to investigate psychophysiological and self-reported emotion regulation processes among emerging adults at putative high or low risk for the development of BD.

Bipolar Disorder as an Important Target of Study

BD is clinically defined by a single lifetime episode of mania (i.e., bipolar I disorder or BD I) or hypomania (i.e., bipolar II disorder or BD II). Although a major depressive episode is not required for the diagnosis of BD I (though it is for the less severe variant of bipolar disorder type II), many individuals with BD I will experience a major depressive episode(s) within their lifetime (e.g., American Psychiatric Association, 2013; Judd et al., 2003). Mania is characterized
by abnormally high positive emotionality and associated symptoms including risk-taking, decreased need for sleep, and increased energy whereas depression is characterized by increased negative emotionality and associated symptoms including trouble sleeping (too much or too little), decreased energy and feelings of worthlessness. BD occurs in approximately 1% of the global population and is ranked as one of the leading causes of worldwide disability and mortality (e.g., Grande, Berk, Bimaher, & Vieta, 2016). Moreover, the total economic impact in 2009 of BD was 151 billion dollars in the United States alone (Dilsaver, 2011). This highlights the importance of identifying potential psychological processes that may confer vulnerability to this chronic and harmful disorder. Therefore, a better understanding of psychological processes that characterize, and confer risk for, BD is warranted.

**Emotion Regulation in BD**

Emotion related disturbances are a central feature among individuals diagnosed with BD. First the current literature on emotion reactivity is briefly reviewed as a foundation, followed by a review of emotion regulation in BD below.

To begin, emotion reactivity is defined as the change in emotional response from a baseline emotional state to an emotional response to an emotion-eliciting stimulus (Gross, Sutton, & Ketelaar, 1998). *Negative emotion reactivity* refers to emotional reactivity that encompasses negative emotion responding (e.g., subjective reports of negative affect, negative behavior and physiological correlates of negative emotion) and/or emotion responses to negatively valenced stimuli, such as a negative film. Negative emotion reactivity is most frequently associated with depressive symptoms in the literature. For example, a meta-analysis of emotion reactivity among adults with a history of major depressive disorder (or MDD; Bylsma, Morris, & Rottenberg, 2008) found that those with MDD tend to have increased emotion
reactivity to negatively valenced stimuli and decreased reactivity in response to positive stimuli. The results are more mixed when examining negative emotional reactivity in BD. For example, BD appears to be associated with increased negative reactivity when depressive symptoms are present only, suggesting it may be state-dependent and largely dependent on depressive mood symptoms severity. By contrast, positive emotion reactivity is defined as refers to emotional reactivity that includes pleasant subjective reports of positive affect, positive behavior and physiological correlates of positive mood. With respect to BD, increased positive emotion reactivity is viewed as a more trait-like or stable component of BD (e.g., Gruber, Dutra, Eidelman, Johnson, & Harvey, 2011; Johnson, Gruber, Eisner, & 2007). For example, individuals diagnosed with BD exhibit increased self-reported positive emotion when compared to controls, as well as in response to emotionally evocative films and photos, and in response to the possibility to earn rewards (Gruber, Kogan, & Murray, 2013). Similarly, adults at risk for BD also have heightened positive emotional responses to emotionally evocative stimuli, rewarding stimuli (e.g., Gruber et al., 2008), and during variable life events, regardless of emotional valence (how positive or negative a stimulus is; Gruber, Dutra, Hay, & Devlin, 2016). This excess positive emotional reactivity seen in individuals with BD is reflective of their emotion regulation difficulties. In sum, individuals with BD do not significantly differ in negative emotion reactivity (unless it is state-dependent and linked to depressive symptom severity) but do appear to exhibit increased positive emotion reactivity across contexts.

Emotion regulation has been defined as the set of processes that determine if an emotion is felt at any given time, what emotion isn’t felt, for how long, and to what magnitude (e.g., Gross & Thompson, 2007). With respect to emotion regulation, BD has been associated with difficulties successfully regulating emotions (e.g., Gruber, Harvey, & Gross, 2012; Heissler,
Kanske, Schonfelder, & Wessa, 2014). The focus here is on three key domains of emotion regulation strategies in BD including reappraisal, suppression, rumination which are described in greater detail below.

*Reappraisal* refers to the way an individual assesses a situation in order to change its emotional significance, and therefore manage the emotional response (Gross, 1998). Reappraisal is often considered to be an adaptive emotion regulation strategy. With respect to BD, It has been shown that individuals with BD self-report utilizing reappraisal more frequently than healthy control participants during viewing of emotion eliciting films (Gruber, Harvey, & Gross, 2012) as well as naturalistically during their own daily lives using an experience sampling paradigm (e.g., Gruber, Kogan, Mennin & Murray, 2013), yet report experiencing less success regulating their emotions in these same studies. These findings suggest that although BD may self-report engaging in a greater frequency or intensity of utilizing reappraisal, they may do so with less reported success in achieving their emotional goals, thus highlighting the emotion regulation difficulties characteristic of BD. At the same time, when instructed or cued to follow reappraisal instructions remitted adults with BD were able to use reappraisal to successfully down regulate emotion intensity (Gruber, Hay & Gross, 2014) suggesting the ability to use reappraisal when cued in intact.

*Suppression* can be defined as the action of dampening an emotional response in order to diminish the emotional experience of the situation (Gross & Thompson, 2007). It is considered to be a maladaptive emotion regulation strategy, in fact, it has been shown to be associated with stress levels, anxiety, depression and PTSD (e.g., Moore, Zoellner, & Mollenholt, 2008). With respect to BD, Gruber, Harvey, and Gross (2012) also found that individuals with BD employed suppression more frequently than the control group in response to viewing of emotion eliciting
films as well as in their daily lives using the same experience sampling paradigm (e.g., Gruber, Kogan, Mennin & Murray, 2013). This suggests that individuals with BD may also engage more frequently in maladaptive strategies such as suppression compared to healthy adults.

*Rumination* is defined as a response to stressors by repetitively and passively focusing on the causes and consequences of their mood and is directly opposite to making active efforts to distract from their mood (Nolen-Hoeksema, 1991). Rumination, often characterized as a maladaptive emotion regulation strategy, can be conceptualized as either negative (i.e., in response to a negative or depressive mood) or positive (i.e., in response to a positive or hypomanic/manic mood). A growing body of work suggests that adults with BD self-report greater positive and negative rumination (e.g., Gruber, Eidelman, Johnson, Smith, & Harvey, 2011; Johnson, McKenzie, & McMurrich, 2008; Kim, Yu, Lee, & Kim, 2012), both of which are described in more detail below. To begin, *negative rumination* is strongly correlated with major depressive disorder (MDD), with depressed mood, and has been shown to prolong and worsen depressive episodes (e.g., Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Nolen-Hoeksema, 1991). It has also been shown that negative rumination is longitudinally predictive of the onset, number, and duration of major depressive episodes in an originally non-clinical, young adult population (Robinson & Alloy, 2003). In reference to BD, individuals with BD self-report greater positive and negative rumination when compared to MDD and healthy control groups (e.g., Johnson, Mckenzie, & McMurrich, 2008; Gruber, Eidelman, Johnson, Smith, & Harvey, 2011) By contrast, *positive rumination* is associated with responses to positive affect, like during a manic or hypomanic episode (Johnson, Mckenzie, & McMurrich, 2008). When compared to healthy controls and individuals with MDD, individuals diagnosed with BD were the only participants who endorsed positive rumination (Johnson, Mckenzie, & McMurrich, 2008).
Therefore, it is not surprising that those diagnosed and at risk for BD display higher positive emotionality across all contexts (e.g., Gruber, Harvey, & Purcell, 2011).

Taken together, research on emotion regulation in BD has found that individuals with BD have difficulties regulating emotions, including greater spontaneous endorsement of maladaptive as well as adaptive strategies and report less success in regulating their emotions despite greater effort (e.g., Gruber, Harvey, & Gross, 2012). In other words, those diagnosed with BD attempt to employ a wide array of emotion regulation strategies in order to down-regulate these elevated levels of positive emotions, but the strategies often end up being ineffective (Gruber, Harvey, and Gross, 2012). However, it has been shown that emotion regulation mechanisms might still be intact in individuals with BD, because when they are instructed to employ emotion regulation strategies, like reappraisal or distraction, they do not differ from the control group. This suggests that the emotion regulation difficulties seen in individuals with BD are with spontaneous or automatic emotion regulation (Hay, Sheppes, Gross, & Gruber, 2015). Despite these advances in understanding emotion regulation in BD, few studies have specifically examined emotion regulation strategies – and their potential psychophysiological correlates – among emerging adults at risk for, but not yet diagnosed with, BD.

**Autonomic Nervous System as a Window into Understanding Emotion Regulation in BD**

Emotional processes involve as a multi-modal response system that critically includes coordinated responding of the autonomic nervous system (e.g., Levenson, 2003). There are many benefits to studying physiological data as a window into investigating emotion dysregulation in BD. First, it allows researchers to examine emotional responses objectively, outside of subjective self-report measures. Also, psychophysiological data can validate theories of emotional constructs by backing them up with physiological correlates of common behavioral responses.
Lastly, and an important aim for the current study, investigation of psychophysiological responses related to emotion reactivity could elucidate endophenotypes (biological markers that are inherited with a certain disorder but are not specific symptoms of that disorder) that are related to a certain disorder, and connect them to self-report measures, which could reveal an objective measure of risk for developing that disorder (Santerre & Allen, 2007). Relevant background information about the autonomic nervous system will be described below.

The autonomic nervous system (ANS) is split into two major divisions: the sympathetic nervous system (SNS), which is responsible for motivating the body to respond to a perceived threat, and the parasympathetic nervous system (PNS), which is responsible for regulating the body’s homeostasis (balance). Activity of the vagus nerve reflects direct activity of the PNS as it is uniquely and specifically responsible for the PNS control of heart rate and respiration rate. According to Porges (1997), the vagus nerve can be divided into two asymmetric main branches: the ventral vagal complex (VVC) which originates in the Nucleus Ambiguus (NA) and the dorsal vagal complex (DVC) which originates in the Dorsal Motor Nucleus (DMN). The focus here will be on the VVC (or NA fibers), for the purpose of this study, as it is the branch most closely associated with emotion. The NA fibers are myelinated (insulated by a fatty sheath, making information transferred through them faster and more efficient), meaning that they can exert their inhibition dynamically so that they can respond to rapid shifts in the environment with parallel shifts in heart rate and respiration. Activity of PNS is frequently quantified and referred to as respiratory sinus arrhythmia (RSA). RSA values represent the difference between the quickening of heart rate during inspiration and the deceleration of heart rate during exhalation (Porges, 1997, 2007).
Importantly, recent research has linked activity of the PNS to emotion regulation (e.g., Fox, 2008; Porges, 1995). RSA is a measurement of NA vagal control of heart rate and respiration rate, and this control can be changed dynamically in response to changes in the environment, which is reflected in changing emotions. Therefore, it stands to reason that the successful employment of this system can be described as emotion regulation—and even further, that the dysfunction of this system could result in faulty emotion regulation (Porges, 1994). It has been demonstrated that the increased employment of the specific emotion regulation strategies of suppression and reappraisal was reflected in greater phasic RSA reactivity, or RSA values in reaction to stimuli (Butler, Wilhelm, & Gross, 2006). In addition, healthy adults with higher baseline RSA values, when compared to individuals with lower baseline RSA values, reported using more reappraisal strategies in response to both positive and negative stimuli (Volokhov & Demaree, 2010), suggesting that RSA is important to the use of adaptive emotion regulation strategies. In addition, higher RSA is thought to be associated with greater positive emotionality (e.g., Porges, 1997, 2007; Thayer & Lane, 2000; Oveis, Cohen, Gruber, Shiota, Haidt, & Keltner, 2009) and resilience to stressors (e.g., Butler, Wilhelm, & Gross, 2006). Yet more recent work suggests that the association between RSA and positive emotionality may not be linear, but may be more accurately represented as a quadratic relationship whereby higher RSA levels beyond a threshold may be associated with problematic positive emotionality (e.g., Kogan, Oveis, Carr, Gruber, Mauss, Shallcross, Impett, van der Lowe, Hui, Cheng, & Keltner, 2014; Duarte & Pinto-Gouveia, 2017). Although this work did not focus on BD risk specifically, it provides a useful conceptual model for individual differences in RSA and positive emotionality that can be tested among clinical populations such as young adult sat risk for BD.
With respect to BD, individuals diagnosed with, or at risk for, BD exhibit elevated tonic RSA (resting or baseline RSA) and positive emotionality across stimuli regardless of the specific emotional valence (Gruber, Harvey, & Purcell, 2011). This suggests that BD diagnosis may be associated with increased RSA levels at rest. Individuals with BD have also been shown to have greater RSA in response to positive emotionally evocative stimuli (Gruber, Dutra, Eidelberg, Johnson, & Harvey, 2011). This suggests that BD diagnosis may also be associated with increased RSA reactivity levels. One suggests that this pattern may also be evident among individuals who are at high risk for developing BD (Gruber, Johnson, Oveis, & Keltner, 2008), though replication studies among emerging adults are needed.

The Present Investigation

The present investigation examined the relationship between RSA and emotion regulation difficulties among emerging adults at putative high or low BD risk using an affective science approach. Participants completed a baseline diagnosis assessment followed by a standardized emotion elicitation task while physiological data was continuously recorded, followed by self-reported emotion regulation strategy questionnaires. This enabled the examination of two main study aims.

Aim 1. Group differences in RSA between high risk (HR) and low risk (LR) BD groups. The first aim examined group-related differences in RSA among emerging adults at high risk (HR) and low risk (LR) for BD. The current study hypothesized that the HR group would exhibit elevated “tonic” RSA (i.e., increased RSA scores at rest) during a five-minute resting baseline (Hypothesis 1a) and elevated “phasic” RSA (i.e., RSA reactivity) in response to emotionally evocative films (2 positive, 1 neutral, and 1 negative) (Hypothesis 1b) when compared to the LR group. It is important to note that elevated phasic RSA reactivity could be
reflected in larger positive RSA reactivity scores, indicating greater increases, or smaller negative RSA reactivity scores, indicating smaller decreases.

These hypotheses were based on preliminary literature that demonstrates that individuals who are risk for developing BD (Gruber, Johnson, Oveis, & Keltner, 2008) and those who have been diagnosed with BD (Gruber, Dutra, Eidelman, Johnson, & Harvey, 2011) exhibit elevated RSA.

**Aim 2. Associations between RSA and emotion regulation strategies in the HR group.** The second aim examined associations between tonic and phasic RSA with self-reported concurrent emotion regulation strategies (i.e., positive and negative rumination, reappraisal, and suppression) specifically within the HR group in order to examine the potential associations between emotion regulation processes and physiological markers among a clinically at-risk BD group. On the one hand, it was hypothesized that elevated tonic RSA during a resting baseline (**Hypothesis 2a**) and elevated phasic RSA in response to emotionally evocative film clips (**Hypothesis 2b**) would be associated with increased general emotion regulation efforts -- as measured by self-reported positive and negative rumination, suppression, and reappraisal use -- suggesting general associations between RSA and emotion regulation in those at high risk for BD. This was based on evidence that individuals diagnosed with BD, compared to a non-psychiatric control group, employed a greater frequency of self-reported emotion regulation strategies (Gruber, Harvey, & Gross, 2012) and greater self-reported levels of positive and negative rumination (Gruber et al., 2011), despite unsuccessful outcomes of those regulation efforts. Also, individuals diagnosed with BD exhibit elevated levels of RSA (e.g., Gruber et al., 2008; Gruber, Harvey & Purcell, 2011). Therefore, it would follow from this perspective that RSA would be associated with increased emotion regulation efforts in the HR group.
On the other hand, it has been demonstrated that RSA is a strategic response that is employed when emotions need to be regulated (e.g., Gross, 2011; Butler, Wilhelm, & Gross, 2006). Furthermore, when compared to baseline or neutral levels, RSA decreases in response to negative stimuli (e.g., Gentzler, Santucci, Kovacs, & Fox, 2009) and increases in response to positive stimuli (e.g., Gruber et al., 2008), suggesting specific links with emotionally evocative stimuli. Further, individuals diagnosed with BD have difficulties with emotion regulation (e.g., Gruber, Harvey, & Purcell, 2011). Therefore, the current investigation also tested the hypothesis that elevated phasic RSA in response to emotionally evocative film clips would be associated with emotion regulation difficulties and general regulation strategy use (Hypothesis 2c) but not during a resting baseline (Hypothesis 2d). Supportive evidence would indicate specific associations between phasic but not tonic RSA such that the HR group should display these emotion regulation difficulties primarily in the context of the emotion eliciting film clips.

**Methods**

**Participants**

Participants were recruited as part of a larger and ongoing study on emotion and mood in young adults (University of Colorado Boulder IRB #15-0247). Participants included a subset of 60 adults enrolled in the ongoing study between the ages of 18-25 recruited via posted flyers in the public and approved areas in the surrounding Boulder community. Undergraduate students at the University of Colorado Boulder were also invited to participate the study in exchange for SONA course credit. See Table 1 for demographic and clinical characteristics.

Inclusion criteria for the high risk (or HR; n = 31) group included scoring above a previously validated cutoff score \( \geq 33 \) on the Hypomanic Personality Scale (HPS; Eckblad &
Chapman, 1986), no current or lifetime diagnoses of mania or hypomania, and no current or lifetime diagnosis of psychotic disorders. Inclusion criteria for the low risk (or LR; $n = 29$) group was scoring below a previously validated HPS cutoff score of $\leq 21$, no current or lifetime diagnoses of any DSM-5 Axis I disorders (i.e., anxiety disorders, major depression, mania/hypomania, dysthymia, schizophrenia, schizoaffective disorder, substance abuse/dependence, eating disorders, hypochondriasis, pain disorder, or adjustment disorders). Exclusion criteria for both groups included current suicidality, substance use disorder within the last 6 months, self-reported history of severe brain trauma, stroke, neurological disease, brain tumors (and surgery), severe medical illness (such as HIV/AIDS, autoimmune disorder, blindness, or cardiovascular disease; or endocrine disorders like Cushing’s disease or thyroid disorder), currently pregnant, or were otherwise unable to follow study procedures.

**Measures**

**Mania Risk.** The Hypomanic Personality Scale (HPS; Eckblad & Chapman, 1986) is a 48-item true or false self-report scale used to assess BD risk. Sample items include “I am frequently so ‘hyper’ that my friends kiddingly ask me what drug I’m taking” whereby higher scores reflected greater levels of risk (or vulnerability) for hypomania. Specifically, previous work indicates that scores above the high-risk threshold score prospectively predict the onset of mania at a 13-year follow-up time point (Kwapil, Miller, Zinser, Chapman, Chapman, & Eckblad, 2000). HPS Scores were used to determine group status using previously established clinical cutoffs noted above (e.g., Ekblad & Chapman, 1986). Internal consistency for the HPS in the present study was good ($\alpha = 0.93$).

**Diagnostic Interview.** The Structured Clinical Interview for the DSM-5 (SCID-5; American Psychiatric Association, 2013) was administered by a trained researcher and was used
to determine the presence of any current or lifetime Axis I diagnoses. As such, it was used to additionally confirm eligibility criteria for the HR or LR group specified above.

**Depressive Symptoms.** The Beck Depression Inventory-Short Form (BDI-SF; Beck & Beck, 1972) is a 13-item self-report measure assessing current levels of depressive symptoms. Sample items include “I am so sad or unhappy that I can’t stand it” and “I feel that the future is hopeless and that things cannot improve,” whereby scores below a 9 reflect no depressive symptoms and scores above a 20 reflect moderate to severe depression. Internal consistency in the present study was good ($\alpha = 0.86$).

**Mania Symptoms.** The Altman Self-Rating Mania Scale (ASRM; Altman, Hedeker, Peterson, & Davis, 1997) is a 5-item self-report measure assessed current levels of manic symptoms. Sample items include, “I feel extremely self-confident all of the time” and “I feel happier or more cheerful than usual all the time,” whereby higher scores reflect greater levels of current manic symptoms (scores greater than or equal to 14 indicate clinically significant symptoms). Internal consistency in the present study was good ($\alpha = 0.83$).

**Emotion Regulation Questionnaires**

**Positive Rumination.** The Responses to Positive Affect (RPA) questionnaire was used to measure trait positive rumination (Feldman, Joormann, & Johnson, 2008). The RPA is a 17-item questionnaire rated on a 1 (almost never) to 4 (almost always) scale. There are three subscales including dampening (i.e., efforts to diminish the positive mood state; “think about things that could go wrong”), self-focused positive rumination (i.e., think positively about oneself in response to a positive mood state; “think about how proud you are of yourself”), and emotion-focused positive rumination (i.e., focus on current positive emotions when in a positive mood state; “savour this moment”). Higher scores on the different subscales reflected elevated positive
rumination. Specifically, on the dampening subscale, higher scores reflected more efforts to decrease positive mood; on the self-focused and emotion-focused subscales they reflected higher self-focused and emotion-focused positive rumination, respectively. Internal consistency in the present study was good for the RPA total score ($\alpha = 0.83$), RPA dampen subscale ($\alpha = 0.80$), RPA emotion-focused subscale ($\alpha = 0.80$), and RPA self-focused subscale ($\alpha = 0.73$).

**Negative Rumination.** The Ruminative Style Questionnaire (RSQ) was used to measure trait negative rumination (Nolen-Hoeksema & Morrow, 1991). The RSQ is a 4-item questionnaire rated on a 1 (almost never) to 4 (almost always) scale. Sample items include, “I think ‘What am I doing to deserve this?’” and “I think ‘Why do I have problems other people don’t have?’” Higher scores reflected greater levels of negative rumination. Internal consistency in the present study was good ($\alpha = 0.77$).

**Reappraisal and Suppression.** Trait reappraisal and suppression were measured using previously published items in BD populations (adapted from: Gruber, Kogan, Mennin, & Murray, 2013). A single item measured reappraisal (“Thought about my feelings in a different way”) and another single item measured suppression (“Not shown my emotions”). Items were rated on a 1 (never) to 5 (all the time) scale, where higher values indicated greater use of a particular emotion regulation strategy.

**Physiological Measures**

Physiological data were collected from the participants during the resting baseline and during each film and a pre-film baseline. The protocol described below for acquisition and processing of psychophysiological data is adapted from the laboratory’s general protocols to ensure standardized description of common methods used across lab studies (e.g., Gruber, Mennin, Fields, Purcell, & Murray, 2015; Gilbert & Gruber, 2014; Dutra, Reeves, Mauss, &
Gruber, 2014; Kang & Gruber, 2013). A Mindware multi-channel chassis device (BioNex 50-3711-08 Mindware Technologies, Gahanna, OH) was utilized to continuously record physiological data at 100 kz. The data were collected and analyzed with Mindware v3.0 software. Physiology data were synchronized automatically with the onset of each emotional film task via a transistor-transistor Logic (TTL) digital signal. Artifacts or recording errors were corrected offline following an in-house detailed laboratory protocol for physiological artifact detection and cleaning.

**Respiratory Sinus Arrhythmia (RSA).** Respiratory sinus arrhythmia was measured as a noninvasive index of PNS activity. It was derived from a power spectral analysis of high frequency heart rate variability (0.12-0.14 Hz; Berntson et al., 1997). Specifically, the ECG signal was digitized (1,000 Hz), an IBI series was derived, and artifacts were identified and edited (Berntson et al., 1990). A 4 Hz (250 msec) time series was then derived by interpolation (Berntson, Quigely & Cacioppo, 1995), and the series was detrended by the second order polynomial to minimize non-stationaries in the data (Litvack et al., 1995). The residual series was then tapered with a Hamming window and a Fast-Fourier Transform (FFT) was applied to the resampled R-R intervals using Mindware HRV Module (ver. 3.0, Mindware Technologies, Inc., Gahanna, OH). RSA was quantified as the integral power within the respiratory frequency band (0.12 to 0.40 Hz), which is equal to the statistical variance of the time series within that band.

**Heart Rate (HRT).** HRT was included as a comparison measure of general cardiovascular arousal. ECG recordings were obtained with two pre-jelled Ag-AgCl snap disposable vinyl electrodes placed in a modified Lead II configuration. A MindWare ECG amplifier, using a bandpass filter of 0.5Hz to 100Hz (high cutoff with a 60hz notch filter), was
used and the ECG signal was converted to R-wave intervals (interbeat intervals [IBIs]), which were converted to beats per minute.

**Absolute Skin Conductance Level (SCL).** SCL was included as a comparison measure of sympathetic nervous system activity (e.g., Dawson, Schell, & Filion, 2000; Demaree, Schmeichel, Robinson, & Everhart, 2004). Electrodermal activity recordings were obtained using a Mindware GSC100C amplifier maintaining a constant voltage of 0.5v between two 38.1x25.4mm Ag-AgCl pre-gelled isotonic (1% Cl) electrodes placed on the thenar and hypothenar eminence of participants’ non-dominant palm. SCL mean level (range 2-20 mS) was calculated separately for each experimental period.

**Resting Baseline Task**

Following the physiology hookup, participants will be asked to remain seated in their chair for 5 minutes while a resting physiology baseline is acquired. During the collection of this data, participants were fixated on a blank computer screen. The time to complete this task was approximately 5 minutes.

**Emotion Film Task**

The emotion film task was based on previously validated tasks used in BD research within the same research laboratory (e.g., Gruber, Harvey & Purcell, 2011; Gruber, Johnson, Oveis, & Keltner, 2008). Before each film, participants were instructed to sit quietly for 60s and report their current emotion experience at the end of this pre-film baseline. Specifically, the neutral film clip depicted a scene of a man and woman doing household tasks taken from the film *Stranger than Paradise* (94s), was presented first.

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1 Other self-report measures unrelated to the present investigation were collected at the end of the resting baseline. After the 5-minute period was complete, participants were prompted to fill out a brief mood questionnaire indicating the intensity of different emotions they were feeling at that moment (the modified Differential Emotions Scale [mDES]; Cohn, Fredrickson, Brown, Mikels, & Conway, 2009).
The happy film depicted figure skater Sarah Hughes winning the Olympic gold medal (150s). The amusing film depicted a man accidentally leaving his microphone on and projecting to a large audience while using the restroom (139s). The sad film depicted a scene from the film *The Champ*, where a young boy cries over the death of his father (170s). The present film focused specifically on the physiological responses during films

**Procedure**

The procedure consisted of three parts. First, participants completed a pre-screening measure. Second, they completed a baseline clinical interview and questionnaire visit. Third, they returned to the lab to complete the resting baseline task, emotion film task, and self-report questionnaires (and other measures separate from the present investigation). Each of these three parts of the study procedure are described in greater detail below.

**Part 1: Prescreening.** First, participants were pre-screened for potential eligibility via a prescreening survey using the HPS through the Qualtrics program, and then were screened over the phone to confirm potential eligibility (with the exception of the undergraduates participating for class credit, who only completed the online prescreening survey).

**Part 2: Initial lab visit.** Potentially eligible participants completed an approximately 2-hour visit consisting of a baseline diagnostic interview (SCID-5) to determine the presence of any current or lifetime Axis I disorders. Potential participants completed a series of other clinical online questionnaires not relevant to the present investigation. Participants were compensated $10/hour to the nearest 15 minutes (or 1 SONA credit per 30 min) for the 2-hour clinical interview. Parking fees were reimbursed as needed.

**Part 3: Experimental laboratory visit.** If participants were eligible following the initial lab visit, they were invited to return to the laboratory to complete a broader variety of laboratory
tasks, including the emotion film task and emotion regulation and current symptom measures (in addition to other tasks and questionnaires that were not included in the present investigation were recorded). Participants were compensated and debriefed at the end of the study visit if they did not plan to continue in the follow-up portion of the broader protocol.

**Results**

**Preliminary Analyses**

Demographic characteristics of the HR and LR groups were first analyzed. There was a significant difference in age between the LR ($M = 22.14, SD = 1.98$) and HR ($M = 20.13, SD = 1.93$) groups, $t(58) = 3.98, p = 0.00$. Then, bivariate correlations were run between age and each of the primary dependent variables (i.e. all physiology variables and emotion regulation measures). Age was significantly correlated with HRT reactivity to the neutral film ($r = 0.34, p = 0.004$) and SCL reactivity to the sad film ($r = 0.28, p = 0.040$), so all analyses ran with either HRT or SCL included age as a covariate. There were no other significant differences between the groups for gender (LR = 65.5% female, HR = 63.3% female) and ethnicity (LR = 65.5% Caucasian, HR = 73.3% Caucasian).

Second, group differences on the clinical characteristics were examined. Three separate univariate ANCOVAs were run to elucidate the group differences on the clinical characteristics measures. Not surprisingly, the HR and LR groups differed on the HPS, ASRM, and BDI-SF. More specifically, the LR group scored lower on the HPS than the HR group given the recruitment strategy, $F(1,58) = 415.28, p < 0.00$; the BDI-SF scores, $F(1,58) = 5.25, p = 0.030$; and the ASRM scores, $F(1,58) = 7.61, p = 0.008$. 
Third, seven separate univariate ANCOVAs were conducted to examine potential differences on the different emotion regulation measures, with BDI-SF and ASRM scores as covariates. Results indicated that the HR group reported increased overall positive rumination, \( F(1,56) = 7.23, p = 0.009 \); self-focused positive rumination, \( F(1,56) = 4.43, p = 0.04 \); and emotion-focused rumination, \( F(1,56) = 5.78, p = 0.02 \) compared to the LR group. Groups did not differ on the positive rumination dampen subscale, \( F(1,56) = 1.66, p = 0.20 \); the RSQ, \( F(1,56) = 0.65, p = 0.42 \); Reappraisal, \( F(1,56) = 2.33, p = 0.13 \); or Suppression items, \( F(1,56) = 0.23, p = 0.64 \). See Table 1 for means and standard deviations.

**Main Analyses**

For Aim 1a, three separate (RSA, HRT, SCL) univariate one-way analyses of covariance (ANCOVAs) were conducted with clinical symptoms as covariates with Group as the between subjects factor for the resting baseline data. For Aim 1b, three separate 4 (Film: Neutral, Happy, Amusement, Sad) x 2 (Group: HR, LR) repeated-measures ANCOVAs were conducted separately for each of the three physiological variables (HRT, RSA, and SCL), with current depressive and manic symptoms included as covariates to examine the unique contribution of BD risk independent of current symptom severity (e.g., Gruber & Johnson, 2009). Physiological reactivity scores were used which were computed by subtracting pre-film baseline scores from film scores (e.g., Gruber, Purcell, & Harvey, 2011; Rogosa & Willett, 1983). A Greenhouse-Geisser correction was employed when assumptions for sphericity were not met and adjusted \( F \) and \( p \) values are reported. Effect sizes are represented as partial eta squared (\( \eta^2_p \)) and all reported \( p \) values are two-tailed.

For Aim 2, partial bivariate correlations were run between physiological measures that differentiated the groups in Aim 1 (i.e., RSA) with the seven emotion regulation measures (RPA
total score, RPA emotion, RPA dampen, RPA self, and RSQ total score, Reappraisal, and Suppression) while controlling for BDI-SF and ASRM scores.

**Aim 1: Group differences in RSA between HR and LR groups**

**Aim 1a: Group RSA differences during a resting baseline.** There were no significant differences between the LR and HR groups on RSA, $F(1, 54) = 0.04, p = 0.85$; HRT, $F(1, 53) = 0.15, p = 0.70$; and SCL, $F(1, 50) = 0.94, p = 0.34$ during the resting baseline.

**Aim 1b: Group RSA reactivity differences during the 4 films.** For RSA, there was no main effect of Film, $F(3, 165) = 0.27, p = 0.84, \eta^2_p = 0.005$. There was a significant main effect for Group, $F(1, 55) = 4.43, p = 0.04, \eta^2_p = 0.008$, indicating that the LR group ($M = -0.488, SE = 0.102$) had smaller decreases in RSA across the films than the HR group ($M = -0.164, SE = 0.098$). In other words, the LR group showed greater reductions in RSA in response to the emotional films compared to the HR group who, hence, had higher RSA reactivity scores across films compared to the LR group. The Group x Film interaction was not significant, $F(3, 165) = 0.495, p = 0.69, \eta^2_p = 0.009$. See Figure 1 for means and standard errors of RSA reactivity$^2$. For HRT, there was a significant main effect of Film, $F(3, 165) = 2.94, p = 0.04, \eta^2_p = 0.05$. Follow-up pairwise comparisons indicated that the neutral film ($M = -0.30, SD = 2.90$) was higher in HRT compared to the amusement film ($M = -3.19, SD = 4.24$), $p < 0.00$, and compared to the sad film ($M = -3.53, SD = 3.95$), $p < 0.000$. HRT was also greater in higher in response to the happy film ($M = -1.65, SD = 3.47$) than the amusement film, $p = 0.003$, and in response to the sad film, $p = 0.001$. There was not a significant main effect for Group, $F(1, 55) =

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$^2$ Note that mean RSA levels across films were examined (i.e., prior to reactivity scores being computed) and no group differences were observed (HR: $M=6.42, SD=1.05$; LR: $M=6.33, SD=1.21$); meaning that the observed group differences are truly in phasic levels of RSA$^2$. In addition, the groups did not significantly differ on cardiovascular (HRT) or sympathetic (SCL) physiological indices, which further solidifies the importance of RSA (specifically phasic) as a psychophysiological marker of BD risk.
0.53, \( p = 0.471, \eta_p^2 = 0.009 \), which indicated that there was no difference between the LR group (\( M = -1.95, SE = 0.61 \)) and HR group (\( M = -2.62, SE = 0.58 \)) on HRT. The Film x Group interaction was not significant, \( F(3,165) = 0.495, p = 0.69, \eta_p^2 = 0.009 \). It should be noted that the Film x Age interaction was significant for HRT, \( F(3,165) = 3.00, p = 0.03, \eta_p^2 = 0.05 \).

For SCL the assumption of sphericity was violated, \( \chi^2(5) = 13.27, p = 0.86 \), so the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity. There was a significant main effect of Film, \( F(2.57,123.40), p = 0.02, \eta_p^2 = 0.07 \). For the Film main effect, follow-up pairwise comparisons indicated that the neutral film (\( M = 0.33, SD = 0.74 \)) was significantly higher in SCL when compared to the sad film (\( M = -0.14, SD = 1.10 \)), \( p = 0.004 \). The happy film (\( M = 0.15, SD = 0.64 \)) was significantly higher in SCL when compared to the sad film, \( p = 0.03 \). There was not a significant main effect for Group, \( F(1, 48) =1.85, p = 0.18, \eta_p^2 = 0.04 \), which indicated that there was no difference between the LR group (\( M = -0.01, SE = 0.11 \)) and the HR (\( M = 0.22, SE = 0.11 \)) group on SCL. The Film x Group interaction was not significant, \( F(2.57,123.34) = 2.16, p = 0.11, \eta_p^2 = 0.04 \). It should be noted that the Film x Age interaction was significant for SCL as well, \( F(2.57,123.40) = 2.997, p = 0.04, \eta_p^2 = 0.06 \).

**Aim 2: Associations between RSA and emotion regulation strategies within the HR group**

**Emotion films.** Because there was no significant Group x Film effect found for RSA in aim 1 suggesting different reactivity for any one particular film, but there was a Group main effect for RSA across all films, these subsequent analyses focused on RSA reactivity scores were averaged across all films. Partial correlations were run, between RSA and the emotion regulation questionnaire measures, while controlling for BDI-SF and ASRM scores. Results suggested there were no significant correlations. Though there was a non-significant negative trend between RSA reactivity and trait suppression in the HR group (\( r = -0.33, p = 0.078 \)).
Resting baseline. Similar to the analyses above, partial correlations were run between tonic RSA and the emotion regulation measures, while controlling for BDI-SF and ASRM scores. As indicated in Table 2, results suggested a positive correlation between tonic RSA and trait reappraisal ($r = 0.386$, $p = 0.042$).

Discussion

Bipolar Disorder (BD) is a chronic and serious psychological disorder associated with difficulties regulating emotions. However, few studies have examined potential psychophysiological features of individuals at risk for BD and whether they may be associated with self-reported emotion regulation difficulties. The present investigation employed a multi-modal experimental approach to examine a putative psychophysiological indicator of emotion regulation – RSA – in response to with emotion eliciting films and in association with and regulation strategies among emerging adults at either high risk or low risk) for BD.

Aim 1: Group differences in RSA between HR and LR groups

The first aim examined whether the HR and LR groups differed on their phasic (i.e. in response to emotion-eliciting films) and tonic (i.e. during a resting baseline period) RSA levels. This was based on work suggesting that those with BD (Gruber, Dutra, Eidelman, Johnson, & Harvey, 2011) and those at risk for BD (Gruber, Johnson, Oveis, & Keltner, 2008) exhibit higher RSA levels than healthy controls. Results indicated that the HR group exhibited smaller decreases in RSA (i.e., smaller negative change scores) across all films compared to the LR group. Both groups did not differ on any other physiological response variables, including cardiovascular and sympathetic reactivity. There are two possible interpretations of this finding with respect to whether this provides supportive evidence for the original hypothesis for Aim 1. On the one hand, these results are consistent with a general model of elevated RSA reactivity
levels in BD. Specifically, previous work has found that remitted patients with BD also exhibit smaller decreases in RSA across emotion-eliciting films compared to the non-clinical control group (e.g., Gruber, Harvey & Purcell, 2011). This finding has been discussed within the BD literature as consistent with a broader model of elevated RSA reactivity levels in BD. Put another way, those high at risk for BD are less likely to decrease RSA levels compared to the low risk group in the presence of emotional stimuli as compared to non-clinical and low BD risk populations. This possible interpretation would be consistent with the perspective that the results for Aim 1 supported the study hypotheses.

On the other hand, a second alternative perspective would suggest that smaller decreases in RSA reactivity might be reflective of general autonomic rigidity, a phenomenon reported among individuals with general anxiety disorder (GAD) who exhibited less autonomic (both parasympathetic and sympathetic) reactivity in response to stressful situations (e.g., Hoehn-Saric, McLeod, & Zimmerli, 1989; Borkovec, Ray, & Stoher, 1998). Put another way, the smaller decreases in RSA seen in the HR group might suggest less vagal withdrawal which reflects less physiological and emotional flexibility. Indeed, vagal withdrawal/flexibility is associated with more adaptive emotion regulation strategy use, and less depression risk (Tonhaizerova, Mestanik, Mestanikova, & Jurko, 2016; Gentzler, Santucci, Kovacs, & Fox, 2009). At the same time, the present study findings did not suggest overall autonomic rigidity or constricted RSA reactivity as results only suggested smaller reactivity scores in one direction (i.e. smaller RSA decreases, and not smaller RSA increases as well). Future work is needed to provide additional evidence to support an autonomic rigidity perspective among emerging adults at risk for BD. Either way, these findings are consistent with the perspective that RSA may meaningfully
differentiate high and low BD risk groups and thus that there may be an optimal level of RSA in regard to emotional functioning (Kogan, et al., 2014).

The second part of Aim 1 predicted increased tonic RSA in the BD group. This was based on literature suggesting that individuals at risk for BD appear to exhibit greater tonic RSA (Gruber, Johnson, Oveis, & Keltner, 2008). Inconsistent with this prediction, the HR group did not exhibit greater tonic RSA compared to the LR group. This could have been because tonic RSA levels are more consistent with within-group differences than between-group, which is supported in the findings from aim 2.

**Aim 2: Associations between RSA and emotion regulation strategies in the HR group**

The second aim examined whether phasic and/or tonic RSA levels, within the HR group only, would be associated with emotion regulation strategy use. This was based on work suggesting that individuals with BD employ emotion regulation strategies more frequently, but with less success (Gruber, Harvey, & Gross, 2012) and self-report greater levels of positive and negative rumination (Gruber et al., 2011). As well as evidence of greater phasic and tonic RSA levels in individuals with and at risk for BD (Gruber, Dutra, Eidelman, Johnson, & Harvey, 2011; Gruber, Johnson, Oveis, & Keltner, 2008). Based upon the observed group differences in RSA levels found in Aim 1, the present investigation specifically examined the relationship between RSA reactivity averaged across films and tonic RSA with self-reported motion regulation strategies (i.e., positive and negative rumination, reappraisal, and suppression) within the HR group.

Surprisingly, and not consistent with our predictions, there were no significant associations between RSA reactivity and self-reported emotion regulation strategies. However,
there was one correlation that did not reach statistical significance but is interesting to note; namely, that RSA reactivity was marginally correlated with decreased suppression ($r = -0.33, p = 0.078$), meaning that higher RSA levels were trending with lower levels of suppression. Although this was not technically significant and should be interpreted with caution, it is interesting to note that one such finding is consistent with literature reporting higher RSA reactivity is predictive of more adaptive emotion regulation strategy use (Tonhaizerova, Mestanik, Mestanikova, & Jurko, 2016; Gentzler, Santucci, Kovacs, & Fox, 2009). Future work should examine whether those at risk for BD may be less likely to employ suppression, a maladaptive emotion regulation strategy, as a way of fostering more adaptive or healthy emotion regulation.

Additionally, it was found that RSA during the resting baseline was significantly positively correlated with reappraisal, but no other emotion regulation strategies. Meaning that higher tonic RSA was significantly associated with greater reappraisal strategy use. This finding is consistent with literature linking RSA with adaptive emotion regulation strategy employment (Butler, Wilhelm, & Gross, 2006; Tonhaizerova, Mestanik, Mestanikova, & Jurko, 2016).

**Limitations and Future Directions**

The present investigation should be interpreted within the confines of several limitations. First, the emotion regulation measures were trait-based (i.e., which strategies the participants employed generally in their everyday lives) while RSA was a state-based measure (i.e., phasic or in the moment). This temporal misalignment could have been the reason for so few associations between phasic RSA and emotion regulation strategies. Future work towards developing more state-based emotion regulation measures would be important for truly unpacking the link between phasic RSA and emotion regulatory efforts in the moment.
Second, as this study is one of the first of its kind, multiple emotion regulation strategies were investigated. However, not all of the emotion regulation strategies have well-validated multi-item measures, so there were a few single-item measures (suppression, reappraisal). As a first step were wanted to sample broadly emotion regulation strategies so we used what was available and feasible towards this end. Future work towards developing multi-item measures for suppression and reappraisal that can be employed in a laboratory setting.

Third, the present study examined a limited range of emotion regulation strategies and so future work should examine strategies like mindfulness (e.g., Chadwick, Kaur, Swelam, Ross, & Ellett, 2011; Stange, Eisner, Hölzel, Peckham, Dougherty, Rauch, Nierenberg, Lazar, & Deckersbach, 2011; Ives-Deliperi, Howells, Stein, Meintjes, & Horn, 2013) that may importantly differentiate BD risk.

Finally, the present study focused centrally on peripheral nervous system measurements of emotion regulation and BD risk. As such it could not draw definitive conclusions regarding potential neural mechanisms. Future work should strive to adopt affective neuroscience techniques to elucidate the underlying neural circuitry found among emerging adults at risk for mood disturbance.
References


### Table 1. Demographic Information and Clinical Characteristics

<table>
<thead>
<tr>
<th></th>
<th>LR (n=29)</th>
<th>HR (n=31)</th>
<th>Statistic</th>
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<tbody>
<tr>
<td><strong>Demographic Information</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Age</td>
<td>22.14 (1.98)</td>
<td>20.13 (1.93)</td>
<td><em>t</em>(58)=3.98&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Gender (% female)</td>
<td>65.5</td>
<td>63.3</td>
<td><em>χ</em>²=1.36</td>
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<tr>
<td>Ethnicity (% Caucasian)</td>
<td>65.5</td>
<td>73.3</td>
<td><em>χ</em>²=0.21</td>
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<tr>
<td><strong>Clinical Characteristics</strong></td>
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<tr>
<td>HPS total</td>
<td>14.10 (5.51)</td>
<td>35.55 (1.95)</td>
<td><em>F</em>(1,58)=415.28&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>BDI-SF total</td>
<td>1.69 (2.25)</td>
<td>3.90 (4.72)</td>
<td><em>F</em>(1,58)=5.25&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>ASRM total</td>
<td>3.48 (2.97)</td>
<td>6.03 (4.06)</td>
<td><em>F</em>(1,58)=7.61&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Emotion Regulation Measures</strong></td>
<td></td>
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<td></td>
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<tr>
<td>RPA total</td>
<td>34.34 (7.38)</td>
<td>41.13 (5.88)</td>
<td><em>F</em>(1,56)=7.23&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>RPA emotion-focused</td>
<td>12.55 (2.93)</td>
<td>14.90 (2.98)</td>
<td><em>F</em>(1,56)=5.78&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>RPA self-focused</td>
<td>9.21 (2.37)</td>
<td>10.71 (2.62)</td>
<td><em>F</em>(1,56)=4.43&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>RPA dampen</td>
<td>12.58 (3.78)</td>
<td>11.77 (3.23)</td>
<td><em>F</em>(1,56)=1.66</td>
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<tr>
<td>RSQ total</td>
<td>10.17 (3.17)</td>
<td>11.77 (3.23)</td>
<td><em>F</em>(1,56)=0.65</td>
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<tr>
<td>Reappraisal</td>
<td>1.97 (1.05)</td>
<td>2.68 (1.25)</td>
<td><em>F</em>(1,56)=2.33</td>
</tr>
<tr>
<td>Suppression</td>
<td>2.59 (1.15)</td>
<td>2.84 (1.32)</td>
<td><em>F</em>(1,56)=0.23</td>
</tr>
</tbody>
</table>

<sup>a</sup> *p*<0.000  
<sup>b</sup> *p*<0.05

Note: LR=Low Risk group; HR=High Risk group; HPS=Hypomanic Personality Scale; BDI-SF=Beck Depression Inventory-Short Form; ASRM=Altman Self-Rating Mania Scale; RPA=Responses to Positive Affect; RSQ=Ruminative Style Questionnaire
<table>
<thead>
<tr>
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<th>RSA Baseline</th>
<th>RSA Across Films</th>
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<tbody>
<tr>
<td></td>
<td>r-value, p-value</td>
<td>r-value, p-value</td>
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<tr>
<td>Suppression</td>
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<td>-0.33, 0.07</td>
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<td>Reappraisal</td>
<td>0.37, 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>RPA total</td>
<td>-0.11, 0.58</td>
<td>0.15, 0.44</td>
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<tr>
<td>RPA emotion</td>
<td>0.09, 0.66</td>
<td>-0.02, 0.91</td>
</tr>
<tr>
<td>RPA self</td>
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<td>0.04, 0.84</td>
</tr>
<tr>
<td>RPA dampen</td>
<td>-0.13, 0.52</td>
<td>0.20, 0.29</td>
</tr>
<tr>
<td>RSQ total</td>
<td>-0.17, 0.39</td>
<td>-0.09, 0.66</td>
</tr>
</tbody>
</table>

<sup>a</sup> p<0.05

Note: RPA=Responses to Positive Affect; RSQ= Ruminative Style Questionnaire; RSA=Respiratory Sinus Arrhythmia; RSA Baseline=RSA during the 5-minute resting baseline; RSA Across Films=RSA averaged across all the emotion-eliciting films.
Figures

Figure 1. Means and standard errors of RSA reactivity across the emotion-eliciting films between the HR and LR groups.

Note: Neutral = neutral emotion film; Happy = happy emotion film; Amuse = amusement emotion film; Sad = sad emotion film; RSA = Respiratory sinus arrhythmia; LR = low risk group; HR = high risk group