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Journal
International Journal of Cognitive Therapy, 9(4)

ISSN
1937-1209

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Publication Date
2016-12-01

DOI
10.1521/ijct_2016_09_12

Peer reviewed

Int J Cogn Ther. Author manuscript; available in PMC 2017 December 01.

Published in final edited form as:
Int J Cogn Ther. 2016 December ; 9(4): 295–312. doi:10.1521/ijct_2016_09_12.

Eye Tracking of Attention to Emotion in Bipolar I Disorder: Links to Emotion Regulation and Anxiety Comorbidity

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Abstract

Research has yielded mixed findings regarding whether bipolar disorder is related to attentional bias for emotionally-relevant stimuli, yet little research has utilized advances in eye-tracking technology to study attention in this population. The current study used a free-viewing eye-tracking paradigm to test whether people with remitted bipolar disorder show preferential attention to positive faces, and to test if comorbid anxiety or emotion regulation strategies are related to attention bias. Twenty-nine adults with bipolar I disorder and 28 control participants viewed images of emotionally valenced faces while their gaze was tracked, and participants completed self-report measures of emotion regulation. Contrary to hypotheses, people with bipolar disorder did not differ from control participants in attention to positive stimuli, and both anxiety comorbidity and emotion regulation were unrelated to attentional indices. Unlike some findings in unipolar depression, these results suggest that attention to valenced faces may not be characteristic of remitted bipolar disorder.

Among individuals diagnosed with mental illness, the experience and regulation of emotion is often disrupted (Kring & Sloan, 2010). Alterations in attention to valenced stimuli (‘attentional bias’) have been hypothesized as a mechanism that might explain some of the emotion disruptions in this population (Beck, 1976; Mathews & MacLeod, 2005). Several decades of empirical findings indicate that attentional bias helps to predict symptoms of depression (Beevers & Carver, 2003; Beevers, Lee, Wells, Ellis, & Telch, 2011), suicidal ideation (Cha, Najmi, Park, Finn, & Nock, 2010), and post-traumatic stress disorder (Wald et al., 2011).

There are several theoretical and empirical reasons to suggest that bipolar disorder may be associated with an attentional bias towards positive stimuli. People with bipolar disorder often continue to experience mood disturbances even after remission (Judd et al., 2008). Mood state influences attention toward emotionally salient cues (Kaspar & König, 2012; Yiend, 2010), and even a subtly positive mood can influence cognitive processes in bipolar disorder (Trevisani, Johnson, & Carver, 2008; Roiser et al., 2009). Beyond current mood state, some evidence suggests that people with bipolar disorder experience trait-like, inflexible elevations in positive emotion (Gruber, 2011a; 2011b), and there is strong

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Conflict of Interest Statement
Mr. Peckham, Dr. Johnson, and Ms. Tharp declare that they have no conflict of interest.

evidence for elevated sensitivity to reward and increased levels of goal pursuit in bipolar disorder (Johnson, Edge, Holmes, & Carver, 2012). Taken together, these findings raise the possibility that trait-like elevations in positive affect, sensitivity to reward, and pursuit of goals would confer a bias towards positive stimuli.

Despite theory, research on attentional bias in bipolar disorder has produced mixed findings, particularly among remitted persons with bipolar disorder (García-Blanco, Salmerón, Perea, & Livianos, 2014; García-Blanco, Salmerón, & Perea, 2015; Jabben, Arts, Jongen, Smulders, van Os, & Krabbendam, 2012; Jongen, Smulders, Ranson, Arts, & Krabbendam, 2007; Kerr, Scott, & Phillips, 2005; Lex, Meyer, Marquart, & Tau, 2008). The lack of consistent findings may be due to several factors. First, bipolar disorder is highly heterogeneous and is frequently comorbid with other disorders (Kessler, Rubinow, Holmes, Abelson, & Zhao, 1997; Tohen et al., 2003). In particular, many individuals with bipolar disorder also meet diagnostic criteria for anxiety disorders (Boylan, Bieling, Mariott, Begin, Young, & MacQueen, 2004; McIntyre, Soczynska, Bottas, Bordbar, Konarski, & Kennedy, 2006; Simon et al., 2004), and anxiety comorbidity has rarely been controlled for in attentional research in this population. Anxiety disorders are often characterized by early attention to threat followed by disengagement (Armstrong & Olatunji, 2012; Bögels & Mansell, 2004). Within bipolar disorder, subsyndromal symptoms of anxiety appear to be generally unrelated to attentional bias (French, Richards, & Scholfield, 1996; García-Blanco et al., 2014; Kerr et al., 2005), whereas the single available study of anxiety comorbidity and attentional bipolar disorder suggests that anxiety diagnosis is an important predictor of attentional bias toward cues of threat within bipolar disorder (Brotman et al., 2007). Thus, it is possible that clinically significant anxiety rather than sub-threshold anxiety symptoms confers a bias towards threat within bipolar disorder.

Second, heterogeneity in findings may relate to differences in emotion regulation strategies. Although few empirical studies are available, Joormann and colleagues have proposed that individual differences in cognitive biases, including attentional biases, may influence the use of specific emotion regulation strategies in major depression (Joormann & D'Avanzato, 2010; Joormann & Vanderlind, 2014). Laboratory studies in healthy populations suggests that aspects of cognition do indeed affect some types of emotion regulation (Schmeichel, Volokhov, & Demaree, 2008), though a recent review highlights that the relationship between cognition and emotion regulatory capabilities may differ depending on the type of regulation and cognition in question, and that much remains to be understood about this broad relationship (Schmeichel & Tang, 2015). Thus, while it is probable that cognitive bias may underlie some aspects of emotion regulation, the direction and nature of this relationship is not well understood in bipolar disorder.

Understanding correlates of emotion regulation strategies may be particularly important in bipolar disorder: not only have people with bipolar disorder been found to report a heightened frequency of using certain emotion regulation strategies (Edge et al., 2013; Gruber, Eidelman, Johnson, Smith, & Harvey, 2011; Thomas, Knowles, Tai, & Bentall, 2007), there is also evidence that they find these strategies somewhat less effective (Gruber, Harvey, & Gross, 2012). Preferred emotion regulation strategies also likely vary within bipolar disorder: whereas some research finds greater use of rumination on positive affect, including a tendency to amplify positive emotion (e.g., Gruber et al., 2011), others have found no differences between those with and without the disorder in this domain (Edge et al., 2013). Other research suggests rumination on negative affect is an important correlate of bipolar disorder, with heightened rumination on negative affect observed even during remission (Thomas et al., 2007; Van der Gucht, Morriss, Lancaster, Kinderman, & Bentall, 2009).

One possibility is that variability in emotion regulation use is related to meaningful differences in cognitive biases within bipolar disorder. Consistent with this idea, in previous research, we found that dampening positive affect was related to reduced attentional bias to positive stimuli in people with bipolar disorder (Peckham, Johnson, & Gotlib, 2015). Beyond the singular emotion regulation strategy assessed in that study, attention to emotion cues may relate to other emotion regulation strategies, including regulation of negative affect, in bipolar disorder.

In sum, some evidence suggests that emotion regulation strategies interact with attention to emotion in bipolar disorder, but heterogeneity in regulatory strategies and in history of mood episodes might also shape how one attends to emotionally relevant cues. The degree to which this inter-individual variability in regulatory strategies is related to underlying differences in attention is unclear, and could also explain why no consistent pattern of attentional bias has emerged in this population.

To test these hypotheses, eye-tracking technology vastly improves ability to capture temporal dynamics of attention compared to older reaction time-based measures of attention (Armstrong & Olatunji, 2012), and as such may help refine models of attention in bipolar disorder. More specifically, eye-tracking methods allow for the differentiation of multiple components of attention, including initial orienting (e.g., location and time of initial fixations), engagement with individual stimuli (e.g., average glance duration), and sustained attention (e.g., total time spent fixating on a given stimulus over time). In a meta-analysis of more than 20 studies, Armstrong and Olatunji (2012) concluded that eye-tracking paradigms have helped identify unique patterns of attention in anxiety disorders and unipolar depression. Despite the rapid growth over the past two decades in use of this technology to assess attentional bias in depression and anxiety, only one published study has used eye tracking methodology in bipolar disorder (García-Blanco et al., 2014). Garcia-Blanco and colleagues evaluated attention to valenced pictures in a sample of euthymic, depressed, and manic individuals; findings indicated that regardless of phase of illness, all participants in the bipolar group showed significant bias towards threatening images, and those with current depression showed reduced attention to positive images. Thus, the advanced specificity provided by this technology may uncover subtle patterns of bias in bipolar disorder that were undetected by earlier paradigms.

The goals of the present study were to test three hypotheses. First, based on previous literature regarding positive affect disturbance (Gruber, 2011a, 2011b), we hypothesized that euthymic persons with bipolar disorder would show enhanced visual attention towards positive cues. Second, drawing on previous findings in the anxiety literature (Armstrong & Olatuni, 2012; Bar-Haim et al., 2007; Bögels & Mansell, 2004), we predicted that comorbid anxiety within bipolar disorder would predict bias towards threat-related cues and particularly to more frequent initial gaze fixations toward threat stimuli. Third, we tested the relationship of two emotion regulation strategies with attentional bias, hypothesizing that greater dampening of positive affect would be associated with less attention to positive cues, and that rumination on negative affect would be associated with greater attention to negatively valenced stimuli.

To examine these hypotheses, we recruited a carefully diagnosed sample of persons with bipolar I disorder, and we followed persons longitudinally until they achieved remission. We compared the bipolar sample to a well-matched control group. Attentional bias was assessed using eye-tracking methodology. To test attentional bias to emotion cues, participants were presented with images of emotionally valenced faces, following on the success of these stimuli for attentional bias in unipolar depression (e.g., Isaac, Vrijsen, Rinck, Speckens, & Becker, 2014; Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013). This is the first study of attentional biases to facial stimuli using eye tracking methodology within bipolar disorder.

Method

Participants

Participants were 33 adults with bipolar I disorder and 31 control adults with no history of a mood disorder (Major Depressive Disorder, Bipolar Disorder, Dysthymia, or Cyclothymia). These participants were recruited as part of a larger study of cognitive and emotional functioning in bipolar disorder (see also Edge, Lwi, & Johnson, 2015; Ng & Johnson, 2013). Due to problems with eye-tracker calibration, five participants (three controls and two with bipolar disorder) were excluded from analysis. Data from two additional participants were excluded due to missing eye-tracking data on the majority of trials, resulting in a final sample of 29 adults with bipolar I disorder and 28 control adults. Participants were recruited via online advertising in the San Francisco Bay Area. Inclusion criteria included age between 18 and 60, English language fluency, and the presence of either bipolar I disorder or no history of mood disorder. Potential participants were excluded from study participation if they met criteria for any of the following: current substance use disorder per the Structured Clinical Interview for DSM-IV (SCID), recent treatment with ECT, a diagnosis of a primary psychotic disorder, developmental or cognitive disabilities that would interfere with task completion, colorblindness, brain injury or neurological disorders, or any history of eye injury or disease that would interfere with data collection.

The SCID was used to verify diagnostic status of those in the bipolar disorder group, and to rule out history of mood disorder among control participants. Participants with bipolar disorder also completed two mood rating interviews, the Modified Hamilton Rating Scale for Depression (MHRSD; Miller, Bishop, Norman, & Maddever, 1985) and the Young Mania Rating Scale (YMRS; Young, Biggs, Ziegler, & Meyer, 1978), to verify remission of mood symptoms. Participants scoring below a seven on the MHRSD and YMRS were invited to complete further study procedures, and those who did not meet this threshold were followed with monthly phone calls to complete symptom rating interviews (MHRSD and YMRS) until their mood symptoms abated.

Measures

SCID (First, Spitzer, Gibbon, & Williams, 1996)—The SCID is a semi-structured diagnostic interview used to assess for the lifetime presence of a number of common psychiatric diagnoses. In the current study, SCID interviewers completed didactic and role-play training and a series of reliability assessments prior to interviewing study participants. Interviews were audio-recorded, and ten recordings were selected at random for analysis of reliability. Reliability for current and lifetime manic episodes as well as lifetime major depressive episodes (ICC = .88 to .89) was found to be good. Participants were classified as having history of an anxiety disorder if they had ever met criteria per the SCID for Generalized Anxiety Disorder, Panic Disorder, Obsessive-Compulsive Disorder, Post-Traumatic Stress Disorder, Agoraphobia, Social Anxiety Disorder, or a Specific Phobia.

Modified Hamilton Rating Scale for Depression (MHRSD; Miller et al., 1985)— The MHRSD is a 17-item semi-structured interview that assesses for the severity of depressive symptoms in the past week, with standardized probes and behavioral anchors added to the original Hamilton Rating Scale for Depression in order to increase reliability. Total scores range from 0 to 52. For the present study, interviewers completed role-plays and training prior to conducting audiotaped interviews. Inter-rater reliability of this measure was very good (ICC = .99; based on four randomly selected interviews). The MHRSD has been well-validated in bipolar disorder (Johnson et al., 2000; 2008).

Young Mania Rating Scale (YMRS; Young et al., 1978)—The YMRS is a well-validated semi-structured interview that assesses for the severity of mania in the past week. This interview contains 11 items that produce a total score ranging from 0 to 60. In the present study, procedures for training and administration of the YMRS were similar to those described for the SCID and MHRSD. Based on ratings from four recordings selected at random, inter-rater reliability for this measure was strong (ICC > .99).

Responses to Positive Affect Scale (RPA; Feldman, Joormann, & Johnson, 2008)—The RPA is a self-report scale designed to measure the frequency of use of positive emotion regulation strategies. Participants are prompted to respond based on how they would typically react when in a positive mood. Each of the 17 items are rated on a four-point scale ranging from 1 = *almost never* to 4 =*almost always*. Responses to the RPA yield three subscales supported by factor analysis (Feldman et al., 2008): Dampening (e.g., “think about things that could go wrong”), Emotion Focus (e.g., “think about how happy you feel,”) and Self-Focus (e.g., “think about how proud you are of yourself”). The RPA has been shown to have good internal consistency and convergent validity (Feldman et al., 2008). For the present study, only the Dampening subscale was analyzed as this scale has been most consistently found to be elevated among those with bipolar I disorder (Edge et al., 2013; Gruber et al., 2011) and to be related to lower functioning within bipolar I disorder (Edge et al., 2013). Internal consistency for this scale was good (alpha = .81).

Ruminative Responses Scale (RRS; Nolen-Hoeksema and Morrow, 1991; Treynor, Gonzalez, & Nolen-Hoeksema, 2003)—The RRS is a self-report measure of rumination on negative affect. The RRS contains 22 items assessing frequency of rumination on negative affect, rated on a four-point scale from *almost never* to *almost always*. These items yield three factor analytically-derived subscales; in the present study, only the Brooding subscale (4 items) was used, as this subscale captures maladaptive repetitive thought that has been found to relate to depression both cross-sectionally and prospectively (Treynor et al., 2003). Internal consistency for this subscale was acceptable in the present study (alpha = .82).

Mood and Confidence Checks (MACC)—Current mood state was assessed by six questions asking about current mood and arousal levels immediately before the experimental task, presented on a computer screen. Participants were presented with a series of six adjectives describing different mood states (enthusiastic, frustrated, tired, confident, nervous, and sad), and were asked to rate their current level of each on a five-point scale, ranging from 1 = *Very little or not at all* to 5 = *Extremely*.

Stimuli

Stimuli for this study were 96 black and white photographs of 24 different actors (12 male, 12 female) portraying happy, sad, or fearful facial expressions, as well as a neutral expression. Stimuli were selected from the Montreal Set of Facial Displays of Emotion (MSFDE; Beaupré & Hess, 2005), a normed dataset of actors posing with valenced facial expressions validated by raters using the FACS coding system (Ekman & Friesen, 1978). The MSFDE is a large, multi-racial stimulus set that has been widely used in studies of emotion in both psychopathology and healthy samples (cf. Adams, Nelson, Soto, Hess, & Kleck, 2012; Beaupré & Hess, 2006; Combs, Chapman, Waguspack, Basso, & Penn, 2011; Stanley & Blanchard-Fields, 2008). Stimuli were adjusted to ensure equivalent luminance using Photoshop (Adobe Software, San Jose, CA).

Eye-tracking Apparatus

Gaze location was measured with a Tobii T120 eye-tracker (Tobii Technologies, Danderyd, Sweden). Participants were seated approximately 70 cm from a 17-inch integrated eye-tracking monitor with a 1280 × 1024 screen resolution, and gaze location (x and y coordinates) of both pupils was recorded via infrared eye-tracking. Gaze location was recorded at 120 Hz, providing one sample every 8.3 milliseconds. Participants' heads were not restrained, as this model of eye-tracker can automatically correct for small head movements (Tobii Eyetracking Whitepaper, Tobii Technologies). Stimuli were programmed with E-Prime software (version 2.0) on a separate computer that was synchronized with the eye-tracker using Tobii extensions for E-prime (Psychology Software Tools, Pittsburgh, PA). Each of the four faces shown per trial was designated as an Area of Interest (AOI) for analysis of gaze patterns. Fixations were defined based on gaze location and velocity of eye movements, with continuous gaze positions of greater than 100 msc and a change in position of fewer than 30 pixels classified as a fixation (cf. Salvucci & Goldberg, 2000).

Procedures

Participants who met eligibility criteria described above were invited to the laboratory to complete SCID interviews as well as the questionnaires described above. Individuals with bipolar disorder completed mood rating interviews (MHRSD and YMRS) over the telephone within two days prior to the eye tracking session. Participants with bipolar disorder who met eligibility requirements but were currently symptomatic (based on criteria described above) were followed with monthly phone calls to re-assess symptoms of depression and mania, and were invited to complete in-person assessments once symptoms were within the remitted range (below seven on both the YMRS and MHRSD). Data collection for this portion of the study took place in a windowless room with constant luminance from overhead lights, to minimize light-related effects on gaze behavior. Immediately before completing the eye-tracking task, participants rated their current mood with a series of questions about current mood state displayed on the computer screen.

Eye-tracking Paradigm—A nine-point calibration was used before beginning experimental procedures. Participants then viewed instructions on the computer screen reminding them to keep their eyes on the screen, and informing them that the task would consist of looking at images of different people's faces. Before the task, participants were not informed that the task would include different expressions of emotion. The eye-tracking paradigm employed in this study was a free-viewing task modeled after similar paradigms used in previous studies investigating attention and unipolar depression (e.g., Kellough, Beevers, Ellis, & Wells, 2008). Participants viewed 24 10-second trials, each of which included four images of the same actor displaying different facial expressions (one each of sad, happy, fearful, and a neutral expression). Each image was 5.8 inches wide by 4.2 inches tall, and four images were displayed simultaneously on the screen in a 2×2 grid. Images were randomized across trials so that a different progression of actors appeared for each participant, and also within trials so that each emotion displayed was randomly allocated to a different position on each trial. Each trial was separated by a 1-second fixation cross in the center of the screen. Eye-tracking data were first cleaned to remove blinks and other periods of missing data, as defined by the standard settings within the Tobii T120 system.

Only trials that included at least 60 percent valid datapoints were analyzed (cf. Beevers et al., 2011). Based on previous eye-tracking studies of attentional bias in psychopathology (Armstrong & Olatunji, 2012; Eizenman et al., 2003; Isaac et al., 2014; Kellough et al., 2008), we focused on three key attentional parameters that have been broadly used in literature on attentional biases in psychopathology: total fixation time (reflecting sustained attention over the entire trial), average duration of individual fixations (number of milliseconds that participants attended to individual stimuli per fixation, reflecting attentional engagement with an individual stimulus) and location of initial fixation (where participants looked first, reflecting initial orienting of attention). Total fixation time was defined as the mean proportion of time per trial spent fixating on a given emotion category. Average duration was defined as the average length of fixations for each emotion, averaged across trials. Location of initial fixation was defined as the proportion of the total trials in which the initial fixation was to a given emotion. Each of these parameters were calculated separately per emotion (happy, sad, fear, and neutral). For analyses within the bipolar group, we focus on initial orientation to threat in relation to anxiety disorders, drawing on previous research within the anxiety field (Armstrong & Olatuni, 2012). In considering the effects of emotion regulation on attentional biases, we focus on total fixation time, as this index has received strong support in prior research on eye-tracking parameters in mood disorders (e.g., Armstrong & Olatunji, 2012, Kellough et al., 2008).

Results

All data were analyzed using SPSS, version 21.0 (IBM, Chicago, IL, USA). Distributions were reviewed for normalcy before conducting primary analyses. Alpha was set to .05. As shown in Table 1, bipolar and control groups were well-matched and did not significantly differ in age, gender, racial or ethnic composition, or level of education. Seventeen of 30 participants with bipolar disorder met diagnostic criteria for a history of at least one diagnosed anxiety disorder, while none of the control participants had a history of anxiety disorder. Of the participants with bipolar disorder, approximately two-thirds (21 participants) met diagnostic criteria for a prior episode of depression. Table 1 also shows that people with bipolar disorder reported using significantly more dampening of positive affect (RPA) and more frequent brooding on negative affect (RRS) than did control participants. Groups were somewhat comparable with regard to current mood state: though people with bipolar disorder reported feeling more tired, less confident, and marginally more sad than controls, groups did not differ on current levels of enthusiasm, frustration, or nervousness.

Influence of Age, Gender, and Current Mood State on Attention

Before testing hypotheses, age, gender, and mood state were considered as potential confounds affecting attention to emotionally valenced images. Age was not significantly correlated with any attentional parameter in either the control or bipolar group (all $|r|$s < .34, $|p|$s > .09). To test the influence of gender, gender was added as a between-groups factor to each of the three ANOVA tests described below. There were no significant main effects of gender, nor were the two-way interactions of Diagnostic Group × Gender significant for any of the attentional parameters.[1]

The effect of current mood state on attention to emotion was also evaluated, using Pearson correlations to test whether self-reported affect influenced attentional parameters within each diagnostic group. Among control participants, confidence correlated with greater total fixation time to neutral faces, $r = .42$, $p = .03$ and with fewer initial fixations to happy faces, $r = -.52$, $p = .01$, and tiredness correlated with fewer first fixations to neutral, $r = -.39$, $p < .05$. Among participants with bipolar disorder, nervousness was correlated with longer average fixations on sad faces, $r = .44$, $p = .02$, and on fearful faces, $r = .38$, $p = .04$.[2]

Among participants with bipolar disorder, current mood symptoms were also evaluated as a potential correlate of attention to emotion. Pearson correlations were computed separately for current manic (YMRS) and depressive symptoms (MHRSD), each with attentional

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[1] A significant Emotion by Gender interaction was observed for average fixation duration, $F(2.23, 118.24) = 3.81$, $p = .01$, partial $\eta^2 = .07$. Post-hoc t-tests showed that women spent significantly less time viewing happy faces compared to men ($t[44.2] = 2.47$, $p = .02$).

[2] The three primary ANOVA tests were also conducted covarying for tiredness, nervousness, and confidence. Parallel to the main analyses, including these covariates did not result in any significant main effects of group (Total fixation time, $F[1,51] = 0.42$, $p = .52$; average fixation time: $F[1,51] = 0.01$, $p = 0.92$); location of first fixation: $F[1,51] = 0.38$, $p = 0.54$) nor any significant group by emotion interactions (Total Fixation Time: $F[1.52, 77.56] = .13$, $p = .82$, average fixation length, $F[2.15, 109.89] = 0.70$, $p = .51$, location first fixation: $F[2,102] = 0.18$, $p = 0.83$). With these covariates included, main effects of Emotion were no longer observed for total fixation time or average fixation time (ps > 0.36).

parameters for total fixation time, average length, and location of first fixation for each of the three valenced faces. Current symptoms were unrelated to total fixation time, average length, or location of first fixation for any emotion (all *p*s > .09). Depressive symptoms were correlated with longer total ($r = .39$, $p = .04$) and average ($r = .46$, $p = .02$) fixation times to neutral faces, but were unrelated to attention to valenced faces.

Do Individuals with Bipolar Disorder Differ from Controls in Attention to Emotion Relevant Stimuli?

Mixed-model analysis of variance was used to test primary hypothesis regarding group differences in attention to affective stimuli, with diagnostic group (2: bipolar or control) as a between-subjects factor and facial emotion (3: happy, sad, and fearful) as a within-subjects factor. Separate, parallel ANOVAs were conducted for total fixation time, average duration, and percentage of initial fixations (see Table 2 for means). When tests of sphericity were violated, the Greenhouse-Geisser correction was used for these analyses. For comparison with the literature, Table 2 includes the means for the neutral condition; these are not included in the ANOVA for Total Fixation Time and Location of First Fixation, however, as they are fully conditional on the means for the emotion conditions.

For total fixation time, analyses revealed a significant main effect of emotion ($F[1.51, 83.06] = 15.27$, $p < .001$, partial $\eta^2 = .22$). Post-hoc pairwise comparisons showed that participants spent significantly less time viewing sad faces than the two other emotions across each trial as a whole ($p < .01$ for each comparison), as well as significantly more time viewing happy faces than the other two emotions ($p < .01$ for each comparison). There was no significant main effect of group ($F[1, 55] = 0.04$, $p = .84$, partial $\eta^2 = .001$), and the interaction of group and emotion was not significant ($F[1.51, 83.06] = 0.01$, $p = .97$, partial $\eta^2 < .001$).

Results were largely parallel when average duration was the dependent variable: again, a main effect of emotion emerged ($F[2.16, 118.81] = 11.71$, $p < .001$, partial $\eta^2 = .18$), but the effect of group ($F[1, 55] = 0.12$, $p = .74$, partial $\eta^2 = .002$) and the interaction of group and emotion ($F[2.16, 118.81] = 0.35$, $p = .72$, partial $\eta^2 = .006$) were not significant. Participants in both groups fixated for a significantly shorter period of time on sad faces than to other images ($p < .001$ for each comparison), and fixated for longer period of times on happiness as compared to other images ($p < .05$ for each comparison). Finally, there was no effect of emotion on location of first fixation ($F[2, 110] = 2.29$, $p = .11$, partial $\eta^2 = .04$), no effect of group ($F[1, 55] = .72$, $p = .40$, partial $\eta^2 = .01$) nor a group by emotion interaction ($F[2, 110] = 0.46$, $p = .64$, partial $\eta^2 < .01$).

In sum, the emotional valence of images was linked with the total time spent viewing those images and the average length of time participants dwelled on an emotion for a given fixation. Nonetheless, bipolar and control groups did not differ significantly in their attention to emotionally valenced images.

Does Comorbid Anxiety Predict Attention to Emotion in Bipolar Disorder?

Within the bipolar disorder group, the proportion of initial fixations to threat was compared for individuals with an anxiety disorder (BD+Anx, $n = 17$) as compared to those with no history of anxiety disorder (BD-Anx, *n* =12). Those with a comorbid anxiety disorder made significantly fewer initial fixations towards sad faces, $t(27) = 2.58$, $p = .02$, Cohen's $d = .99$, but contrary to hypotheses, did not differ in the proportion of initial fixations to fear faces, $t(27) = 0.94$, $p = .36$, Cohen's $d = .36$.

Are Emotion Regulation Strategies Related to Attention to Emotionally Valenced Images?

Pearson correlations within the bipolar and control groups separately were used to test the relationship of brooding and dampening with total fixation time per emotion (see Table 3). One participant with bipolar disorder did not complete the RPA and RRS measures. Within the bipolar group and the control group, rumination on negative affect was unrelated to total fixation times for any emotion. Dampening of positive affect was numerically associated with reduced attention to happy faces in both groups, but this association did not reach significance, and dampening was also unrelated to total fixation times for fear or sadness.

Discussion

Previous literature on attentional bias in remitted bipolar disorder has been inconclusive, but the majority of these findings rest on reaction-time based paradigms that are less sensitive than eye-tracking technology (Armstrong & Olatunji, 2012), and many have used paradigms that have been criticized on methodological grounds, such as the emotional Stroop task (Algom, Chajut, & Lev, 2004) and the dot probe task (Schmukle, 2005). We also argued that these mixed results might reflect important sample differences in anxiety comorbidity or emotion regulation strategies. The current study was one of the first studies to use the technological advances afforded by eye-tracking to test attentional biases for emotion-relevant stimuli in remitted bipolar disorder. Attentional bias for emotionally valenced stimuli was tested in a sample of adults with bipolar I disorder and a well-matched control group with no history of mood disorder, using eye-tracking technology. Participants with bipolar disorder were followed with monthly interviews until they achieved remission, and then tested during that state. Multiple indices of attention to emotion-relevant cues were considered: initial orientation of attention, attentional engagement, and sustained attention to happy, sad, and fearful faces.

Participants with bipolar disorder did not differ from control participants on any attentional variable. That is, bipolar and control groups did not differ on initial orienting of attention, average duration, or total fixation time, to sad, fearful, or happy stimuli. This null effect of diagnostic group appeared to be consistent across genders. The null results did not appear to be explained by the low sample sizes: Effect sizes for Group and Group × Emotion effects were small, explaining two percent or less of the variance in attention to emotion. This central finding suggests that even with high-resolution, sensitive eye tracking assessment, attentional biases to valenced stimuli are difficult to document within bipolar disorder. People with remitted bipolar disorder allocated attention to emotionally valenced images in nearly identical ways to control participants.

Caution is warranted concerning the absence of group effects. In other recent studies using eye-tracking methods to study attentional bias to emotionally valenced stimuli, euthymic participants with bipolar disorder showed evidence of bias towards threatening images, such as pictures of a gun pointed at the viewer (García-Blanco et al., 2014, 2015). Although people with bipolar disorder may not attend to social cues of threat and danger expressed in facial expressions any differently from those without the disorder, they may show abnormal attentional processing of more overtly threatening images.

In parallel, we failed to obtain support for the hypothesis that comorbid anxiety disorders within bipolar disorder would be related to initial attentional vigilance for threat, as operationalized by a higher proportion of initial fixations to faces depicting fear. We cannot rule out the possibility that the observed link of anxiety with fewer initial fixations to sad faces is spurious. Comparing this finding to other studies of attention in bipolar disorder again suggests that specificity in stimuli is key: Brotman and colleagues (2007) found that children with bipolar disorder and anxiety showed enhanced attention to angry faces, while the present study used faces expressing fear rather than anger. It is possible that the fear faces stimuli in the present study were not evocative enough of threat, whereas overtly threatening stimuli such as the angry faces used by Brotman and colleagues (2007) or the threatening images employed by Garcia-Blanco and colleagues (2014; 2015) each were sufficient to draw greater attention.

Beyond the null findings for negative stimuli, our findings are consistent with those of García-Blanco and colleagues (2014; 2015) in observing no significant bias toward positively valenced stimuli during euthymic states. Despite other disturbances in positive affect noted in bipolar disorder (Gruber, 2011a, 2011b; Johnson et al., 2012), these three studies suggest that euthymic bipolar disorder may not be characterized by abnormal attentional processing of positive stimuli.

The present study is also unique in conjointly considering the relationship between attentional bias and two emotion regulation strategies previously linked with bipolar disorder: ruminating on negative affect and dampening positive affect. We predicted that dampening positive affect would be associated with reduced attention to happy faces, and that ruminating on negative affect would be associated with greater attention for sad faces. Consistent with previous research, participants diagnosed with bipolar disorder endorsed significantly higher levels of both rumination on negative affect and dampening positive affect than did controls (Edge et al., 2013; Gruber et al., 2011; Thomas, et al., 2007), but these emotion regulation strategies were similarly unrelated to their attention to emotionally valenced faces.

Further, we note that these null findings do not rule out the possibility that other aspects of cognition influence emotion regulation in bipolar disorder. Joormann and colleauges (2010; 2014), in reviewing findings within unipolar depression, have proposed that many aspects of cognition, including cognitive control deficits, interpretation bias, and biased memory of affective stimuli may all influence emotion regulation strategies. In parallel, there is evidence for the alteration of numerous aspects cognition in bipolar disorder, including cognitive control deficits (Bora, Yucel, & Pantelis, 2009) and intrusive affective memories (Gregory, Brewin, Mansell, & Donaldson, 2010), so it will be important for future studies to continue testing links between these cognitive and affective aspects of bipolar disorder.

Several limitations of the present study are important to note. First, the relatively small sample size limits our ability to detect small effect sizes; in this regard, it is notable that none of the ANOVA effect sizes tested reached even a moderate level. Second, our reliance on a cross-sectional design precludes any statements about whether attentional biases will help predict or understand mood symptoms or emotion regulation over time. Third, our study is only relevant to understanding remitted bipolar disorder. At least one eye-tracking study of unipolar depression has found evidence of alterations in average fixation time to valenced faces during mood episodes that were not observed during remission (Isaac et al., 2014), and others have noted mood episode-specific patterns of attentional bias in bipolar disorder (García-Blanco et al., 2014), so further studies may benefit from studying attention to valenced faces in different mood states. Fourth, the current study focused entirely on facial displays of emotion. Other types of positive valenced stimuli might be important to consider in eye-tracking paradigms in this population. As one example, previous research has suggested that people with bipolar disorder engage in high levels of goal pursuit (Johnson et al., 2012)—one potential avenue for study would be to consider a broader range of reward-relevant cues, such as images of success, reward, and attainment of goals. Similarly, as noted above, more directly threatening stimuli may also be more powerful determinants of attention within bipolar disorder.

In sum, this study found that remitted people with bipolar disorder did not differ significantly from control participants on any aspect of attention to emotion-relevant stimuli, and that anxiety comorbidity and emotion regulation strategies did not predict attentional vigilance for threat cues. Although the study of attentional biases to facial displays of emotion has been enormously helpful in other psychopathology, current findings join with a series of other findings using less sensitive technologies to suggest that it may be best to focus on cognitive parameters other than attentional biases to facial expressions of emotion within bipolar disorder. Given the limited resources available for research, we suggest that future studies would do well to consider more powerful stimuli to capture attention, other cognitive processes, and other facets of emotion. Taken together with the present findings, increased use of cognitive paradigms with greater sensitivity may help to refine cognitive models of psychopathology.

Acknowledgments

The authors wish to thank: Silvia Bunge, Oliver John, and Elizabeth L. Johnson for helpful comments on earlier versions of this manuscript; Anna Feiss, Sant Kumar, and Steven Wandrey for their help in data collection and compilation, and Christopher Beevers for sharing the basis for the E-Prime program described in the manuscript. This manuscript was prepared with support from NIMH grant T32-MH089919.

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Table 1

Demographic Information, Mood, and Emotion Regulation Measures.

	Bipolar *N*=29 Mean (SD)	Control *N*=28 Mean (SD)	*t* or χ^2 (*p*)
GAF **	63.64 (12.3)	87.35 (7.27)	8.54 (<.001)
Age	37.21 (10.74)	32.89 (12.79)	1.38 (.17)
Years of education	15.0 (1.56)	15.0 (2.14)	<.01 (.99)
Percent female	51.7%	39.3%	.89 (.35)
Percent Hispanic or Latino	13.8%	25%	1.30 (.25)
Percent minority race	20.7%	32.1%	.96 (.33)
Percent with anxiety history **	58.6%	0%	23.39 (<.001)
MHRSD total	2.61 (3.03)	n/a	n/a
YMRS total	1.32 (1.58)	n/a	n/a
Percent taking mood-stabilizing or antipsychotic medication	77 %	n/a	n/a
RPA Dampening **	14.25 (4.15)	10.93 (2.83)	3.55 (.001)
RRS Brooding **	11.64 (3.82)	9.14 (2.59)	2.86 (.006)
MACC Enthusiasm	2.79 (1.18)	2.75 (1.14)	0.14 (.89)
MACC Tired *	2.21 (0.82)	1.67 (0.78)	2.52 (.02)
MACC Frustration	1.62 (1.02)	1.22 (0.51)	1.88 (.07)
MACC Sadness	1.24 (0.64)	1.00 (0.00)	2.05 (.05)
MACC Nervous	1.34 (0.61)	1.22 (0.42)	.86 (.39)
MACC Confidence *	2.72 (0.96)	3.22 (0.80)	2.10 (.04)

Note: GAF=Global Assessment of Functioning; HRSD=Hamilton Rating Scale of Depression; MACC=Mood and Confidence Check; YMRS=Young Mania Rating Scale; RPA=Responses to Positive Affect Scale; RRS= Ruminative Responses Scale. Mood stabilizing medications included any of the following: lithium, lamictal, carbamazepine, or valproate; antipsychotic medications included any first or second-generation antipsychotic medication.

* $p < .05$,

** $p < .01$

Table 2

Components of Attention to Emotion in People with Bipolar Disorder and Controls.

	Bipolar *n* = 29 Mean (SD)	Control *n* = 28 Mean (SD)
Location of First Fixation (%)		
Happy	26.77 (7.91)	25.15 (6.85)
Sad	23.28 (10.45)	21.43 (8.23)
Fear	25.37 (10.82)	26.93 (9.92)
Neutral	24.57 (8.48)	26.49 (8.58)
Average Fixation Length (msc)		
Happy	935.22 (298.59)	990.09 (439.69)
Sad	712.43 (207.23)	729.49 (273.67)
Fear	765.90 (318.35)	871.03 (372.77)
Neutral	873.41 (338.03)	852.75 (360.15)
Total Fixation Time (%)		
Happy	29.7 (9.9)	30.06 (8.99)
Sad	20.79 (8.09)	20.63 (4.27)
Fear	24.06 (7.75)	24.18 (4.72)
Neutral	25.46 (7.89)	25.13 (3.91)

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Table 3

Pearson Correlations of Emotion Regulation Measures with Attentional Bias Indices.

	Bipolar Disorder *n* **= 28**		**Control Participants** *n* **= 28**	
	Brooding	**Dampening**	**Brooding**	**Dampening**
TFT-Happy	−.22	−.31	−.28	−.28
TFT-Fear	.32	−.02	.32	.27
TFT-Sad	−.20	−.10	.10	.24

TFT = Total Fixation Time, Brooding = Brooding subscale of RRS; Dampening = Dampening subscale of RPA.