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Research Paper

Attention bias modification reduces neural correlates of response monitoring

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ABSTRACT

The error-related negativity (ERN) is an electrophysiological response to errors. Individual differences in the ERN have been posited to reflect sensitivity to threat and linked with risk for anxiety disorders. Attention bias modification is a promising computerized intervention that has been shown to decrease threat biases and anxiety symptoms. In the present study, we examined the impact of a single session of attention bias modification, relative to a control task, on the neural correlates of response monitoring, including the ERN, correct response negativity (CRN), and their difference (i.e., the ERN – CRN or ΔERN). The final sample included 60 participants who first completed a flanker task to elicit the ERN and CRN, and were then randomly assigned to attention bias modification (n = 30) or a control task (n = 30). After completing the attention bias modification or control task, participants completed the same flanker task to again elicit the ERN and CRN. Among participants who completed attention bias modification training, the ERN, CRN, and ΔERN decreased from the pre- to post-training assessment. In contrast, in participants who completed the control task, the CRN, ERN, and ΔERN did not differ between the pre- and post-training assessment. The presents study suggests that a single session of attention bias modification reduces neural correlates of response monitoring, including error-related brain activity. These results also support attention bias modification as a potential mechanistic-based intervention for the prevention and treatment of anxiety pathology.

1. Introduction

Errors are motivationally-salient events that have the potential to place an individual in danger (Weinberg, Riesel, & Hajcak, 2012). The detection of errors is evolutionarily important as errors may signal potential harm (e.g., slipping and cutting oneself) or missed opportunities (e.g., food acquisition). Error commission elicits a number of physiological changes consistent with defense system activation, including skin conductance response (Hajcak, McDonald, & Simons, 2003), heart rate deceleration (Hajcak et al., 2003), pupil dilation (Critchley, Tang, Glaser, Butterworth, & Dolan, 2005), potentiated startle reflex (Hajcak & Foti, 2008), and amygdala activation (Pourtois et al., 2010). As such, error detection is considered an important element of a general performance monitoring system that further evaluates the consequences of behavior and makes adjustments to optimize outcomes (Holroyd & Coles, 2002).

A neural index of error detection is the error-related negativity (ERN), a negative deflection in the event-related potential (ERP) that peaks at frontocentral electrodes approximately 50 ms following error commission (Hajcak, 2012). The ERN magnitude is sensitive to the motivational salience of errors, such that it is enhanced when errors are punished (Riesel, Weinberg, Endrass, Kathmann, & Hajcak, 2012), performance is evaluated (Barker, Troller-Renfree, Pine, & Fox, 2015; Hajcak, Moser, Yeung, & Simons, 2005; Kim, Iwaki, Uno, & Fujita, 2005), or accuracy is emphasized over speed (Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Gehring, Goss, & Coles, 1993). The ERN has excellent psychometric properties, including high test-retest reliability across two weeks (Olvet & Hajcak, 2009a) and two years (Weinberg & Hajcak, 2011), and high internal consistency in as few as six trials (Olvet & Hajcak, 2009b). The ERN is also moderately heritable (Anokhin, Golosheykin, & Heath, 2008) and related to particular genotypes (Manoach & Agam, 2013), suggesting genetic contributions.

Although there are many theories surrounding the mechanisms that underlie the generation of the ERN (see Weinberg, Dieterich, & Riesel, 2015 for review), it is commonly believed to reflect the activity of a generic error monitoring system which tracks ongoing performance

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(Falkenstein et al., 2000; Gehring et al., 1993; Holroyd & Coles, 2002). In addition to its role in a generic performance monitoring system, there is growing evidence that variability in the magnitude of the ERN indexes individual differences in sensitivity to errors. Consistent with this notion, an enhanced ERN has been associated with increased anxiety symptoms (Hajcak, 2012; Moser, Moran, Schroder, Donnellan, & Yeung, 2013; Proudfit, Inzlicht, & Mennin, 2013), and risk for anxiety disorders. Specifically, the ERN is larger in healthy individuals with a family history of obsessive-compulsive disorder (Carrasco et al., 2013; Riesel et al., 2011), and an enhanced ERN prospectively predicts the new onset of anxiety disorders in children (Meyer, Hajcak, Torpey-Newman, Kujawa, & Klein, 2015). Thus, the ERN has been suggested to be a potential marker of risk for anxiety disorders (Hajcak, 2012; Meyer, 2016; Olvet & Hajcak, 2008).

In a recent investigation, Nelson, Jackson, Amir, and Hajcak (2015) examined whether a single session of attention bias modification could reduce the ERN. Attention bias modification is a computerized intervention that trains attention away from negative stimuli and towards positive stimuli, and targets a core mechanism of dysfunction in anxiety disorders (i.e., attentional bias toward threat) (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). Attention bias modification has been shown to successfully decrease threat biases and anxiety symptoms (Kuckertz & Amir, 2015; Macleod & Clarke, 2015). Given that attention bias modification is designed to modify attentional biases away from threat and reduce vulnerability to anxiety, we hypothesized that attention bias modification would modulate the ERN, a posited neural index of threat sensitivity (Weinberg et al., 2016). In Nelson et al., participants were randomly assigned to complete attention bias modification either before or after the ERN was measured (i.e., AB/BA design). Results revealed that the ERN was smaller in participants who completed attention bias modification before, relative to those who completed attention bias modification after, the ERN was measured. These results support the hypothesis that individuals who completed attention bias modification first showed a smaller ERN relative to their attention bias modification-naive counterparts. Furthermore, changes in attentional bias occurred on a continuum, with some participants showing more or less change in their biases away from negative and toward positive stimuli. Upon examining these bias scores, we found that greater attentional disengagement from negative stimuli during attention bias modification was associated with a smaller ERN across both groups, suggesting that the ERN may be both a mechanism and predictor of attention bias modification-related changes in attentional bias to threat.

Nelson et al. (2015) provides a critical first indication that the ERN—a posited neural marker of threat sensitivity and risk for anxiety—can be altered by a computerized attention bias modification task. However, Nelson et al. contained several methodological limitations that proscribe causal conclusions about the effect of attention bias modification on the ERN. Specifically, it did not include a control group that completed an analogous cognitive task. Thus, it is unclear if attention bias modification training directly altered the ERN, or if there were other factors (e.g., task fatigue) that indirectly impacted the ERN. Additionally, Nelson et al. did not include pre- and post-training assessments of the ERN, thereby prohibiting the examination of within-subject changes in the ERN.

The present study examined the impact of attention bias modification on the ERN using a pre-test/post-test design, across both attention bias modification and a control task. Specifically, 64 participants completed a flanker task designed to elicit the ERN and correct response negativity (CRN)—a smaller negative deflection in the ERP which also peaks at frontocentral electrodes approximately 50 ms following correct responses—and were then randomly assigned to complete a single session of attention bias modification or a control task. The control task included similar instructions, stimuli, and an identical number of trials, but did not train attention away or toward stimuli. After completing the attention bias modification or control task, participants again completed the flanker task to elicit the ERN and CRN. The present study focused on a sample of individuals who were unselected for initial attention bias or anxiety symptoms to minimize the contribution of psychopathology that may be more prevalent in clinical populations on initial attention bias or the ERN. We hypothesized that participants who completed attention bias modification, but not the control task, would demonstrate a within-subject reduction in the ERN. Furthermore, in the participants who completed attention bias modification, we hypothesized that a greater change in negative attention bias would be associated with a smaller ERN.

2. Method

2.1. Participants

In an attempt to replicate and extend Nelson et al. (2015), the present study recruited a sample that was of similar size and demographic composition. To this end, the sample included 64 undergraduates from Stony Brook University who participated for course credit. Participants were randomly assigned to attention bias modification (n = 34) or the control condition (n = 30). Informed consent was obtained prior to participation and participants were allowed to terminate participation at any time during the experimental session. The research protocol was approved by the Institutional Review Board at Stony Brook University.

2.2. Measures

2.2.1. Inventory of depression and anxiety symptoms

To verify that the attention bias modification and control groups were comparable on current internalizing symptoms, participants completed the expanded Inventory of Depression and Anxiety Symptoms (IDAS-II) (Watson et al., 2012). The IDAS-II is a 99-item factor-analytically derived self-report inventory of empirically distinct dimensions of depression and anxiety symptoms. Each item assesses symptoms over the past two weeks on a 5-point Likert scale ranging from 1 (*not at all*) to 5 (*extremely*). The present study examined the IDAS-II subscales for depression, panic, social anxiety, claustrophobia, traumatic intrusions, traumatic avoidance, checking, orderliness, and cleanliness.

2.3. Procedure

After providing informed consent, participants completed a self-report demographic questionnaire and the IDAS while an electroencephalography (EEG) cap was applied to the participant's head. Next, EEG was recorded while participants completed a flanker task. After completing the flanker task, participants were randomly assigned to either the attention bias modification or control task. Finally, after completing the attention bias modification or control task, EEG was again recorded while participants completed the same flanker task.

2.3.1. Flanker task

The flanker task was administered with Presentation software (Neurobehavioral Systems Inc., Albany, CA). On each trial, five horizontally aligned white arrowheads were presented for 200 ms. Participants were instructed to indicate the direction of the central arrowhead using the left or right mouse button. Half of the trials were compatible (e.g., < < < < < or > > > > >) and half were incompatible (e.g., < < > < < or > > < > >), and trial type was randomly determined. After the participant response, there was a variable intertrial interval of 600–1000 ms prior to the beginning of the next trial. The arrows filled 2° of visual angle vertically and 10° horizontally, and were presented at a viewing distance of approximately 65 cm. Participants initially completed a practice block containing 20 trials, and the actual task consisted of 11 blocks of 30 trials (330 total