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Short communication

Influence of worry on sustained attention to emotional stimuli: Evidence from the late positive potential

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HIGHLIGHTS

- When women viewed emotional pictures, LPPs were largest for threatening stimuli.
- Worry was positively correlated with LPPs to emotional, but not neutral, stimuli.
- Link between worry and threat/positive stimuli maintained controlling for anxiety.

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ABSTRACT

There is preliminary evidence to suggest that worry is associated with dysregulated emotion processing resulting from sustained attention to emotional versus neutral stimuli; however, this hypothesis has not been directly tested in prior research. Therefore, the current study used the event-related late positive potential (LPP) to directly examine if high levels of trait worry moderate sustained attention to emotional versus neutral stimuli. Electroencephalogram data was recorded while twenty-two women passively viewed neutral, positive, dysphoric, and threatening emotional images. Consistent with our hypotheses, higher levels of worry were associated with larger LPP amplitudes for emotional images but not neutral images. Importantly, the positive correlations between trait worry and LPP responses to threatening and positive images were maintained even when controlling for the influence of current anxiety symptoms, suggesting that worry may influence emotion processing whether or not the person is currently anxious. This sustained attention to emotional information may be one mechanism underlying how trait worry increases risk for anxiety disorders.

Worry typically involves contemplating the potential negative outcomes of future events [1,2]. The tendency to worry varies across healthy populations [3] and, in moderation, may serve as an adaptive response in preparing for future events [4]. However, when worry becomes persistent and chronic, it may increase risk for emotional disorders. For example, the main diagnostic criterion of generalized anxiety disorder (GAD) is the presence of worry that is uncontrollable, global, excessive, and distressing [5]. Pathological worry also places individuals at risk for other anxiety disorders [6] and depression [7] as well as a variety of long-term health consequences, such as cardiovascular disease [8].

Although the consequences of worry are clear, less is known about why worriers are at such increased risk for these disorders. One hypothesis is that worry is associated with dysregulated emotion processing. There is some evidence to suggest that worry may be a strategy employed in an attempt to suppress emotional responses and to feel more in control of future situations [9]. However, worry often has a contradictory effect in that it results in greater difficulty ignoring irrelevant threat distractors [10], greater negative emotionality [11], and increased sympathetic and decreased parasympathetic nervous system activity [12,13]. These studies clearly indicate an association between worry and increased psychological and physiological reactivity to emotional events. However, there is still little evidence for the specific mechanisms underlying worry and dysregulated emotion processing, so further research is necessary. Given the central role of worry in GAD, studies examining the effects of GAD on attention and emotion processing may provide one way forward.

Several studies have shown that individuals with GAD, compared to controls, display increased attention to emotional words and faces [e.g.,14–17]. It has been proposed that this increased

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attention to emotional stimuli may be associated with biological hyperreactivity to emotional information [18]. Supporting this, studies have shown that the link between GAD and emotional reactivity is largely heritable and accounts for a significant proportion of the genetic variability of GAD [19]. In addition, imaging studies have shown that individuals diagnosed with GAD, compared with controls, display hyperreactivity of the amygdala to emotional stimuli [18]. Taken together, these studies suggest that individuals with GAD are more likely to display neural hyperreactivity to emotional stimuli, which may lead to sustained attention to emotional information. This sustained attention may be one reason why worry is often a counterproductive emotion regulation strategy for these individuals as they are unable to disengage from emotionally-salient information. However, no studies of which we are aware have directly tested the link between worry and sustained attention to emotional stimuli.

The late positive potential (LPP) event-related potential (ERP) component is one way of directly measuring sustained attention to salient visual stimuli [20]. Studies using source analysis and concurrent fMRI and ERP methods have found that the LPP is related to neural activity in limbic, parietal and occipital regions, key regions underlying attention to emotionally-salient information [21–23]. Importantly, studies show that the LPP is enhanced in response to emotional faces, pictures, and words and is activated after emotional picture offset, suggesting that it reflects the sustained processing of emotional stimuli [24]. Therefore, the LPP may be a useful measure to elucidate whether chronic worrying is associated with a sustained attentional response to emotional stimuli.

The primary aim of the current study was to examine the link between trait worry and differences in LPP responses to emotional images. As previously discussed, there has been limited research examining associations between worry and neural responses to emotional stimuli; however, studies have found that both neuroticism [25] and trait anxiety [26], which are highly comorbid with worry, are positively associated with the LPP and amygdala responses, respectively, to both positive and negative emotional stimuli. Consistent with this literature, we predicted that participants who endorsed higher levels of worry would exhibit an increased LPP response compared to individuals endorsing lower levels of worry, and that this difference would be specific for emotional versus neutral images. Exploratory analyses were also conducted to determine whether our findings would be maintained when controlling for the influence of current anxiety symptoms.

1. Method

1.1. Participants

Twenty-two female undergraduates participated in exchange for partial course credit. Participants ranged in age from 18 to 22 years old (M = 18.95, SD = 1.29) and 91% were Caucasian.

1.2. Measures

Levels of worry were assessed with the Penn State Worry Questionnaire (PSWQ) [27]. The PSWQ is a 16-item self-report questionnaire assessing the generality, excessiveness, and uncontrollability of pathological worry. Responses are rated on a 5-point Likert-type scale from *not at all typical of me* to *very typical of me*. Higher scores on the PSWQ reflect higher levels of worry with scores ranging from 16 to 80. Previous research has supported the reliability and validity of the PSWQ [27]. In the current study, the PSWQ demonstrated excellent internal consistency (α = .95) and scores ranged from 16 to 77 (M = 49.45, SD = 16.17).

Anxiety symptoms were assessed using the Beck Anxiety Inventory (BAI) [28], a 21-item questionnaire that assesses the severity of current anxiety symptoms in the past week. Higher scores on the BAI reflect higher levels of anxiety with scores ranging from 0 to 63. Prior studies demonstrate that the BAI has good internal consistency and validity [29]. In the current study, the BAI exhibited excellent internal consistency (α = .93) and scores ranged from 0 to 43 (M = 9.05, SD = 9.68). For more details regarding the PSWQ and BAI, please see supplementary materials.

Participants completed a passive viewing task in which they viewed 2 blocks of 12 positive, 12 neutral, 12 dysphoric, and 12 threatening images selected from the International Affective Picture System (IAPS) [30]. For more details regarding the selected images, please see supplementary materials. Images from the IAPS picture system are well standardized and have been used extensively in psychological studies. Images were counterbalanced and presented for 5000 ms with a jittered interstimulus interval of 1751–2250 ms.

1.3. Procedure

The current study was approved by the Institutional Review Board at Binghamton University (SUNY) and was performed in accordance with the ascribed guidelines and regulations. Upon arrival at the laboratory, participants were asked to provide informed consent. Participants completed a series of questionnaires then the passive viewing task.

1.4. EEG recording and processing

Continuous EEG was recorded using a custom cap and the BioSemi ActiveTwoBio system. The EEG was digitized at 64-bit resolution with a sampling rate of 512 Hz. Recordings were taken from 34 scalp electrodes based on the 10/20 system. The electrooculogram was recorded from four facial electrodes. Off-line analysis was performed using the Matlab extension EEGLAB [31] and the EEGLAB plug-in ERPLAB [32]. All data was re-referenced to the average of the left and right mastoid electrodes and band-pass filtered with cutoffs of 0.1 Hz and 80 Hz. EEG data was processed using both artifact rejection and correction. First, large, and stereotypical ocular components were identified and removed using independent component analysis (ICA) scalp maps (e.g., eye blinks project mainly from frontal regions) [33]. Artifact detection and rejection was then conducted on epoched uncorrected data files to identify and remove trials containing large artifacts (greater than 100 μV). Participants' trial rejection did not exceed 35%. The average number of trials rejected was 12.16 (SD = 8.88). The interval from −200 ms to 0 ms served as the baseline for ERPs. Consistent with previous research [34], the LPP component was calculated by averaging across centroparietal electrode sites (Pz, Cz, CP1, and CP2). Participants mean LPP amplitude within a time window of 400–2000 ms after stimulus presentation was used in analyses.

2. Results

To test our hypotheses, we used a generalized linear model with LPP amplitudes for each emotion type (positive, dysphoric, threat, and neutral) serving as the within-subject variables and PSWQ scores as a continuous between-subjects variable. We used a family wise error rate of α = .05 for this analysis. Results indicated significant main effects of emotion (F (1, 20) = 3.84, p = .01, η_p^2 = .16) and PSWQ (F (1, 20) = 8.96, p = .01, η_p^2 = .31), and a significant emotion × PSWQ interaction (F (3, 18) = 8.19, p < .001, η_p^2 = .29). To investigate the main effect of emotion, we conducted Bonferroni pairwise post-hoc comparisons. Results indicated that the LPP in response to neutral images was significantly smaller

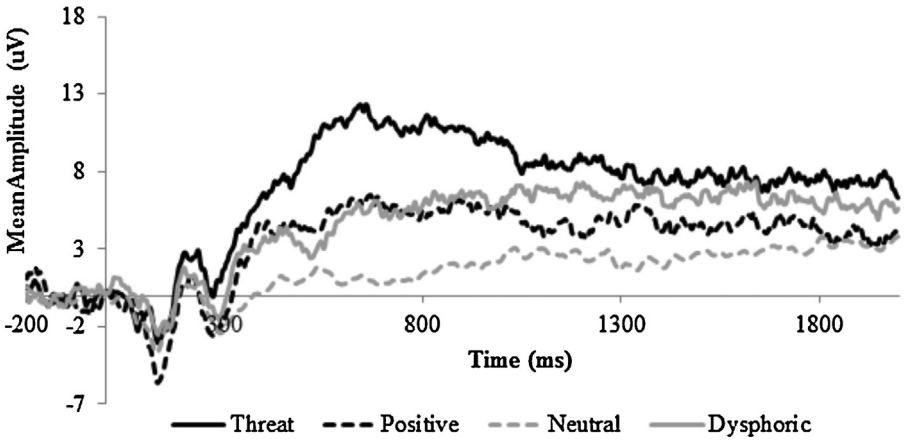

Fig. 1. Late positive potential response to emotional images across participants.

than those observed for threatening (mean difference = −6.68; CI = −8.83, −4.52, $p < .001$) and dysphoric (mean difference = −3.34; CI = −5.76, −.90, $p < .01$) images, but not for positive images (mean difference = −2.49; CI = −5.53, .55, $p = .16$). The LPP to threatening images was also larger than that observed for dysphoric (mean difference = 3.34; CI = 2.04, 4.63, $p < .001$) and positive (mean difference = 4.18; CI = 2.26, 6.11, $p < .001$) images; however, the LPPs to positive did not differ significantly from dysphoric images (mean difference = −.85; CI = −2.86, 1.16, $p = 1.00$). These findings are displayed in Fig. 1. Regarding the main effect of PSWQ, results indicated that the PSWQ was positively related with LPP magnitudes, collapsing across emotion type ($r = .57$, $p = .01$).

Next, to investigate the significant emotion × PSWQ interaction, we conducted follow-up bivariate correlations between PSWQ scores and the LPPs for each emotion. The PSWQ was positively correlated with LPPs to threatening ($r = .69$, $p < .001$; Fig. 2a), dysphoric ($r = .41$, $p = .05$; Fig. 2b), and positive ($r = .58$, $p < .01$; Fig. 2c) images. However, the PSWQ was not significantly correlated with LPPs to neutral images ($r = .13$, $p = .56$; Fig. 2d).

Finally, we examined whether our findings would be maintained after statistically controlling for the influence of current anxiety symptoms (BAI). When including the BAI as a covariate in the GLM, the PSWQ × emotion interaction remained significant (F (3, 17) = 3.84, $p = .01$, $\eta_p^2 = .17$). In addition, the PSWQ remained correlated with LPPs associated with threatening ($r = .60$, $p < .01$) and positive ($r = .44$, $p = .047$) images when controlling for BAI; however, it was no longer significantly correlated with LPPs elicited by dysphoric stimuli ($r = .20$, $p = .38$).

3. Discussion

The primary aim of the current study was to examine the association between trait worry and differences in LPP responses to emotional stimuli. We found that among all participants, LPPs

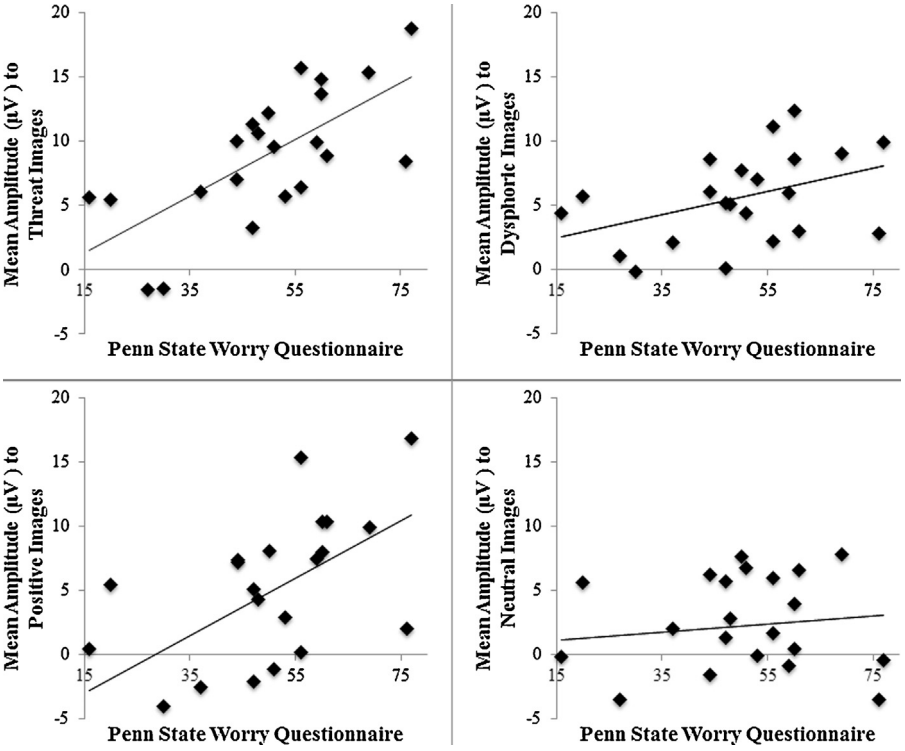

Fig. 2. Association between scores on the Penn State Worry Questionnaire and LPP response to emotional images.

were larger for threatening and dysphoric, compared with neutral, images and were highest for threatening images, which is consistent with prior research [cf. 35]. Examining the role of worry on LPP responses, we found that participants' levels of worry were positively correlated with the magnitude of LPP responses to emotional stimuli. Specifically, we found that participants with relatively higher, compared to lower, levels of trait worry exhibited an increased LPP response to threatening, dysphoric, and positive images. However, the association between worry and LPP response to neutral images was not significant. Importantly, we found that the links between worry and LPP responses to threatening and positive images were maintained when statistically controlling for the influence of current anxiety symptoms, suggesting that worry contributed unique variance to these responses. However, it appears that the association between worry and LPPs associated with dysphoric images was less robust and was reduced to non-significant once we statistically controlled for levels of anxiety. These findings suggest that worry may increase sustained attention to threatening and positive stimuli at the neural level whether or not the person is currently anxious.

The current study contributes to existing literature in important ways. This is the first study to show that worry is positively associated with sustained attention at the neural level for both positive and negative stimuli. These findings parallel studies with GAD populations showing an emotion processing bias for both threatening and positive stimuli [e.g.,14–17]. The lack of emotion specificity for this bias among worriers may be the result of the emotional intensity or novelty of the stimulus as rated by the participant rather than its valence. For example, a previous study showed that valence was not of importance in predicting cognitive interference with naming emotional words among individuals with anxiety; rather, words that were judged to be highly related to likely concerns or relevant threats caused the most interference [36]. Therefore, it may be the case that both positive and negative images in the current study could signal threat or intense emotions based on personal experience. The current study did not have participants rate the intensity or novelty of the images; therefore, future studies are needed to determine if images rated as more intense or personally-relevant by high worriers are associated with increased LPP responses.

Importantly, this sustained attention to emotional information might be one mechanism underlying how trait worry increases risk for anxiety disorders. That is, theorists have suggested that attention biases may play a causal role in the development of anxiety pathology [37,38]. For instance, one study showed that distress levels among individuals could be altered by an attention bias induction such that those trained to demonstrate increased attention to negative stimuli had higher levels of distress following the induction [39]. Therefore, one possibility is that this sustained attention to emotional stimuli demonstrated at the neural level may mediate the association between trait worry and future anxiety disorders. The current study provides initial evidence for this hypothesis by demonstrating that the association between worry and sustained attention to emotional stimuli is independent of current anxiety symptoms. However, future longitudinal studies are needed to fully examine this hypothesis.

To understand the specific neural circuitry associated with this increased LPP response to emotional images in worriers, we refer back to previous work utilizing fMRI and EEG concurrently to elucidate the brain regions correlated with LPP activation. As previously discussed, studies show that the LPP is correlated with activity in the occipital and parietal neural regions [22,23]. It has been suggested that the increased occipital activation, in particular, may be a result from projections from the amygdala [21]. Therefore, the increased LPP response demonstrated in worriers may index downstream processes resulting from hyperactivation of the amygdala [34]. This would be consistent with a previous study suggesting that individuals with high-trait anxiety demonstrate increased amygdala activation to emotional stimuli [26]. This increased amygdala activation may also interact with deficits in top-down processes. For example, high worry has been associated with impaired top-down control for irrelevant threat stimuli; however, only threatening faces were assessed in this study [10]. As such, disrupted prefrontally-mediated control may be related to an overall dysregulation of emotion processing in worry. Future studies will need to be conducted to determine the role of top-down processes on the sustained processing of emotional stimuli in worry.

The current study exhibited a number of strengths, including the use of an electrophysiological index (LPP) to help shed light on the processes involved in disrupted emotion processing and worry. This said, there were some limitations that highlight areas for future research. The current study only focused on women and future research is needed to determine the generalizability of the results to men. Second, although studies utilizing concurrent fMRI and EEG methodology have found the LPP to be correlated with activity in the visual and parietal regions of the brain, future studies are needed to determine the exact underlying mechanisms associated with this increased response to emotional stimuli among worriers.

4. Conclusions

In summary, the current results provide important information about the association between trait worry and emotion processing biases. Specifically, this study adds to the growing literature that suggests that high levels of chronic worry are linked to greater sustained attention to emotional stimuli at the neural level. If examined longitudinally, these results could contribute to a better understanding of the mechanisms by which worry increases risk for the development of emotional disorders. If this risk is indeed inherent in disrupted emotion processing, this knowledge could contribute to the further development of clinical intervention programs that seek to retrain emotion processing biases through techniques such as attention bias modification treatments [40].

Author contributions

K.L.B. and M.L.W. developed the study concept and design; testing and data collection were performed by K.L.B. and M.L.W. under the supervision of B.E.G. K.L.B. and M.L.W. performed the data analysis and interpretation under the supervision of M.O. and B.E.G. K.L.B. and M.L.W. drafted the paper, and M.O. and B.E.G. provided critical revisions. All authors approved the final version of the paper for submission.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.neulet.2014.11.006.

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