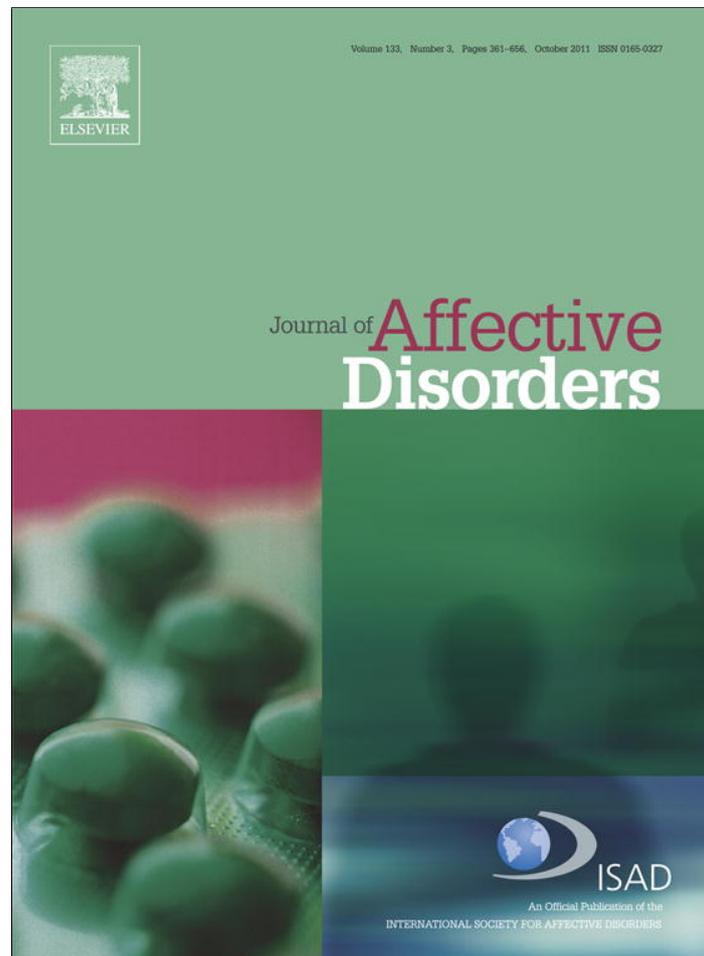


Provided for non-commercial research and education use.
Not for reproduction, distribution or commercial use.



This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier's archiving and manuscript policies are encouraged to visit:

<http://www.elsevier.com/copyright>



Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Research report

What goes up can come down? A preliminary investigation of emotion reactivity and emotion recovery in bipolar disorder

June Gruber ^{a,*}, Allison G. Harvey ^b, Amanda Purcell ^a^a Psychology Department, Yale University, United States^b Psychology Department, University of California, Berkeley, United States

ARTICLE INFO

Article history:

Received 21 November 2010
 Received in revised form 3 April 2011
 Accepted 8 May 2011
 Available online 12 June 2011

Keywords:

Bipolar disorder
 Positive emotion
 Emotion reactivity
 Emotion regulation

ABSTRACT

Background: How is emotion disrupted in bipolar disorder? Two studies are presented that adopt a multi-method approach to investigate emotion reactivity and emotion recovery in bipolar I disorder.

Methods: Across both studies, individuals with inter-episode bipolar disorder and healthy controls were shown three emotion-eliciting films (neutral, happy, and sad) and experiential and physiological responses were measured. In Study 1, bipolar (BD; $n = 23$) and non-clinical control (NC; $n = 24$) participants' emotional reactivity during film clips was assessed. In Study 2, a separate sample of BD ($n = 23$) and NC ($n = 25$) participants' emotion recovery was assessed after the film clips were assessed.

Results: Results indicated that the BD group exhibited increased self-reported positive emotion and respiratory sinus arrhythmia across all films compared to the NC group. There were no group differences in emotion recovery.

Discussion: Taken together, these results suggest that bipolar disorder is associated with increased positive emotion reactivity, but not emotion recovery, across contexts.

© 2011 Elsevier B.V. All rights reserved.

1. Introduction

Extreme perturbations in emotion are an understudied feature of bipolar disorder (e.g., Johnson et al., 2007; Kring and Werner, 2004). Indeed, the core diagnostic criterion for bipolar disorder involves disrupted affective functioning, including periods of abnormally and persistently elevated mood (American Psychiatric Association, 2002). Only recently have affective scientists begun to understand more precisely the emotion disturbances that occur in bipolar disorder.

1.1. Bipolar disorder and emotion reactivity

Emotion reactivity refers to the magnitude of change in emotion from an emotional baseline state in response to

* Corresponding author at: Department of Psychology, Yale University, P.O. Box 208205, New Haven, CT 06520, United States. Tel.: +1 510 410 3822.

E-mail addresses: June.gruber@yale.edu, june.gruber@gmail.com (J. Gruber).

emotion-eliciting stimuli (Gross et al., 1998). Individuals with bipolar disorder exhibit greater positive emotional reactivity compared to healthy controls, independent of current symptom levels (Johnson, 2005; Johnson et al., 2007). For example, inter-episode bipolar individuals report greater positive affect in response to photos (M'Bailara et al., 2009) and at the prospect of earning rewards in their daily lives compared to controls (Meyer et al., 2001). Two studies report that individuals at high risk for bipolar disorder reported greater positive emotion across a variety of contexts, including responses to positive, negative, and neutral film clips (Gruber et al., 2008), and in response to false success feedback (Meyer and Baur, 2009). Several studies employing experience-sampling methodologies report that that individuals identified as at high risk for bipolar disorder (Hofmann and Meyer, 2006) and those classified into a bipolar spectrum disorder group (Lovejoy and Steuerwald, 1995) report higher levels of positive compared to healthy controls.

With respect to physiological responses, one startle eye-blink study demonstrated that non-diagnosed individuals at

risk for bipolar disorder exhibited greater startle attenuation while viewing photos of peaceful landscapes and pleasant imagery (Sutton and Johnson, 2002; though see M'Bailara et al., 2009). Another study demonstrated elevated levels of cardiac vagal tone to film clips – including happy and pride elicitors – in high compared to low bipolar risk groups (Gruber et al., 2008). Heightened vagal tone reactivity has been associated with positive emotion (Porges, 1991), suggesting an elevation in autonomic indices of positive emotion. Neuroimaging studies further suggest that bipolar patients exhibit increased activity in brain regions that have been associated with the experience of positive affect and reward in bipolar disorder, including the putamen and orbitofrontal cortex (Elliott et al., 2004; Lawrence et al., 2004; Phillips and Vieta, 2007). These studies suggest that both risk for, and a diagnosis of, bipolar disorder are associated with greater positive emotion reactivity.

Research investigating negative emotion reactivity suggests bipolar patients do systematically not differ from controls. Specifically, inter-episode and at risk bipolar participants do not appear to differ from healthy controls in their experiential, behavioral, cognitive, or psychophysiological responses to failure feedback (Ruggero and Johnson, 2006; Stern and Berrenberg, 1979), interpersonal criticism (Cuellar et al., 2009), negative photos (Sutton and Johnson, 2002), and challenging math tests (Depue et al., 1985). Studies of neural response to negative emotional stimuli in bipolar disorder provide mixed evidence (Yurgelun-Todd et al., 2000).

1.2. Bipolar disorder and emotion recovery

Emotion recovery is defined as the extent to which an individual exhibits a decline in emotional responding following an emotion-relevant (e.g., Davidson, 1998). We refer to emotion recovery as the magnitude of change in emotional responding from when an emotional stimulus is presented to the subsequent period in which the stimulus has been removed and is no longer explicitly present (also referred to as spontaneous emotion regulation; Gross and Thompson, 2007; Volokhov and Demaree, 2010).

Bipolar disorder has been conceptualized as involving difficulties in emotion recovery (Johnson et al., 2007). There is surprisingly little data that tests this assumption. Indirect data provides evidence consistent with the perspective that people with bipolar disorder exhibit trouble recovering from emotional stimuli. First, using a startle eyeblink paradigm, bipolar participants continue to exhibit heightened startle eyeblink magnitude during a 3 to 5 s period following positive and negative photos (Forbes et al., 2005). Second, Goplerud and Depue (1985) found that cyclothymic participants exhibited a more sustained change in mood, behavior, and cognitions following a stressful event. Third, bipolar participants demonstrate a tendency to dwell on positive feelings and thoughts following a positive life event compared to unipolar depressed and control participants (Johnson et al., 2008b). Finally, a study by Farmer et al. (2006) demonstrated that inter-episode bipolar patients reported sustained elevations in self-reported happiness relative to controls after a positive mood induction. This suggests individuals with bipolar disorder could experience trouble returning to a baseline state.

1.3. Overview of the present research

The aim of the present research was to investigate differences in emotion reactivity and emotion recovery between individuals with bipolar disorder and healthy controls using a multi-method approach across two studies. The first study examined differences in emotion reactivity by having participants watch three films (neutral, happy, sad) while their experiential and physiological responses were measured. The second study examined emotion recovery in a separate sample of bipolar and control participants. Participants watched the same set of three films with an additional 120 s at the end of each film to assess emotion recovery.

2. Method – Study 1

2.1. Participants

Participants were 23 individuals with bipolar I disorder (BD: 6 men; 17 women), currently inter-episode (i.e., neither manic nor depressed), and 24 non-clinical controls (NC: 12 men; 12 women) between 18 and 63 years. Exclusion criteria included history of severe head trauma, stroke, neurological disease, autoimmune disorder and arrhythmias.

The average age at onset of BD participants was 20.37 years (± 11.30), and the average illness duration was 18.76 years (± 13.46). The lifetime average of manic/hypomanic episodes for BD participants was 8.00 (± 8.29) and for major depressive episodes was 10.03 (± 10.19). Psychotropic medications included lithium ($n = 3$), anticonvulsants ($n = 10$), antidepressants ($n = 19$), neuroleptics ($n = 9$), anxiolytics ($n = 7$), stimulants ($n = 1$), and sedatives/hypnotics ($n = 2$). BD participants had an average of 0.57 (± 0.90) current Axis I comorbidities, including agoraphobia ($n = 1$), social phobia ($n = 3$), specific phobia ($n = 4$), obsessive-compulsive disorder ($n = 2$), generalized anxiety disorder ($n = 2$), and anorexia ($n = 1$).

The NC group did not meet criteria for any current or lifetime Axis I disorder using the SCID-IV and scored below cut-offs on the YMRS and IDS-C.

2.2. Measures of clinical functioning

2.2.1. Diagnostic evaluation

Diagnoses were confirmed using the Structured Clinical Interview for DSM-IV (SCID-IV; Spitzer et al., 1990). Fifteen randomly selected audiotapes of SCID interviews were rated by a set of independent reviewers and matched 100% ($\kappa = 1.00$) of diagnoses made by the interviewer.

2.2.2. Mania and depression severity

The Young Mania Rating Scale (YMRS; Young et al., 1978) is an 11-item, clinician-rated measure of manic symptoms with scores ranging from 0 to 60. The Inventory of Depressive Symptomatology (IDS-C; Rush et al., 1996) is a 30-item clinician-rated measure of depressive symptoms with scores ranging from 0 to 84. Scores on the YMRS (≤ 7) and IDS-C (≤ 11) were used to confirm current inter-episode status (i.e., neither currently manic nor depressed) for both groups. Intra-class correlations (Shrout and Fleiss, 1979) between the interviewer and an independent rater for a random subset

($n=13$) were strong for the IDS-C ($=0.98$) and YMRS ($=0.99$).

2.3. Emotion-eliciting stimuli

Two happy, two sad, and two neutral validated film clips were used (Rottenberg et al., 2007). Happy films included Sarah Hughes winning the Olympic medal (150 s) and Andy Roddick winning the US Open (181 s). Sad films included a young boy watching his father die (170 s) and a mother crying over the death of her family (231 s). Neutral films depicted a man and a woman doing household tasks (94 s) and two men sitting quietly in a room (131 s). The neutral film came first and the order of happy and sad film was counterbalanced. The specific film for a given valence was also counterbalanced.

2.4. Measurement of three channels of emotional response

A multi-method approach was employed to measure emotion at experiential and physiological levels. These data were assessed across a baseline period (60 s) preceding each film and a film period. Change scores were used to calculate emotional reactivity by subtracting the baseline period from the film period (Rogosa and Willett, 1983).

2.4.1. Self-reported positive and negative affect

Self-reported positive (PA) and negative (NA) affect were assessed using the 10-item short form of the Positive and Negative Affect Schedule (PANAS; MacKinnon et al., 1999). Both PA (average $\alpha=0.89$) and NA (average $\alpha=0.72$) demonstrated good internal consistency in the present study.

2.4.2. Self-reported arousal level

Self-reported arousal level was assessed using the affect grid (Russell et al., 1989). The affect grid contains a self-reported rating of arousal level from -4 (extremely low arousal) to 4 (extremely high arousal) with 0 in the middle (neutral).

2.4.3. Physiology

Physiological data were recorded continuously at 1 kHz using a Biopac multi-channel device (MP150-BIOPAC Systems Inc., Goleta, CA) and analyzed with AcqKnowledge v3.9.1 software. A transistor-transistor Logic (TTL) digital signal automatically enabled the synchronization of physiological data with the onset of the different baseline and film periods. Averages for each baseline and film clip period were computed for HR, RSA, and SCR rate. Artifacts and recording errors were corrected offline and values ± 3.0 standard deviations were winsorized ($<1.6\%$ of all data; Howell, 2007). Three measures were selected to broadly sample peripheral autonomic activity implicated in emotional responding:

2.4.4. Heart rate (HR)

HR is influenced by both sympathetic and parasympathetic branches and was assessed as a general index of cardiovascular activity. ECG recordings were obtained with two pre-jelled Ag–AgCl snap disposable vinyl electrodes placed in a modified Lead II configuration. The ECG signal

was converted to R-wave intervals (interbeat intervals [IBIs]) to the nearest millisecond, and IBI values were converted to beats per minute.

2.4.5. Respiratory sinus arrhythmia (RSA)

RSA was employed as a noninvasive index of cardiac vagal tone, or parasympathetic nervous activity (for reviews, see Berntson et al., 1997; Grossman and Taylor, 2007). RSA was calculated offline following a well-validated peak-valley method (Grossman et al., 1990). The maximum heart rate (“peak”) expressed in milliseconds (IBI) during the expiration window of the respiration cycle was subtracted from the minimum heart rate (“valley”) during the inspiration window of the respiration cycle. The RSA index was calculated in milliseconds (ms), with higher values reflecting greater cardiac vagal tone.

2.4.6. Skin conductance response (SCR) rate

SCR rate was assessed as a measure of sympathetic nervous system activity (Dawson et al., 2000). A constant voltage of 0.5 V between two 10 mm Ag–AgCl electrodes on the palmar surface was passed between the distal phalanges of the first and third fingers of the non-dominant hand. An isotonic (0.5% NaCl) electrode paste was used as a conductant. SCRs were identified as increases in skin conductance level exceeding 0.05μ Siemens (Fowles et al., 1981).

2.5. Procedure

Participants first completed written informed consent procedures. Next, the SCID, YMRS, and IDS-C were administered. Participants were seated in front of a 17 in. computer monitor and physiological sensors were attached. Questionnaires, films, and additional experimental instructions were presented using computerized software (MediaLab v2006, MediaLab, Inc., Atlanta, GA). Before each film, the following instructions were presented on the monitor: “Please relax and watch the screen for the next minute.” After the 60 s baseline period, participants completed the PANAS. Next, they received the following instructions: “We will now be showing you a short film clip. It is important that you watch the film clip carefully.” These instructions were followed by the neutral, happy, or sad film. At the end of each film, participants again completed the PANAS. At the end, physiological sensors were disconnected and participants were debriefed.

3. Results – Study 1

3.1. Demographic and clinical characteristics

As evident in Table 1, BD and NC participants did not significantly differ with respect to age, gender, ethnicity, education level, employment status, partnership status, and living status ($ps>0.05$). Although both groups scored below YMRS (≤ 7) and IDS-C (≤ 11) cutoffs ($ps<$ respectively), BD participants scored higher than NC participants on the YMRS and IDS-C ($ps<0.01$). Hence, current symptoms were included as covariates in subsequent analyses.

Table 1
Demographic and clinical characteristics of bipolar (BD) and non-clinical control (NC) participants across Study 1 and Study 2.

	Study 1 Emotion reactivity			Study 2 Emotion recovery		
	BD (n = 23)	NC (n = 24)	Statistic	BD (n = 23)	NC (n = 25)	Statistic
<i>Demographic</i>						
Age	39.13 (2.61)	35.46 (2.56)	$F = 1.51$	32.30 (2.13)	35.76 (2.05)	$F = 1.37$
Female (%)	77.8%	52.0%	$\chi^2 = 3.81$	78.3%	72.0%	$\chi^2 = 0.25$
Caucasian (%)	77.8%	56.0%	$\chi^2 = 2.80$	43.5%	28.0%	$\chi^2 = 1.26$
Education (years)	15.30 (0.42)	14.54 (0.41)	$F = 2.17$	15.30 (0.49)	15.76 (0.47)	$F = 0.51$
Employed (%)	74.1%	84.0%	$\chi^2 = 0.77$	65.2%	80.0%	$\chi^2 = 1.33$
Partnered (%)	33.3%	26.1%	$\chi^2 = 0.31$	26.1%	24.0%	$\chi^2 = 0.03$
Living alone (%)	22.2%	28.0%	$\chi^2 = 0.23$	22.7%	25.0%	$\chi^2 = 0.03$
<i>Clinical</i>						
YMRS	3.29 (0.45)	1.25 (0.42)	$F = 8.61^a$	2.29 (0.38)	0.76 (0.35)	$F = 8.67^b$
IDS-C	7.68 (0.79)	3.56 (0.76)	$F = 19.64^a$	7.35 (0.67)	2.96 (0.64)	$F = 22.37^b$

Note: BD = Bipolar participants; NC = Non-clinical control participants; YMRS = Young Mania Rating Scale; IDS-C = Inventory to Diagnose Depression; Mean values (adjusted for covariates) are displayed with standard errors in parentheses where applicable.

^a $p < 0.05$ for BP and NC in Study 1.
^b $p < 0.05$ for BP and NC in Study 2.

3.2. Preliminary analyses

First, we examined whether our primary emotion reactivity change scores were normally distributed using the Kolmogorov–Smirnov test. Three emotion reactivity variables did not meet this criterion (i.e., NA, SCR, RSA; $Z_s > 1.20$, $p < 0.05$) and natural log transformations were performed to normalize these variables for the main analyses (non-transformed values are presented for ease of interpretation). Second, we examined whether gender or film order impacted emotional responding and no significant main effects or interactions emerged ($ps > .05$).

3.3. Overview of main analyses

Given the loose coupling among distinct channels of emotional response (e.g., Mauss et al., 2005), separate 2 (Group) × 3 (Film) repeated-measures analyses of variance (ANCOVAs) controlling for current symptoms of mania (YMRS) and depression (IDS-C) were conducted for each emotion reactivity variable (PA, NA, Arousal, RSA, HR, and SCR rate) with Group (BD, NC) as the between-subjects factor and Film (neutral, happy, sad) as the within-subjects factor. A Greenhouse–Geisser correction was used when assumptions for sphericity were not met and adjusted F and p (two-tailed) values are reported. Effect sizes are reported as partial eta squared (η_p^2).

3.4. Differences across channels of emotional responding

All findings are based upon emotion reactivity change scores (see Table 2).

3.4.1. Positive affect (PA)

For self-reported PA, there was a significant main effect for Film, $F(2, 78) = 20.17$, $p < 0.001$, $\eta_p^2 = 0.34$. For the Film main effect, pairwise comparisons indicated that all participants reported greater increases in PA to the happy ($M = 1.04$, $SE = 0.12$) than in the sad ($M = -0.23$, $SE = 0.10$) and neutral

($M = -0.11$, $SE = 0.11$) films ($ps < 0.001$). Sad and neutral films did not differ in PA ($p > 0.40$). There was also a significant Group main effect, Group, $F(1, 39) = 4.69$, $p < 0.05$, $\eta_p^2 = 0.11$. For the Group main effect, the BD group reported greater increases in PA across all films ($M = 0.39$, $SE = 0.10$) compared to the NC group ($M = 0.08$, $SE = 0.09$). The Film × Group interaction was not significant, $F(2, 78) = 1.88$, $p = 0.16$, $\eta_p^2 = 0.05$.

3.4.2. Negative affect (NA)

For NA, there was no significant main effect for Film, $F(1.51, 58.97) = 2.28$, $p = 0.11$, $\eta_p^2 = 0.06$; Group, $F(1, 39) = 0.02$, $p = 0.90$, $\eta_p^2 = 0.00$; or for the Group × Film interaction, $F(1.51, 58.97) = 0.42$, $p = 0.66$, $\eta_p^2 = 0.01$.

3.4.3. Self-reported arousal

For arousal, there was a significant main effect for Film, $F(2, 78) = 13.42$, $p < 0.001$, $\eta_p^2 = 0.26$. For the Film main effect, pairwise comparisons indicated that participants reported a greater increase in self-reported arousal during the happy ($M = 1.92$, $SE = 0.24$) compared to sad ($M = 0.83$, $SE = 0.28$) and neutral ($M = -0.39$, $SE = 0.22$) films ($ps < 0.01$). The sad film was associated with greater arousal than the neutral film ($p < 0.01$). There was no significant main effect for Group, $F(1, 39) = 1.07$, $p = 0.31$, $\eta_p^2 = 0.03$; or for the Group × Film interaction, $F(2, 78) = 2.17$, $p = 0.12$, $\eta_p^2 = 0.05$.

3.4.4. Heart rate (HR)

For HR, there was no significant main effect for Film, $F(2, 72) = 0.79$, $p = 0.46$, $\eta_p^2 = 0.02$; Group, $F(1, 36) = 1.23$, $p = 0.28$, $\eta_p^2 = 0.03$; or for the Group × Film interaction, $F(2, 72) = 0.26$, $p = 0.77$, $\eta_p^2 = 0.01$.

3.4.5. Respiratory sinus arrhythmia (RSA)

For RSA, there was a significant main effect for Group, $F(1, 35) = 4.23$, $p < 0.05$, $\eta_p^2 = 0.11$. For the Group main effect, pairwise comparisons indicated that BD participants exhibited smaller decreases in RSA levels across all films ($M = -2.02$, $SE = 17.61$) compared to NC participants ($M = -54.70$,

Table 2

Mean change (and standard error) of self-reported emotion and physiological responding of participants by Film condition, diagnostic Group across Study 1 and Study 2.

	Study 1 Emotion reactivity		Study 2 Emotion recovery	
	BD	NC	BD	NC
<i>Neutral film</i>				
PA	−0.14 (0.18) [CI: −0.50, 0.22]	0.08 (0.16) [CI: −0.41, 0.25]	−0.24 (0.11) [CI: −0.45, −0.02]	−0.06 (0.10) [CI: −0.25, 0.14]
NA	−0.10 (0.06) [CI: −0.23, 0.03]	−0.03 (0.06) [CI: −0.15, 0.08]	0.04 (0.10) [CI: −0.16, 0.24]	−0.14 (0.09) [CI: −0.32, 0.04]
Arousal	−0.62 (0.36) [CI: −1.34, 0.10]	−0.16 (0.33) [CI: −0.82, 0.51]	0.27 (0.86) [CI: −1.49, 2.03]	0.18 (0.81) [CI: −1.47, 1.83]
RSA	−11.97 (28.46) [CI: −69.74, 45.80]	−39.49 (34.34) [CI: −88.91, 9.93]	18.70 (14.79) [CI: −11.26, 48.67]	15.44 (13.58) [CI: −12.08, 42.95]
HR	−0.01 (0.77) [CI: −1.56, 1.58]	−0.62 (0.65) [CI: −1.92, 0.69]	−0.99 (0.76) [CI: −2.53, 0.55]	0.25 (0.68) [CI: −1.12, 1.62]
SCR	0.08 (0.29) [CI: −0.51, 0.66]	−0.42 (0.26) [CI: −0.95, 0.12]	−0.05 (0.07) [CI: −0.20, 0.10]	−0.08 (0.07) [CI: −0.22, 0.06]
<i>Happy film</i>				
PA	1.39 (0.20) [CI: 0.99, 1.79]	0.70 (0.18) [CI: 0.33, 1.06]	−0.36 (0.18) [CI: −0.73, 0.00]	−0.67 (0.17) [CI: −1.00, −0.33]
NA	−0.08 (0.08) [CI: −0.26, 0.06]	−0.02 (0.07) [CI: −0.17, 0.13]	−0.12 (0.07) [CI: −0.27, 0.01]	−0.03 (0.06) [CI: −0.16, 0.10]
Arousal	2.48 (0.39) [CI: 1.70, 3.26]	1.37 (0.36) [CI: 0.65, 2.08]	−0.64 (0.69) [CI: −2.05, 0.76]	−0.22 (0.65) [CI: −1.53, 1.10]
RSA	29.45 (17.83) [CI: −6.74, 65.65]	−41.79 (15.25) [CI: −72.76, −10.83]	−18.62 (27.32) [CI: −73.98, 36.73]	0.30 (25.08) [CI: −50.52, 51.13]
HR	−0.98 (0.87) [CI: −2.74, 0.79]	−2.64 (0.73) [CI: −4.11, −1.16]	−1.46 (0.99) [CI: −3.47, 0.56]	−1.38 (0.88) [CI: −3.18, 0.41]
SCR	−0.24 (0.28) [CI: −0.81, 0.34]	0.11 (0.26) [CI: −0.41, 0.64]	−0.11 (0.05) [CI: −0.22, 0.00]	−0.19 (0.05) [CI: −0.29, −0.09]
<i>Sad film</i>				
PA	−0.07 (0.17) [CI: −0.41, 0.28]	−0.39 (0.16) [CI: −0.70, −0.07]	−0.07 (0.10) [CI: −0.28, 0.13]	−0.17 (0.09) [CI: −0.36, 0.02]
NA	0.57 (0.16) [CI: 0.24, 0.90]	0.45 (0.15) [CI: 0.15, 0.75]	−0.51 (0.18) [CI: −0.86, −0.15]	−0.64 (0.16) [CI: −0.97, −0.31]
Arousal	1.11 (0.45) [CI: 0.20, 2.03]	0.55 (0.42) [CI: −0.29, 1.39]	2.06 (0.87) [CI: 0.28, 3.84]	1.26 (0.82) [CI: −0.40, 2.93]
RSA	−23.55 (29.69) [CI: −83.82, 36.73]	−82.81 (25.40) [CI: −134.37, −31.25]	60.21 (22.05) [CI: 15.53, 104.89]	63.26 (20.25) [CI: 22.24, 104.28]
HR	−1.11 (1.10) [CI: −3.34, 1.12]	−2.17 (0.92) [CI: −4.03, −0.30]	−0.75 (0.76) [CI: −2.29, 0.80]	−0.64 (0.68) [CI: −2.01, 0.74]
SCR	−0.11 (0.25) [CI: −0.62, 0.40]	−0.39 (0.23) [CI: −0.86, 0.07]	1.13 (0.36) [CI: 0.39, 1.86]	0.64 (0.33) [CI: −0.03, 1.32]

Note: BD = Bipolar participants; NC = Non-clinical control participants; PA = Positive affect; NA = Negative affect; HR = Heart rate; SCR = Skin conductance response rate/min; RSA = Respiratory sinus arrhythmia. Self-reported PA and NA rated on a 1 (very slightly or not at all) to 7 (extremely) scale. CI = 95% confidence interval with lower bound value followed by upper bound value. Mean values (adjusted for covariates) are displayed with standard errors in parentheses where applicable.

SE = 15.06). It is important to note that mean RSA levels across all films prior to computing change scores were higher for BD ($M = 160.84$, $SE = 34.30$) compared to NC ($M = 134.61$, $SE = 29.34$) participants. In other words, BD participants exhibited greater increases in RSA from an already higher RSA levels¹. There was no significant main effect for Film, $F(2, 70) = 1.74$, $p = 0.18$, $\eta_p^2 = 0.05$; or for the Group × Film interaction, $F(2, 70) = 0.34$, $p = 0.71$, $\eta_p^2 = 0.01$.

¹ To ensure group differences in RSA reactivity that were independent of a more general cardiovascular response (e.g., heart rate), we re-ran these analyses with IBI entered as a covariate. This did not substantially change the results, consistent with the notion that RSA findings were independent of a more general cardiovascular response.

3.4.6. Skin conductance response (SCR) rate

For SCR rate, there was no significant main effect for Film, $F(2, 74) = 0.02$, $p = 0.98$, $\eta_p^2 = 0.00$; Group, $F(1, 37) = 0.31$, $p = 0.58$, $\eta_p^2 = 0.01$; or for the Group × Film interaction, $F(2, 74) = 1.31$, $p = 0.28$, $\eta_p^2 = 0.03$.

4. Discussion – Study 1

This study adopted a multi-method approach to investigate whether BD and NC participants differed in emotion reactivity. BD participants were characterized by increases in self-reported positive emotion and RSA – a putative physiological marker of positive emotion – across all films. These results also dovetail with the perspective that BD is associated with elevated positive emotion reactivity (for review, see Johnson et al., 2007) and that BD is associated with

heightened reward sensitivity (Meyer et al., 2001). These findings support an extension of this view such that BD also involves increased positive emotion in non-rewarding contexts as well (e.g., Gruber in press). Although findings from Study 1 helped illuminate differences in the amplitude and context of positive emotion reactivity, it left unanswered whether bipolar disorder is associated with differences in emotion recovery. Few studies to date have examined the temporal dynamics (i.e., “affective chronometry;” Davidson, 1998) of emotional responding. Hence, Study 2 examined whether bipolar disorder was characterized by differences recovering from an emotional provocation compared to controls.

5. Study 2

5.1. Method – Study 2

In Study 2, participants watched the same three films as in Study 1. At the end of each film, there was a 120 s post-film period consistent with other studies on emotion recovery (Fredrickson and Levenson, 1998).

5.1.1. Participants

An independent sample of BD and NC participants was recruited for Study 2. Participants were 23 inter-episode BD I (5 men; 18 women) and 25 NC (7 men; 18 women) participants between 18 and 60 years of age. As in Study 1, DSM-IV-TR diagnoses were confirmed using the SCID-IV.

For the BD group, the average age at onset was 13.22 years (± 6.91), average illness duration was 15.50 years (± 10.86), and a lifetime average of 9.35 (± 12.72) manic/hypomanic episodes and of 10.94 (± 11.38) major depressive episodes was reported. The average number of comorbidities was 0.68 (± 0.78) including agoraphobia ($n=2$), social phobia ($n=1$), specific phobia ($n=5$), obsessive-compulsive disorder ($n=1$), post-traumatic stress disorder ($n=1$), generalized anxiety disorder ($n=3$), pain disorder ($n=1$), and hypochondriasis ($n=1$). All but 6 BD participants (74%) were receiving psychotropic medication, including lithium ($n=4$), anticonvulsants ($n=9$); antidepressants ($n=11$), neuroleptics ($n=8$); stimulants ($n=1$), and sedatives/hypnotics ($n=2$)².

5.1.2. Clinical assessment instruments

The diagnostic evaluation and measures of symptom severity were identical to Study 1.

5.1.3. Emotion-eliciting stimuli

The set of films and counterbalancing procedures from were identical to Study 1.

5.1.4. Emotion response measurement

The same multi-method approach described in Study 1 was used.

² Analyses were re-run excluding BD participants who were not currently receiving medication ($n=6$) and similar results with respect to group status emerged.

5.1.5. Emotion rating dial

Study 2 had the addition of a continuous emotion rating dial developed by Medialab© and comparable to validated rating dials (Ruef and Levenson, 2007). Participants used a small plastic dial which could be easily moved on a linear scale from “–50” (very negative) to “50” (positive), with “0” in the middle (neutral). Participants were instructed to move the lever as needed to reflect their current emotion experience. The rating dial communicated with the computer over a standard serial port and provided second by second numerical values. Recent work suggests that utilization of a rating dial does not interfere with emotion experience (Mauss et al., 2005).

5.1.5.1. Emotion recovery motivation. Participants completed a single self-report item assessing the extent to which they were motivated to emotionally recover during the post-film period (“I was motivated to down-regulate my feelings”) on a 1 (strongly disagree) to 7 (strongly agree) scale.

5.1.5.2. Emotion recovery calculation. Two approaches to assessing emotion recovery were examined. First, the *change score approach* assessed emotion recovery between two static time points (i.e., pre-film baseline and the post-film period). Change scores were computed by subtracting pre-film baseline period scores from post-film period scores. Data reduction for physiological data was based on the pre-film baseline and post-film periods³. Second, the *continuous measurement approach* assessed emotion recovery by examining differences in the temporal dynamics of emotion based on continuous measures of self-reported affect using the rating dial (described above) and second-by-second changes in physiological response (i.e., HR and RSA as SCR did not provide second-by-second data). Following procedures outlined by Fredrickson and Levenson (1998), these measurements were used to create an individualized, time-based index of emotion recovery. A baseline confidence interval for each participant was defined as the participant's own 60-second pre-film mean, plus and minus one standard deviation from that mean. Emotion recovery was evidenced when a participant returned to her own pre-film confidence interval during the 120-second post-film period and remained within this confidence interval for a minimum of five or six consecutive seconds. A participant was classified as either returning to her pre-film confidence interval (did recover) or not (did not recover).

5.1.6. Procedure

A similar procedure was adopted in Study 2 as in Study 1. However, immediately following each film was the post-film recovery period in which participants were instructed to, “Remain seated for the next two minutes.” Following the end of the post-film period, the PANAS was administered separately in reference to the film and the post-film periods. Although the retrospective nature of reporting one's feelings

³ We calculated an alternative change score for emotion recovery by calculating a post-film minus film period score, which enables examination of changes in emotion response during the film compared with that in the immediate post-film period. Parallel findings emerged (i.e., no group differences in emotion recovery).

during the film later on may contain memory bias, we opted not to disrupt the emotion generative process between the film and post-film periods.

6. Results – Study 2

6.1. Demographic and clinical characteristics

As seen in Table 1, BD and NC participants did not differ with respect to gender, age, ethnicity, partnered status, living status, employment status, and years of education ($ps > 0.20$). BD participants scored higher on the YMRS and IDS-C compared to NC participants ($ps < 0.01$). As in Study 1, current symptoms were used as covariates.

6.2. Preliminary analyses

First, we examined whether our emotion recovery change scores were normally distributed using the Kolmogorov–Smirnov test. Three variables did not meet this criterion (i.e., PA, NA, Arousal, SCR; $Z_s > 1.30$, $ps < 0.05$) and natural log transformations were performed. Second, no main effects or interactions emerged for gender or film order ($ps > .05$). Third, we felt it important to ensure the films once again elicited the appropriate target emotion as in Study 1. Seven 2 (Group) \times 3 (Film) repeated-measures ANCOVAs, controlling for current clinical symptoms, revealed a similar pattern of findings for Film clip main effects described in Study 1.

6.3. Emotion recovery: Change score approach

All findings for Study 2 are based upon emotion recovery change scores, defined earlier as the post-film period minus the pre-film period. Table 2 (and the text below) displays mean values and standard deviations.³

6.3.1. PA

For PA, there was no significant main effect for Film, $F(1.72, 67.37) = 0.30$, $p = 0.74$, $\eta_p^2 = 0.01$; Group, $F(1, 37) = 0.31$, $p = 0.58$, $\eta_p^2 = 0.01$; or for the Group \times Film interaction, $F(1.72, 67.37) = 1.66$, $p = 0.20$, $\eta_p^2 = 0.04$.

6.3.2. NA

For NA, there was no significant main effect for Film, $F(1.62, 63.06) = 0.44$, $p = 0.65$, $\eta_p^2 = 0.01$; Group, $F(1, 39) = 0.34$, $p = 0.57$, $\eta_p^2 = 0.01$; or for the Group \times Film interaction, $F(1.62, 63.06) = 0.79$, $p = 0.46$, $\eta_p^2 = 0.02$.

6.3.3. Self-reported arousal

For arousal, there was no significant main effect for Film, $F(2, 64) = 0.82$, $p = 0.44$, $\eta_p^2 = 0.03$; Group, $F(1, 32) = 0.05$, $p = 0.82$, $\eta_p^2 = 0.00$; or for the Group \times Film interaction, $F(2, 64) = 0.25$, $p = 0.78$, $\eta_p^2 = 0.01$.

6.3.4. RSA

For RSA, there was no significant main effect for Film, $F(1.34, 49.61) = 2.66$, $p = 0.08$, $\eta_p^2 = 0.07$; Group, $F(1, 37) = 0.11$, $p = 0.75$, $\eta_p^2 = 0.00$; or for the Group \times Film interaction, $F(1.34, 49.61) = 0.13$, $p = 0.88$, $\eta_p^2 = 0.00$.

6.3.5. HR

For HR, there was no significant main effect for Film, $F(1.44, 53.13) = 1.77$, $p = 0.18$, $\eta_p^2 = 0.05$; Group, $F(1, 37) = 0.21$, $p = 0.65$, $\eta_p^2 = 0.01$; or for the Group \times Film interaction, $F(1.44, 53.13) = 0.88$, $p = 0.39$, $\eta_p^2 = 0.02$.

6.3.6. SCR rate

For SCR rate, there was a main effect for Film, $F(1.04, 38.32) = 4.40$, $p < 0.05$, $\eta_p^2 = 0.11$. Pairwise comparisons revealed a higher SCR rate following the sad ($M = 0.88$, $SE = 0.23$) compared to happy ($M = -0.15$, $SE = 0.03$) and neutral ($M = -0.07$, $SE = 0.05$) post-film periods ($ps < 0.001$). The happy post-film period was associated with a lower SCR rate than the neutral post-film period ($p > 0.05$). There was no significant main effect for Group, $F(1, 37) = 1.48$, $p = 0.23$, $\eta_p^2 = 0.04$; or for the Group \times Film interaction, $F(1.04, 38.32) = 0.55$, $p = 0.58$, $\eta_p^2 = 0.01$.

6.4. Emotion recovery: Continuous measurement approach

For continuous emotion experience, results indicated that the proportion of BD and NC participants who met criteria for emotion recovery did not for the neutral (48% and 55% respectively, $\chi^2 = 0.22$), happy (33% and 35% respectively, $\chi^2 = 0.01$), or sad (29% and 40% respectively, $\chi^2 = 0.60$) films. The remaining sample size of those participants who did recover was not large enough to examine subgroup differences in time to recover.

6.5. Emotion recovery: Motivation

For self-reported motivation to recover, there was no main effect for Film, $F(2, 78) = 2.34$, ns , $\eta_p^2 = 0.06$; Group, $F(1, 39) = 3.08$, ns , $\eta_p^2 = 0.07$; or a Film \times Group interaction, $F(2, 78) = 0.48$, ns , $\eta_p^2 = 0.01$ ($ps > 0.05$).

7. Discussion – Study 2

Study 2 investigated whether BD and NC participants differed in emotion recovery. No group differences for emotion recovery emerged across experiential or physiological channels. This pattern of findings did not change even when more fine-grained temporal dynamics of emotion recovery were calculated.

8. General discussion

The overall aim of this research was to examine emotion reactivity (in Study 1) and emotion recovery (in Study 2) in inter-episode bipolar disorder compared to a healthy non-clinical control group. Results from Study 1 supported a new notion that bipolar disorder is associated with persistently heightened positive emotional responses across contexts in both experiential and physiological channels. Study 2 found no supportive evidence for the thesis that bipolar disorder is characterized by trouble recovering from emotions. Overall, the present work suggests that bipolar disorder is associated with amplified positive emotional responses pervasive across varying stimuli and contexts, but that they do not exhibit trouble recovering from these intense feelings when the emotional stimuli are no longer present.

8.1. Emotion reactivity: Supporting evidence for positive emotion persistence

BD participants were found to report higher PA and RSA levels across all films relative to the NC group. For PA, this result is consistent with the perspective that bipolar disorder is associated with elevated positive emotion across contexts (Gruber, *in press*; Gruber et al., 2008). Prior research had focused on responses positive or rewarding stimuli in isolation (e.g., Alloy et al., 2009; Meyer et al., 2001). Data from the present study suggests that amplified positive feelings may extend across negative and non-emotional contexts as well. The fact that elevated levels of RSA across all films were also greater provides convergent cross-channel evidence in support of this perspective as RSA (i.e., vagal tone) has been theorized to be a physiological marker of positive emotion experience in both healthy (Oveis et al., 2009) and bipolar disorder (Cohen et al., 2003; Gruber et al., 2008) populations. Importantly, BD participants did not exhibit greater overall physiological (HR, SCR rate) or self-reported arousal across groups, suggesting it was not an amplified state of arousal across films.

BD and NC participants did not differ in negative emotion reactivity. This extends recent work suggesting that negative emotional reactivity is not present during asymptomatic phases of bipolar disorder (e.g., Johnson et al., 2007). Rather, it appears that negative emotion covaries with depressive symptoms, and is not a trait-like marker of bipolar disorder (Ernst et al., 2004; Johnson et al., 2007). Future research employing within-subject designs across depressed, manic, and mixed mood phases however, is warranted.

In sum, BD participants were associated with an expansive and persistent pattern of pleasant emotional responses across differing contexts relative to NC participants. This account of positive emotional disruption in bipolar disorder has been termed “positive emotion persistence” (PEP; Gruber *in press*), suggesting that a core emotional feature may be an inappropriate positive emotion that persists in even unwarranted contexts.

8.2. Emotion recovery: No group differences

Findings from Study 2 indicated that BD and NC participants did not differ in emotional recovery. These findings are inconsistent with conceptions of bipolar disorder involving difficulties in both positive and negative emotion recovery (e.g., Green et al., 2007; Johnson et al., 2007). There are several possible accounts. First, the present study examined emotion recovery using both change score and temporal dynamic approaches. Prior studies have focused on examining regulatory strategies, such as rumination, that may lead to trouble recovering rather than directly assessing emotion recovery per se (Feldman et al., 2008; Johnson et al., 2008a, 2008b). Second, work demonstrating sustained emotional responding in bipolar disorder has included a very brief time window (i.e., 3–5 s; Forbes et al., 2005) whereas we examined emotional recovery over a longer period in the present study (i.e., 120 s).

8.3. Limitations and future directions

Our findings should be interpreted within the confines of several limitations. First, the sample sizes were relatively modest. Specifically, assuming a medium effect size of 0.40 we were powered to primarily detect large main effects and interactions. Thus, there may not have been sufficient statistical power to reject the null hypotheses and so it will be important to replicate these findings in a larger sample. Second, only three emotional states (neutral, happy, and sad) were assessed. Other emotions implicated in bipolar disorder, such as irritability and positive emotions related to reward striving and achievement (Gruber et al., 2009) should be included in future studies. Third, the precise role of RSA activity (or lack thereof) is tentative, given debate surrounding its putative affective function (Beauchaine, 2001; Butler et al., 2002). Fourth, interpretations about potential elevations in positive emotion reactivity and a lack thereof in negative reactivity should be interpreted with caution as there are concerns when controlling for current symptoms (Miller and Chapman, 2001). Future studies be conducted comparing BD participants who scored high and low on symptom measures to examine the relative influence of symptoms on positive emotional responding. Fourth, commonly prescribed medications have been shown to alter neural responses to emotional stimuli (e.g., Yurgelun-Todd et al., 2000; Lawrence et al., 2004). Given that an unmedicated BD group is often unfeasible, future studies with larger sample sizes and random assignment to different medication classes are needed.

What is the clinical significance of heightened positive emotion in bipolar disorder? Tentative data suggests that bipolar patients who exhibit more pronounced disturbance in positive emotion may face a worse prognosis. For example, several studies suggest that increases in positive emotion reactivity predict increases in manic symptoms over time (Johnson, 2005; Meyer et al., 2001). Recent work additionally indicates that greater reports of reward-focused emotions like joy predicted increased manic symptom severity at a six-month follow up in bipolar patients (Gruber et al., 2009). It will be important for future work to more carefully ascertain the clinical significance of positive emotion disturbance.

Role of funding source

This project was supported by National Institute of Mental Health Grant No. R34 MH080958 (AGH) and an NRSA predoctoral training grant (JG).

Conflict of interest

The authors declare no conflicts of interest related to the content of this article.

Acknowledgments

We thank Robert Levenson and Ann Kring for feedback on earlier versions of this manuscript and Polina Eidelman, Ilana Hairston, and Lisa Talbot for facilitation of the study.

References

- Alloy, L.B., Abramson, L.A., Urosevic, S., Bender, R.E., Wagner, C.A., 2009. Longitudinal predictors of bipolar spectrum disorders: a behavioral approach system (BAS) perspective. *Clinical Psychology: Science and Practice* 16 (2), 206–226.

- American Psychiatric Association, 2000. Task Force on DSM-IV, Diagnostic and Statistical Manual of Mental Disorders 4th ed. Author, Washington, DC. text rev.
- Beauchaine, T., 2001. Vagal tone, development, and Gray's motivational theory: toward an integrated model of autonomic nervous system functioning in psychopathology. *Developmental Psychopathology* 13, 183–214.
- Berntson, G.G., Bigger Jr., J.T., Eckberg, D.L., Grossman, P., Kaufmann, P.G., Malik, M., Nagaraja, H.N., Porges, S.W., Saul, J.P., Stone, P.H., Vand Der Molen, M.W., 1997. Heart rate variability: origins, methods, and interpretive caveats. *Psychophysiology* 34 (6), 623–648.
- Butler, E.A., Wilhelm, F.H., Gross, J.J., 2002. Respiratory sinus arrhythmia, emotion, and emotion regulation during social interaction. *Psychophysiology* 43, 612–622.
- Cohen, H., Kaplan, Z., Kotler, M., Mittelman, I., Osher, Y., Bersudsky, Y., 2003. Impaired heart rate variability in inter-episode bipolar patients. *Bipolar Disorders* 5 (2), 138–143.
- Cuellar, A., Johnson, S.K., Ruggero, C., 2009. Affective reactivity in response to criticism in remitted bipolar disorder: a laboratory analog of expressed emotion. *Journal of Clinical Psychology* 65 (9), 925–941.
- Davidson, R.J., 1998. Affective style and affective disorders: perspectives from affective neuroscience. *Cognition and Emotion* 12, 307–330.
- Dawson, M.E., Schell, A.M., Filion, D.L., 2000. The electrodermal system. In: Cacioppo, J.T., Tassinary, L.G., Bernston, G.G. (Eds.), *Handbook of Psychophysiology*, 2nd edition. Cambridge University Press, New York, NY, pp. 265–293.
- Depue, R.A., Kleiman, R.M., Davis, P., Hutchinson, M., Krauss, S.P., 1985. The behavioral high-risk paradigm and bipolar affective disorder: VIII. Serum free cortisol in nonpatient cyclothymic subjects selected by the General Behavior Inventory. *American Journal of Psychiatry* 142, 175–181.
- Elliott, R., Ogilvie, A., Rubinsztein, J.S., Calderon, G., Dolan, R.J., Sahakian, B.J., 2004. Abnormal ventral frontal response during performance of an affective go/no go task in patients with mania. *Biological Psychiatry* 55, 1163–1170.
- Ernst, M., Dickstein, D.P., Munson, S., Eshel, N., Pradella, A., Jazbec, S., Pine, D.S., Leibenluft, E., 2004. Reward-related processes in pediatric bipolar disorder: a pilot study. *Journal of Affective Disorders* 82S, S89–S101.
- Farmer, A., Lam, D., Sahakian, B., Roiser, J., Burke, A., O'Neill, N., Keating, S., Powell Smith, G., McGuffin, P., 2006. A pilot study of positive mood induction in inter-episode bipolar subjects compared with healthy controls. *Psychological Medicine* 36, 1213–1218.
- Feldman, G.C., Joormann, J., Johnson, S.L., 2008. Responses to positive affect: a self-report measure of rumination and dampening. *Cognitive Therapy and Research* 32 (4), 507–525.
- Forbes, E.E., Miller, A., Cohn, J.F., Fox, N.A., Kovacs, M., 2005. Affect-modulated startle in adults with childhood-onset depression: relations to bipolar course and number of lifetime depressive episodes. *Psychiatry Research* 143, 11–25.
- Fowles, D.C., Christie, M.J., Edelberg, R., Grings, W.W., Lykken, D.T., Venables, P.H., 1981. Publication recommendations for electrodermal measurements. *Psychophysiology* 18, 232–239.
- Fredrickson, B.L., Levenson, R.W., 1998. Positive emotions speed recovery from cardiovascular sequelae of negative emotion. *Cognition and Emotion* 12 (2), 191–220.
- Goplerud, E., Depue, R.A., 1985. Behavioural response to naturally occurring stress in cyclothymia and dysthymia. *Journal of Abnormal Psychology* 94, 128–139.
- Green, M.J., Cahill, C.M., Malhi, G.S., 2007. The cognitive and neurophysiological basis of emotion dysregulation in bipolar disorder. *Journal of Affective Disorders* 29–42.
- Gross, J.J., Thompson, R.A., 2007. Emotion regulation: Conceptual foundations. In: Gross, J.J. (Ed.), *Handbook of emotion regulation*. Guilford Press, New York, NY, pp. 3–24.
- Gross, J.J., Sutton, S.K., Ketelaar, T., 1998. Relationships between affect and personality: support for the affect-level and affective-reactivity views. *Personality and Social Psychology Bulletin* 24 (3), 279–288.
- Grossman, P., Taylor, E.W., 2007. Toward understanding respiratory sinus arrhythmia: relations to cardiac vagal tone, evolution and biobehavioral functions. *Biological Psychology* 74, 263–285.
- Grossman, P., van Beek, J., Wientjes, C., 1990. A comparison of three quantification methods for estimation of respiratory sinus arrhythmia. *Psychophysiology* 27, 702–714.
- Gruber, J., in press. A review and synthesis of positive emotion and reward disturbance in bipolar disorder. *Clinical Psychology and Psychotherapy*.
- Gruber, J., Johnson, S.L., Oveis, C., Keltner, D., 2008. Risk for mania and positive emotional responding: too much of a good thing? *Emotion* 8 (1), 23–33.
- Gruber, J., Culver, J.L., Johnson, S.L., Nam, J., Keller, K.L., Ketter, T.K., 2009. Do positive emotions predict symptomatic change in bipolar disorder? *Bipolar Disorders* 11, 330–336.
- Hofmann, B.U., Meyer, T.D., 2006. Mood fluctuations in people putatively at risk for bipolar disorders. *British Journal of Clinical Psychology* 45, 105–110.
- Howell, D.C., 2007. *Statistical Methods for Psychology*. Cengage Wadsworth, Belmont, CA.
- Johnson, S.L., 2005. Mania and dysregulation in goal pursuit. *Clinical Psychology Review* 25, 241–262.
- Johnson, S.L., Gruber, J., Eisner, L., 2007. Emotion in bipolar disorder. In: Rottenberg, J., Johnson, S.L. (Eds.), *Emotion and Psychopathology: Bridging Affective and Clinical Science*. American Psychological Association, Washington, DC, pp. 123–150.
- Johnson, S.L., Cuellar, A.K., Ruggero, C., Winett-Perlman, C., Goodnick, P., et al., 2008a. Life events as predictors of mania and depression in bipolar I disorder. *Journal of Abnormal Psychology* 117, 268–277.
- Johnson, S.L., McKenzie, G., McMurrich, S., 2008b. Ruminative responses to positive and negative affect among students diagnosed with bipolar disorder and major depressive disorder. *Cognitive Therapy and Research* 32 (5), 702–713.
- Kring, A.M., Werner, K.H., 2004. Emotion regulation in psychopathology. In: Philippot, P., Feldman, R.S. (Eds.), *The Regulation of Emotion*. LEA, New York, NY, pp. 359–385.
- Lawrence, N.S., Williams, A.M., Surguladze, S., Giampietro, V., Brammer, M.J., Andrew, C., et al., 2004. Subcortical and ventral prefrontal cortical neural responses to facial expressions distinguish patients with bipolar disorder and major depression. *Biological Psychiatry* 55, 578–587.
- Lovejoy, M.C., Steuerwald, B.L., 1995. Subsyndromal unipolar and bipolar disorders: comparisons on positive and negative affect. *Journal of Abnormal Psychology* 104, 381–384.
- M'Bailara, K., Demotes-Mainard, J., Swendsen, J., Mathieu, F., Leboyer, M., Henry, C., 2009. Emotional hyper-reactivity in normothymic bipolar patients. *Bipolar Disorders* 11, 63–69.
- Mackinnon, A., Jorm, A.F., Christensen, H., Korten, A.E., Jacomb, P.A., Rodgers, B.A., 1999. A short form of the positive and negative affect schedule: evaluation of factorial validity and invariance across demographic variables in a community sample. *Personality and Individual Differences* 6, 392–405.
- Mauss, I.B., Levenson, R.W., Loren, M., Wilhelm, F., Gross, J.J., 2005. The tie that binds? Coherence among emotion experience, behavior, and physiology. *Emotion* 5, 175–190.
- Meyer, B., Baur, M., 2009. Positive and negative affect in individuals at high and low risk for bipolar disorders. *Journal of Individual Differences* 30 (3), 169–175.
- Meyer, B., Johnson, S.L., Winters, R., 2001. Responsiveness to threat and incentive in bipolar disorder: relations of the BIS/BAS scales with symptoms. *Journal of Psychopathology and Behavioral Assessment* 23, 133–143.
- Miller, G.A., Chapman, J.P., 2001. Misunderstanding analysis of covariance. *Journal of Abnormal Psychology* 110, 40–48.
- Oveis, C., Cohen, A.B., Gruber, J., Shiota, M.N., Haidt, J., Keltner, D., 2009. Respiratory sinus arrhythmia is associated with tonic positive emotionality. *Emotion* 9, 265–270.
- Phillips, M.L., Vieta, E., 2007. Identifying functional neuroimaging biomarkers of bipolar disorder: toward DSM-V. *Schizophrenia Bulletin* 33 (4), 893–904.
- Porges, S.W., 1991. Vagal tone: an autonomic mediator of affect. In: Garber, J.A., Dodge, K.A. (Eds.), *The Development of Affect Regulation and Dysregulation*. Cambridge University Press, New York, NY, pp. 111–128.
- Rogosa, D.R., Willett, J.B., 1983. Demonstrating the reliability of the difference score in the measurement of change. *Journal of Education Measurement* 20 (4), 335–343.
- Rottenberg, J., Ray, R.R., Gross, J.J., 2007. Emotion elicitation using films. In: Coan, J.A., Allen, J.J.B. (Eds.), *The Handbook of Emotion Elicitation and Assessment*. Oxford University Press, New York, NY, pp. 9–28.
- Ruef, A.M., Levenson, R.W., 2007. Continuous measurement of emotion. In: Coan, J.A., Allen, J.J.B. (Eds.), *The handbook of emotion elicitation and assessment*. Oxford University Press, New York, pp. 286–297.
- Ruggero, C., Johnson, S.L., 2006. Reactivity to a laboratory stressor among individuals with bipolar I disorder in full or partial remission. *Journal of Abnormal Psychology* 115 (3), 539–544.
- Rush, A.J., Gullion, C.M., Basco, M.R., Jarrett, R.B., Trivedi, M.H., 1996. The Inventory of Depressive Symptomatology (IDS): psychometric properties. *Psychological Medicine* 26, 477–486.
- Russell, J.A., Weiss, A., Mendelsohn, G.A., 1989. Affect grid: a single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology* 57, 493–502.
- Shrout, P.E., Fleiss, J.L., 1979. Intraclass correlations: uses in assessing rater reliability. *Psychological Bulletin* 86, 420–428.
- Spitzer, R.L., Williams, M., Gibbon, M., First, M.B., 1990. *Structured Clinical Interview for DSM-III-R*. American Psychiatric Press, Washington, DC.

Stern, G.S., Berrenberg, J.L., 1979. Skill-set, success outcome, and mania as determinants of the illusion of control. *Journal of Research in Personality* 13, 206–220.

Sutton, S.K., Johnson, S.L., 2002. Hypomanic tendencies predict lower startle magnitudes during pleasant pictures. *Psychophysiology* 39, 80.

Volokhov, R.N., Demaree, H.A., 2010. Spontaneous emotion regulation to positive and negative stimuli. *Brain and Cognition* 73, 1–6.

Young, R.C., Biggs, J.T., Ziegler, V.E., Meyer, D.A., 1978. A rating scale for mania: reliability, validity and sensitivity. *British Journal of Psychiatry* 133, 429–435.

Yurgelun-Todd, D.A., Gruber, S.A., Kanayama, G., Killgore, W.D.S., Baird, A.A., Young, A.D., 2000. fMRI during affect discrimination in bipolar affective disorder. *Bipolar Disorders* 2, 237–248.